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Glyphosate-Tolerant Alfalfa Events J101 and J163: Request for Nonregulated Status

**Draft Environmental Impact
Statement—November 2009**

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Executive Summary

APHIS is proposing to grant nonregulated status to genetically-engineered glyphosate-tolerant alfalfa lines J101 and J163 based on the agency's analysis and conclusions that these genetically-engineered alfalfa lines are unlikely to pose plant pest risks. Additionally, APHIS has preliminarily concluded in this Draft Environmental Impact Statement (DEIS) that granting nonregulated status to glyphosate-tolerant (GT) alfalfa lines J101 and J163 will not result in significant impacts to the human environment.

Purpose and Need

"Protecting American agriculture" is the basic charge of the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS). APHIS provides leadership in ensuring the health and care of plants and animals. By ensuring plant and animal health, the agency improves agricultural productivity and competitiveness, and contributes to the national economy and the public health. USDA asserts that all methods of agricultural production (conventional, organic, or the use of genetically engineered varieties) can provide benefits to the environment, consumers, and farm income, and they can and should "coexist." The APHIS Biotechnology Regulatory Service's (BRS) mission is to protect America's agriculture and environment using a dynamic and science-based regulatory framework that allows for the safe development and use of genetically engineered organisms.

The regulations in 7 CFR part 340, "Introduction of Organisms and Products Altered or Produced Through Genetic Engineering Which Are Plant Pests or Which There Is Reason to Believe Are Plant Pests," regulate, among other things, the introduction (importation, interstate movement, or release into the environment) of organisms and products altered or produced through genetic engineering that are plant pests or that there is reason to believe are plant pests. Such genetically engineered organisms and products are considered "regulated articles." The regulations in § 340.6(a) provide that any person may submit a petition to APHIS seeking a determination that an article does not pose a plant pest risk and should therefore not be regulated under 7 CFR part 340. Paragraphs (b) and (c) of § 340.6 describe the form that a petition for a determination of nonregulated status must take and the information that must be included in the petition.

Background

On April 16, 2004, APHIS received a petition from Monsanto Company and Forage Genetics International (Monsanto and FGI), requesting a determination of nonregulated status under 7 CFR part 340 for two alfalfa

lines designated as J101 and J163, which have been genetically engineered for tolerance to the herbicide glyphosate.

APHIS evaluated the plant pest risks posed by the use of lines J101 and J163 and prepared an environmental assessment (EA) to identify and evaluate any environmental impacts resulting from the approval of the deregulation petition. In a notice published in the Federal Register on June 27, 2005 (70 FR 36917-36919, Docket No. 04-085-3), APHIS advised the public of its determination, effective June 14, 2005, that the Monsanto and FGI GT alfalfa lines J101 and J163 did not pose a plant pest risk and were therefore no longer considered regulated articles under 7 CFR part 340.

Approximately 9 months later, a group of organic alfalfa growers and several other associations filed a lawsuit in the United States District Court for the Northern District of California that challenged APHIS' decision to grant nonregulated status to J101 and J163. On February 13, 2007 the Court ruled that APHIS' EA failed to adequately consider certain environmental and economic impacts as required by the National Environmental Policy Act (NEPA), and the Court vacated APHIS' decision to grant nonregulated status to J101 and J163. The Court also ordered APHIS to prepare a NEPA-compliant environmental impact statement (EIS) before deciding whether to grant nonregulated status to J101 and J163. On March 23, 2007, APHIS published a notice in the *Federal Register* (72 FR 13735-13736 APHIS Docket No. 04-085-1) announcing the Court's decision that Monsanto and FGI GT alfalfa lines J101 and J163 were once again regulated articles under 7 CFR part 340. The GT alfalfa seed sales and planting that took place after the June 2005 deregulation decision were halted.

Once the GT alfalfa lines were deregulated in June 2005, those GT alfalfa lines' seeds were sold and plantings were started. In the two growing seasons (2005 and 2006) that GT alfalfa was on the market, ~200,000 total acres were planted in 1,552 counties and 48 States with the exception of Alaska and Hawaii. These GT alfalfa fields are still permitted to be harvested pursuant to the court order and have court ordered stewardship practices to minimize any potential of GT alfalfa being present in harvests of non-GT alfalfa harvests. APHIS prepared this draft EIS in connection with the order by the United States District Court for the Northern District of California that vacated determined the deregulated status of J101 and J163 alfalfa.

Alternatives and Affected Environment

In a Notice of Intent published on January 7, 2008, APHIS suggested three alternatives for evaluation. APHIS has removed from consideration the

concept of approving only one of the GT alfalfa lines (either J101 or J163) and not both lines because APHIS' plant pest risk assessment concluded that GT alfalfa lines J101 and J163 are unlikely to pose a plant pest risk. Since neither line poses a plant pest risk, both lines must be deregulated. Additionally, none of the comments received during the public comment period of the original EA in 2005 and during the public comment period of the NOI cited concerns regarding a difference in or occurrence of any plant pest risks in GT alfalfa lines J101 and J163. APHIS also removed from consideration the concept of approving GT alfalfa lines based on geographical restrictions, because both GT alfalfa lines are unlikely to pose plant pest risks, and there would be no regulatory basis for imposing restrictions in certain geographical areas.

Therefore, this document considered two of the alternatives described in the Notice of Intent: to grant nonregulated status to GT alfalfa lines J101 and J163 (preferred alternative), or to maintain the status of GT alfalfa lines J101 and J163 as regulated articles. Alternatives were analyzed with regard to their potential impacts on gene flow between GT alfalfa and non-GT alfalfa, weed development, wildlife species, special status species, herbicide use, plant species, socioeconomics (including conventional and organic alfalfa markets, dairy and beef markets, and trade), human health and safety, land use and production practices, and the physical environment (including soil, climate and air quality, and water).

Environmental Consequences

Based on the impact analyses in this DEIS, APHIS has preliminarily concluded that there is no significant impact on the human environment due to granting nonregulated status to GT alfalfa lines J101 and J163.

Summary of Environmental Consequences

Biology of Alfalfa

- Movement of genes between alfalfa plants is dependent on weather, timing of flowering, availability of pollinators, successful pollination, and time needed seed maturity. Although the probability is low, GT alfalfa genes may be found in non-GT alfalfa but cannot be considered a significant impact because, among other factors, contractual "best practices" have been found to produce non-GT alfalfa seed with >99.5 percent purity.

Weeds in Alfalfa

- Biology/ecology of alfalfa (perennial status) and production practices (mowing, less glyphosate used compared to other crops) in alfalfa farming suggest that glyphosate-resistant weeds would be slow to develop, if they develop at all, due to GT alfalfa.

Impacts of GT Alfalfa on Wildlife and Plants

- GT alfalfa is not toxic to animals, will not compete with plants any differently than non-GT alfalfa, and has no significant effect on threatened or endangered species (T&E) or their critical habitat.

Herbicide Use

- Due to the use of glyphosate on GT alfalfa, overall glyphosate use may increase in alfalfa production, but such an increase should be not be a significant impact on the environment for several reasons:
 - Glyphosate is currently used on conventional alfalfa to “take out” (remove) an alfalfa field.
 - Use of other, more toxic herbicides will decrease in alfalfa production with the increased adoption and planting of GT alfalfa.
 - Glyphosate is environmentally less adverse than other herbicides (a lower environmental impact quotient compared to other herbicides currently used in alfalfa production). Thus, the net effect on alfalfa production with the increased adoption and planting of GT alfalfa should be some increased use of the less toxic glyphosate with a decreased use of more toxic herbicides.
 - Animal threatened or endangered (T&E) species are not at risk, and terrestrial and semi-aquatic T&E plants may be at some risk of direct effects from exposure to glyphosate used in agriculture, if they are found near alfalfa fields. All plants are at some risk of direct effects from exposure to herbicides currently used in alfalfa production.

Socioeconomic Impacts

- *Businesses Lost and Gained*
 - Farmers adopting GT alfalfa may have decreased costs or improved markets as GT-sensitive farmers may have a reduction in demand.
 - Early GT alfalfa adopters may gain markets while conventional non-GT alfalfa farmers producing high quality alfalfa may lose markets, due to potentially higher costs and lower quality of conventional non-GT alfalfa when compared to GT alfalfa.
 - If there is GT-sensitivity in the market for organic alfalfa, organic farmers most affected by the unintended presence of GT alfalfa may lose some markets (decrease the quantity sold), while organic farmers less affected by the unintended presence of GT alfalfa may expand their markets (increase the quantity sold).
 - Although individual farmers may be affected, when examined in total, none of the potential business losses or

gains are expected to be so severe as to amount to a significant impact.

- *Market Structure*

- Overall, alfalfa production may shift to larger farms.
 - If purchasing land to provide a separation distance between GT and non-GT alfalfa is the only mechanism used to minimize the presence of GT alfalfa in GT-sensitive alfalfa fields, these increased land costs could benefit larger non-GT alfalfa farmers.
 - To the extent that organic farming is more suitable for small farms than conventional farming (less economies of scale related to greater dependency on labor), a reduction in the demand for organic products could favor larger farmers.
 - However, land needs for GT-sensitive alfalfa forage growers may be reduced as there are other mechanisms available to minimize the presence of GT alfalfa in GT-sensitive alfalfa fields.
- If adoption rates of GT alfalfa were high, alfalfa seed farmers may find an increased demand for GT alfalfa seeds and could shift production to this variety.

- *Distribution of Costs of Loss of Production and Avoidance*

- Organic producers could have either a loss of production or need to add additional measures to reduce the likelihood of unintended presence if 1) there is an amount of GT alfalfa in organic alfalfa that the organic market will reject, or 2) current alfalfa production practices are not already in place to protect against unintended presence of GT alfalfa in GT-sensitive alfalfa fields. There is no evidence that supports either of these assumptions.

- *Social Aspects of Organic Farming*

- The analyses found no GE-sensitivity in domestic sales of organic alfalfa; however, this does not mean that GE products are necessarily welcome by organic consumers or producers. It is difficult to empirically quantify GE-sensitivity in the domestic sales of organic alfalfa and by-products in the marketplace because: there are no governmental standards for GE content in organic products; organic standards are process-based, not product-based (organic processes do not require a GE-free product); and researchers cannot quantify real-world preferences as consumers do not have the means to accurately discern between GE and non-GE products.

Human Health and Safety

- GT alfalfa has no adverse effects on human health and worker safety.
- Overall risk of glyphosate use to human health and worker safety does not change with the adoption of GT alfalfa. The EPA has determined that the use in accordance with the labeling of currently registered pesticide products containing glyphosate will not pose unreasonable risks or adverse effects to humans or the environment, including its use on alfalfa.

Land Use and Physical Environment

- Overall land devoted to alfalfa cultivation will be impacted largely by the price of alfalfa hay and not by the availability of GT technology.
- GT alfalfa is not expected to have an adverse impact on soils, climate or air quality, or water and water use.

In summary, the impacts analyses in this DEIS have not found any significant impacts of GT alfalfa on the biological properties of alfalfa, weediness, threatened and endangered species, wildlife, other plants, other agricultural production systems and markets, trade, human health and safety, land use or the physical environment. Although glyphosate may likely increase in alfalfa agriculture due to the adoption of GT alfalfa, the number and use of other, more toxic herbicides will decrease, and there is no significant impact of glyphosate use on weediness of alfalfa, glyphosate-resistant weeds, human health and safety, land use or the physical environment.

The draft environmental impact statement will have a 60-day comment period. We will consider all public comments received during the comment period in preparation of the final environmental impact statement.

I. Purpose and Need

A. Introduction

"Protecting American agriculture" is the basic charge of the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS). APHIS provides leadership in ensuring the health and care of plants and animals. By ensuring plant and animal health, the agency improves agricultural productivity and competitiveness, and contributes to the national economy and the public health. USDA asserts that all methods of agricultural production (conventional, organic, and the use of genetically engineered varieties) can provide benefits to the environment, consumers, and farm income.

One of APHIS' many functions is to regulate the introduction of genetically engineered (GE) organisms, including crop and noncrop plants, vertebrate and invertebrate animals, and microorganisms that might pose a plant pest risk. Genetic engineering refers to the process in which genes or other genetic elements from one or more organisms are inserted into the genetic material of a second organism using molecular biology methods. Moving a new gene or genes in this way allows researchers to introduce useful new traits into an organism from individuals of the same species or from unrelated species.

GE organisms are subject to APHIS oversight if they have the potential to pose a plant pest risk as defined in the regulations at 7 Code of Federal Regulations (CFR) part 340. After appropriate analysis, APHIS may determine that a GE organism is unlikely to pose a plant pest risk and grant that GE organism nonregulated status. APHIS has been petitioned by Forage Genetics International (FGI) and the Monsanto Company to grant nonregulated status to two lines of GE alfalfa, J101 and J163, that are tolerant of applications of glyphosate, an herbicide. This draft environmental impact statement (DEIS) was prepared to comply with an order from the United States District Court for the Northern District of California to identify and analyze any environmental impacts associated with APHIS' determination on whether to grant nonregulated status to GE alfalfa lines J101 and J163.

B. Regulatory Authority

In 1986, the Federal Government's Office of Science and Technology Policy (OSTP) published a policy document known as the Coordinated Framework for the Regulation of Biotechnology (51 *Federal Register* (FR) 23302). This document specifies three Federal agencies that are responsible for regulating biotechnology in the United States: USDA's APHIS, the U.S. Department of Health and Human Services' Food and

Drug Administration (FDA), and the Environmental Protection Agency (EPA).

1. USDA

The APHIS Biotechnology Regulatory Service's (BRS) mission is to protect America's agriculture and environment using a dynamic and science-based regulatory framework that allows for the safe development and use of genetically engineered organisms. APHIS regulations at 7 CFR part 340, which were promulgated pursuant to authority granted by the Plant Protection Act, as amended (7 United States Code (U.S.C.) 7701–7772), regulate the introduction (importation, interstate movement, or release into the environment) of certain GE organisms and products. A GE organism is considered a regulated article if the donor organism, recipient organism, vector, or vector agent used in engineering the organism belongs to one of the taxa listed in the regulation (7 CFR § 340.2) and is also considered a plant pest. A GE organism is also regulated under part 340 when APHIS has reason to believe that the GE organism may be a plant pest or APHIS does not have sufficient information to determine if the GE organism is unlikely to pose a plant pest risk.

A person may petition the agency to evaluate submitted data and determine that a particular regulated article is unlikely to pose a plant pest risk, and, therefore, should no longer be regulated, under 7 CFR § 340.6 "Petition for Determination of Nonregulated Status." The petitioner is required to provide information (§ 340.6(c)(4)) related to plant pest risk that the agency uses to determine whether the regulated article is unlikely to present a greater plant pest risk than the unmodified organism. An organism is no longer subject to the regulatory requirements of 7 CFR part 340 when APHIS determines that it is unlikely to pose a plant pest risk.

2. FDA

FDA regulates under the authority of the Federal Food Drug and Cosmetic Act (FFDCA). FDA is responsible for ensuring the safety and proper labeling of all plant-derived foods and feeds, including those developed through genetic engineering such as glyphosate-tolerant alfalfa. All foods and feeds, whether imported or domestic and whether derived from plants modified by conventional breeding techniques or by genetic engineering techniques, must meet the same rigorous safety standards. Under the FFDCA, it is the responsibility of food and feed manufacturers to ensure that the products they market are safe and properly labeled. In addition, any food additives, including ones introduced into food or feed by way of plant breeding, must receive FDA approval before marketing. To help developers of foods and feeds derived from GE plants to comply with their obligations, FDA encourages them to participate in its voluntary consultation process. In that process, developers submit to FDA data and information that provide the basis for a conclusion that a GE food is as

safe as comparable non-GE food in the food supply. FDA believes that developers of bioengineered food that is intended to be commercially marketed have followed the recommendations in FDA's guidance documents for consulting with FDA.

The FDA policy statement concerning regulation of products derived from new plant varieties, including those genetically engineered, was published in the *Federal Register* on May 29, 1992 (57 FR 22984-23005). Under this policy, FDA uses what is termed a consultation process to ensure that human food and animal feed safety issues or other regulatory issues (e.g., labeling) are resolved prior to commercial distribution of bioengineered food. Products are regulated according to their intended use and some products are regulated by more than one agency.

3. EPA

Through a registration process that is independent of APHIS, EPA regulates the sale, distribution, and use of pesticides in order to protect health and the environment. This registration process includes the registration of pesticides that are produced by organisms developed using techniques of modern biotechnology. Under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), the Biopesticides and Pollution Prevention Division of the Office of Pesticide Programs regulates the distribution, sale, use, and testing of pesticidal substances produced in plants and microbes, as well as the microbes themselves, if EPA considers them to be biocontrol agents or pesticidal in function. Under FIFRA, EPA also regulates the herbicides that are applied to GE herbicide-tolerant crops, such as glyphosate-tolerant (GT) alfalfa. Under FFDCA, EPA regulates pesticide residues. Additionally, under section 5 of the Toxic Substances Control Act (TSCA), EPA acquires information in order to identify and regulate potential hazards and exposures of all new chemicals intended for entry into commerce that are not specifically covered by other regulatory authorities, for example, substances other than food, drugs, cosmetics, and pesticides. TSCA's applicability to the regulation of products of biotechnology is based on the interpretation that microorganisms are chemical substances under TSCA.

Together, these agencies ensure that the products of modern biotechnology are safe to grow, safe to eat, and safe for the environment. USDA, EPA, and FDA enforce agency-specific regulations regarding products of biotechnology that are based on the specific nature of each GE organism.

C. Glyphosate-Tolerant Alfalfa

On April 16, 2004, APHIS received a petition from Monsanto Company of St. Louis, Missouri and Forage Genetics International of West Salem, Wisconsin (Monsanto and FGI), requesting a determination of nonregulated status under 7 CFR part 340 for two alfalfa (*Medicago sativa*

L.) lines designated as J101 and J163, which have been genetically engineered for tolerance to the herbicide glyphosate. The Monsanto and FGI petition stated that the two GT alfalfa lines should not be regulated by APHIS because they do not present a plant pest risk.

Alfalfa plants, like most plants, produce an enzyme called 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS). EPSPS is necessary for the production of certain amino acids essential for plant growth. Alfalfa plants were genetically engineered by inserting a bacterial gene (from *Agrobacterium* sp. strain CP4), responsible for the production of a different 5-enolpyruvylshikimate-3-phosphate synthase (CP4-EPSPS), into the alfalfa genome. This gene, along with its regulatory sequences, was introduced into these alfalfa plants via the well-characterized *Agrobacterium*-mediated transformation method. Two different, genetically independent alfalfa lines, J101 and J163, were produced using this transformation method.

Glyphosate is an herbicide, a chemical that kills plants, and it kills plants by inhibiting the activity of EPSPS. Glyphosate is a "non-selective" herbicide, which means that almost all plant species are killed when sprayed with enough glyphosate because almost all plants need normal EPSPS activity for growth. Alfalfa plants genetically engineered to produce CP4-EPSPS are glyphosate-tolerant because glyphosate does not inhibit the activity of CP4-EPSPS. If alfalfa plants producing CP4-EPSPS are growing in a field with weeds, applying glyphosate to the field will kill the weeds but not the alfalfa plants.

Monsanto and FGI completed FDA's voluntary consultation process for both lines of GT alfalfa. The FDA letter to Monsanto and FGI, and analysis by FDA, in response to their submission regarding GT alfalfa lines J101 and J163 can be found at <http://www.cfsan.fda.gov/~lrd/biocon.html> and appendix P.

a. History

1. National Environmental Policy Act Processes

APHIS evaluated the plant pest risks posed by the nonregulated use of lines J101 and J163 and prepared an environmental assessment (EA) to identify and evaluate any environmental impacts resulting from the approval of the petition. In a notice published in the *Federal Register* on June 27, 2005 (70 FR 36917-36919, Docket No. 04-085-3), APHIS advised the public of its determination, effective June 14, 2005, that the Monsanto and FGI GT alfalfa lines J101 and J163 were no longer considered regulated articles under 7 CFR part 340.

Approximately 9 months later, a group of organic alfalfa growers and several other associations filed a lawsuit in the U.S. District Court for the

Northern District of California that challenged APHIS' decision to grant nonregulated status to J101 and J163.¹ On February 13, 2007, the Court ruled that APHIS' EA failed to adequately consider certain environmental and economic impacts as required by the National Environmental Policy Act (NEPA), and the Court vacated APHIS' decision to grant nonregulated status to J101 and J163. The Court also ordered APHIS to prepare a NEPA-compliant environmental impact statement (EIS) before deciding whether to grant nonregulated status to J101 and J163. On March 23, 2007, APHIS published a notice in the *Federal Register* (72 FR 13735-13736 APHIS Docket No. 04-085-1) announcing the Court's decision that Monsanto and FGI GT alfalfa lines J101 and J163 were once again regulated articles under 7 CFR part 340. GT alfalfa seed sales and planting were halted.

Once the GT alfalfa lines were deregulated in June 2005, those GT alfalfa lines' seeds were sold and plantings were started. In the two growing seasons (2005 and 2006) that GT alfalfa was on the market, ~200,000 acres were planted in 1,552 counties and 48 states with the exception of Alaska and Hawaii. These GT alfalfa fields are still permitted to be harvested, and have court ordered stewardship practices to minimize the potential of GT alfalfa being present in harvests of non-GT alfalfa harvests (Hubbard, 2008).

b. Scoping

The granting of nonregulated status to GT alfalfa lines raises a number of issues that may be addressed in this DEIS. These issues were identified by the agency through a scoping process. Public scoping is required under NEPA, as amended, Council on Environmental Quality (CEQ) regulations for implementing NEPA, the USDA regulations implementing NEPA, and APHIS' National Environmental Policy Act of 1969 (NEPA) Implementing Procedures. Scoping for this DEIS began on January 7, 2008, when APHIS gave notice in the *Federal Register* (73 FR 1198-1200) of its intent to prepare a DEIS. The notice listed several questions to be discussed in the EIS—

- (1) What are the particular management practices for organic alfalfa, conventional alfalfa, and glyphosate-tolerant alfalfa? What are the procedures and associated costs of establishing, growing, harvesting, and marketing (includes selling prices and premiums for various quality standards) for each of the three types of alfalfa? What crop rotation regimes are used with each type of alfalfa?
- (2) What are the production levels of organic and conventional alfalfa seed and hay by region, State, and county? Which regions of the

¹ The lawsuit raised claims under the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), and the Plant Protection Act (PPA).

country areas may be affected more than others with the deregulation of glyphosate-tolerant alfalfa? What is the acreage of cultivated, volunteer, or feral alfalfa? What are the potential impacts on adjacent, nonagricultural lands such as natural areas, forested lands, or along transportation routes that may occur with the use of GT alfalfa?

- (3) What is the expected effect of GT alfalfa release on animal production systems?
- (4) What are the potential impacts of GT alfalfa release on food and feed? How does glyphosate tolerance affect food or feed value or nutritional quality? Should the low level presence of GT alfalfa occur in situations where it is unwanted, unintended, or unexpected, what impact would this have on the ability of producers to market affected organic or conventional alfalfa or livestock fed this material? What are the negative impacts, if any, on food or feed value or quality from the use of glyphosate?
- (5) What differences are there in weediness traits of conventional alfalfa versus GT alfalfa under managed crop production systems as well as in unmanaged ecosystems?
- (6) What is the occurrence of common and serious weeds found in organic alfalfa systems, in conventional alfalfa systems, and in GT alfalfa systems? What are the current impacts of weeds, herbicide-tolerant weeds, weed management practices, and unmet weed management needs for organic and conventional alfalfa cultivation? How may the weed impacts change with the use of GT alfalfa?
- (7) What are the particular management practices for controlling weeds in organic alfalfa systems, in conventional alfalfa systems, and in GT alfalfa systems? What are the potential changes in crop rotation practices and weed management practices for control of volunteer alfalfa or herbicide-tolerant weeds in rotational crops that may occur with the use of GT alfalfa? What are the potential effects on alfalfa stand termination and renovation practices that may occur with the use of GT alfalfa? What is the potential weediness of GT alfalfa?
- (8) What is the potential cumulative impact of glyphosate-resistant weeds, especially with the increase in acreage of GT crops? Are there glyphosate-resistant weeds and what is their prevalence in crops and in non-crop ecosystems? Will the release of GT alfalfa cause an increase in glyphosate-resistant weeds in alfalfa and in other crops? Which weeds are the most likely to gain glyphosate resistance with the use of GT alfalfa? What are the alternatives for management of GT or other herbicide-tolerant weeds in GT alfalfa stands or in subsequent crops? What are the potential changes that may occur in GT alfalfa as to susceptibility or tolerance to other herbicides?

- (9) What are current or prospective herbicide-tolerant weed mitigation options, including those addressed by the EPA-approved label for glyphosate herbicides?
- (10) What is the potential for gene flow in all combinations between seed fields, hay fields, and feral plants? To what extent will deregulation of GT alfalfa impact hybridization between cultivated and feral alfalfa, alfalfa's introgression or establishment outside of cultivated lands, and alfalfa's persistence in situations where it is unwanted, unintended, or unexpected? What are the risks associated with feral GT alfalfa plants? How will the removal of GT alfalfa in situations where it is unwanted, unintended, or unexpected result in adverse impacts? In such situations, how will GT alfalfa be controlled or managed differently from other unwanted, unintended, or unexpected alfalfa? To what extent can organic or conventional alfalfa farmers prevent their crops from being commingled with unwanted, unintended, or unexpected GT alfalfa?
- (11) What are the potential economic and social impacts of GT alfalfa release on organic and conventional alfalfa farmers? What are the potential impacts of the presence of GT alfalfa caused by pollen movement or seed admixtures? What are the economic issues associated with using alfalfa seed or hay commingled with GT alfalfa? What are the particular economics of growing seed or hay of organic alfalfa, conventional alfalfa, or GT alfalfa? What are the potential changes in the economics of growing and marketing organic and conventional alfalfa that may occur with the use of GT-tolerant alfalfa? What are the potential changes in production levels of other crops that may occur with the use of GT alfalfa (i.e., will the release of GT alfalfa result in more or fewer acres of corn, wheat, other forage crops, etc.)? What are the potential changes in growing practices, management practices, and crop rotational practices in the production of alfalfa hay or seed for planting or sprouting purposes that may occur with the use of GT alfalfa? What are the potential changes in the choice of seeds available for organic and conventional alfalfa farmers that may occur with the use of GT alfalfa?
- (12) What are the potential impacts of the deregulation of GT alfalfa on U.S. trade? If the presence of GT alfalfa should occur in organic or conventional alfalfa where it is unwanted, unintended, or unexpected, what are the expected impacts on trade with countries that normally import alfalfa seed or hay? What are the expected impacts on trade with countries that do not normally import alfalfa? Is there an expected impact on trade in other commodities?
- (13) What is the potential cumulative impact of increased glyphosate usage with the release of GT crops? Have changes in glyphosate usage impacted soil quality, water quality, air quality, weed populations, crop rotations, soil microorganisms, diseases, insects, soil fertility, food or feed quality, crop acreages, and crop yields?

Does the level of glyphosate tolerance within GT alfalfa plants have a major impact on the amount of glyphosate applied on the GT alfalfa crop on a routine basis?

- (14) What are the potential impacts of the release of GT alfalfa on threatened or endangered species and designated critical habitat? What are the potential effects of GT alfalfa use on listed threatened or endangered species, species proposed for listing, designated critical habitat, or habitat proposed for designation? What are the potential effects of glyphosate use on listed threatened or endangered species, species proposed for listing, designated critical habitat, or habitat proposed for designation; including glyphosate used on GT alfalfa?
- (15) What are the potential health and safety risks to field workers or other workers that would come into contact with GT alfalfa?
- (16) Can any of the potential negative environmental impacts resulting from the deregulation of GT alfalfa be reasonably mitigated, and what is the likelihood that mitigation measures will be successfully implemented? The EIS will consider the stewardship measures outlined in the addendum to section VIII of the petition, as well as any other mitigation measures APHIS considers applicable and viable. Such measures, some of which may be outside the jurisdiction of APHIS, are designed to reduce inadvertent gene flow of GT alfalfa to negligible levels, as well as to monitor and minimize the potential development of GT weeds.
- (17) What are the impacts of the mitigation measures on coexistence with organic and conventional alfalfa production and export markets?
- (18) Are there any other potential direct, indirect or cumulative impacts from the release of GT alfalfa other than those mentioned above?

The notice solicited public involvement in the form of written comments regarding the above issues and alternatives for regulatory action. Written comments were accepted from the public during a comment period which lasted until February 6, 2008 (<http://www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=APHIS-2007-0044> and appendix B).

c. Scoping Analysis and Documentation

All comments and proposed alternatives received were evaluated on the basis of whether they addressed the issues in question, whether they were based on valid science, and whether they were reasonable and practicable. A summary of the public comments are provided in appendix B. The results of the scoping process assisted APHIS in the formulation of the alternatives that are analyzed in this DEIS. Relevant issues raised through the scoping process were incorporated into the formulation of the

regulatory alternatives as described in chapter 2 and issues discussed in chapters 3 and 4.

Under the authority of 7 CFR part 340, APHIS has the responsibility for overseeing the safe development and use of GE organisms under the provisions of the Plant Protection Act. APHIS must respond to petitioners that request a determination of the regulated status of GE organisms, including GE crop plants such as GT alfalfa events J101 and J163. If a petition for nonregulated status is submitted, APHIS must make a determination whether the GE organism is unlikely to pose a plant pest risk.

As a Federal agency subject to compliance with the National Environmental Policy Act (NEPA) (42 U.S.C. 4321 et seq.), APHIS has prepared this DEIS to consider the potential environmental effects of this proposed action (granting nonregulated status) and the reasonable alternatives to that action consistent with NEPA regulations (40 CFR parts 1500-1508, 7 CFR 1b, and 7 CFR part 372). This DEIS has been prepared to comply with an order of the U.S. District Court for the Northern District of California to evaluate the effects on the quality of the human environment that may result from the deregulation of GT alfalfa lines J101 and J163.

d. How the Draft Environmental Impact Statement was Developed

On January 7, 2008, APHIS published in the *Federal Register* a Notice of Intent (NOI) (73 FR 1198-1200) to prepare an EIS, in compliance with NEPA and APHIS' own NEPA implementation rules. The purpose of the EIS is to identify and analyze any environmental impacts that could result from the granting of nonregulated status to two lines of genetically engineered, GT alfalfa, designated J101 and J163. As described in chapter 1, the NOI posed several questions in broad categories related to issues that could be of concern. The 30-day comment period closed on February 6, 2008. Approximately 240 public comments were received and reviewed by APHIS. These and all other comments were analyzed, and APHIS identified any new issues not originally provided in the NOI.

APHIS used all the comments that it collected from the *Federal Register* notice to ensure that the agency was addressing all pertinent issues, and that the EIS examined environmental impacts that could result from deciding to grant or not to grant nonregulated status to GT alfalfa lines J101 and J163. The results of the scoping process and NOI are summarized in appendix B.

2. Requirements for Further Environmental Analysis

APHIS will issue a final EIS that addresses public comments received on this DEIS, in accordance with NEPA. Supplements to the final EIS may be necessary as new information is brought to APHIS' attention, changes occur in the program or its administration, or coverage of the document is expanded. Two classes of supplements could be issued:

- Insignificant Supplements—Supplements that cause no substantive change in emphasis or classes of activities and do not have significant environmental impacts (40 CFR § 1508.27).
- Significant Supplements—Supplements that substantively change program emphasis or that have potentially “significant” impacts to the environment (40 CFR § 1508.27).

Insignificant supplements will be made by the APHIS Administrator or his or her delegated representative with appropriate public notification. Significant supplements will be subjected to NEPA analysis and put in force with the appropriate NEPA documentation and determination as required by CEQ and APHIS–NEPA implementing regulations.

II. Alternatives

A. Introduction

The U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) is responsible for regulating the introduction (importation, interstate movement, and environmental release) of genetically engineered (GE) organisms that are known to, or could, pose a plant pest risk. GE organisms are considered to have the potential to pose a plant pest risk if the donor organism, recipient organism, vector, or vector agent used in their creation is a member of a genus (listed in the regulations at 7 CFR part 340) known to contain plant pests.

A person may petition the agency to evaluate submitted data and determine that a particular regulated article is unlikely to pose a plant pest risk, and, therefore, should no longer be regulated, under 7 CFR § 340.6 “Petition for Determination of Nonregulated Status.” The petitioner is required to provide information (§ 340.6(c)(4)) related to plant pest risk that the agency uses to determine whether the regulated article is unlikely to present a greater plant pest risk than the unmodified organism. If, based on this information, the agency determines that the article is unlikely to pose a plant pest risk, the agency may approve the petition, the regulated article may be granted deregulated status, and APHIS is divested of regulatory authority over this GE organism.

A. Description of Alternatives

This draft EIS analyzes the potential environmental consequences of a proposal to grant nonregulated status to glyphosate-tolerant (GT) alfalfa lines J101 and J163. USDA asserts that all production systems, conventional, organic, and the use of genetically-engineered varieties, provide benefits to agriculture and the environment, thus the alternatives have been developed in conjunction with this philosophy.

In order for a GE organism to be granted nonregulated status, it must be unlikely to pose a plant pest risk. The analysis provided in the plant pest risk assessment (USDA-APHIS, 2009) demonstrates that there was sufficient data to determine that both GT alfalfa lines J101 and J163 are unlikely to pose a plant pest risk. Once APHIS determines that the GT alfalfa lines do not pose a plant pest risk, APHIS would have no regulatory authority over GT alfalfa events J101 and J163 and these GT alfalfa lines are eligible for nonregulated status.

The regulations at 7 CFR § 340.6(d)(3)(i) state that APHIS may “approve the petition in whole or in part.” Approval ‘in part’ can be given if there is

a plant pest risk associated with some but not all lines requested in a petition.

APHIS has removed from consideration the concept of approving only one of the genetically-engineered GT alfalfa lines (either J101 or J163) and not both lines. APHIS conducted a risk assessment of the plant pest risks posed by GT alfalfa lines J101 and J163 (USDA-APHIS, 2009). The risk assessment of GT alfalfa J101 and J163 indicates that neither J101 and J163 pose a plant pest risk: 1) the two lines show no evidence of increased weediness compared to the non-transgenic control; 2) neither line exhibits increased insect or disease susceptibility; 3) the genetic sequences from plant pests inserted into the alfalfa lines do not pose a plant pest risk; and 4) neither line exhibits increased plant pest risk characteristics. There are also no significant biological differences between the two lines in terms of transgene protein expression and composition (chapter 3). Additionally, none of the comments received during the public comment period of the original EA in 2005 (USDA, 2005) and during the public comment period of the NOI cited concerns regarding a difference in or occurrence of any plant pest risks in GT alfalfa lines J101 and J163. Since there are no biological differences between GT alfalfa lines J101 and J163 (and the public comments did not call attention to any perceived differences in GT alfalfa lines J101 and J163), and since there is no plant pest risk associated with either alfalfa line, there is no environmental or public health advantage in granting nonregulated status to one line over the other GT alfalfa line. Therefore, APHIS will only issue a decision in conjunction with both GT alfalfa lines and will not consider granting nonregulated status to only one of the GT alfalfa lines.

Because APHIS has found that both GT alfalfa lines J101 and J163 are unlikely to pose a plant pest risk, the preferred alternative considered in this DEIS is to grant nonregulated status “in whole.” Under another type of granting nonregulated status there could be approval “in part,” where the petition may be approved with geographic restrictions if there is a geographic variation in plant pest risk. There are no geographic differences in plant pest risks for these GE alfalfa lines (USDA-APHIS, 2009). Thus, there are two alternatives that will be considered in this draft EIS: (1) no action and (2) to grant nonregulated status to GT alfalfa events J101 and J163, “in whole.”

1. No Action

Under the "no action" alternative, APHIS would not change the regulated status of glyphosate-tolerant (GT) alfalfa lines J101 and J163 under the regulations in 7 CFR part 340. As stated in the Purpose and Need, chapter 1, GT alfalfa lines J101 and J163 were granted nonregulated status by APHIS in 2005. Approximately 9 months later, a group of organic alfalfa growers and several other associations filed a lawsuit in the U.S. District Court for the Northern District of California that challenged

APHIS' decision to grant nonregulated status to J101 and J163. On February 13, 2007 the Court ruled that APHIS' EA failed to adequately consider certain environmental impacts as required by the National Environmental Policy Act of 1969 (NEPA), and the Court vacated APHIS' decision to grant nonregulated status to J101 and J163. In March of 2007 USDA published notice in the Federal Register that GT alfalfa was once again a regulated article and GT alfalfa seed sales and plantings were halted.

In the two growing seasons that GT alfalfa was on the market after being deregulated, ~200,000 total acres were planted in 1,552 counties and 48 States, with the exception of Alaska and Hawaii, during the 2005 and 2006 growing seasons. These GT alfalfa fields are still permitted to be harvested, and has court ordered stewardship practices to minimize potential of GT alfalfa being present in harvests of non-GT alfalfa harvests (Hubbard, 2008).

Under the no action alternative, the approximately 200,000 acres of alfalfa fields currently planted with GT alfalfa would still be permitted to be harvested. No new commercial plantings of GT alfalfa would be allowed because GT alfalfa lines J101 and J163 would continue to be considered regulated articles. APHIS would require permits for new introductions of GT alfalfa events J101 and J163, and these introductions would only be for non-commercial, research and development purposes.

This alternative is not the preferred alternative because APHIS has determined through a plant pest risk assessment (USDA-APHIS, 2009) that the GT alfalfa lines under consideration are not plant pests and are unlikely to pose plant pest risks. Choosing this alternative would hinder the purpose and need of APHIS to allow for the safe development and use of GE organisms given that GT alfalfa lines J101 and J163 are unlikely to pose plant pest risks.

2. Determination that J101 and J163 Alfalfa Plants are No Longer Regulated Articles, In Whole (Preferred Alternative)

Under the preferred alternative, GT alfalfa lines J101 and J163 would no longer be regulated articles under the regulations at 7 CFR part 340. Permits issued by APHIS would no longer be required for introductions of GT alfalfa derived from these events. Additional acreage planted to GT alfalfa, in addition to the ~200,000 acres of GT alfalfa currently planted, would be allowed.

Once APHIS has determined that GT alfalfa lines J101 and J163 are unlikely to pose a plant pest risk, APHIS would not have regulatory authority over these GE organisms. By granting nonregulated status to GT alfalfa lines J101 and J163 since they do not pose a plant pest risk, the purpose and need to allow the safe development and use of GE organisms is met.

With respect to the issues and associated alternatives, APHIS has made a preliminary determination that action should be taken, and that action will be to grant nonregulated status to GT alfalfa lines J101 and J163, in whole (Alternative 2). The introduction of these GT alfalfa lines has no significant impact on the environment. These GT alfalfa plants, lines J101 and J163, are not plant pests and are unlikely to pose plant pest risks. GT alfalfa lines J101 and J163 do not meet the definition of a regulated article under 7 CFR part 340.

A. Alternatives Rejected from Further Consideration

APHIS assembled a comprehensive list of alternatives that might be implemented in the decision process for lines J101 and J163 of GT alfalfa. The agency individually evaluated each alternative on the basis of legality, environmental safety, efficacy, and practicality to identify which alternatives would be further considered during the decision process. Based on this evaluation, APHIS rejected several alternatives. In the interest of transparency, these alternatives are discussed briefly below along with the specific reasons for rejecting each.

1. Prohibit Glyphosate- Tolerant Alfalfa

In response to public comments submitted during scoping that stated a preference that no GE organisms enter the marketplace, APHIS considered prohibiting the release of any GT alfalfa, including denying any permits associated with the continued environmental releases or field testing of GT alfalfa. APHIS determined that this alternative is not appropriate in that GT alfalfa events J101 and J163 have been determined in APHIS' Plant Pest Risk Assessment not to be plant pests (USDA-APHIS, 2009). APHIS has no jurisdiction to regulate plants as plant pests once APHIS has determined that those plants are not plant pests.

A risk-management process based on sound science must consider a growing body of scientific evidence documenting the safe use of GE organisms in U.S. agriculture, and in the rest of the world, to determine whether their use poses any unacceptable risks. Because Congress has mandated a science-based approach in APHIS regulations and because there is no basis in science for banning the release of GT alfalfa, a blanket prohibition of the release of GT alfalfa would contravene Congressional intent and must be rejected.

2. Impose Isolation Distances

In response to public comments submitted during scoping that described concerns about the gene movement between GE and non-GE plants, APHIS considered requiring isolation distances separating GT alfalfa from non-GT alfalfa fields. However, because GT alfalfa is unlikely to pose a plant pest risk (USDA-APHIS, 2009), APHIS will have no regulatory authority over GT alfalfa and will be unable to require regulatory

restrictions or management practices for these GE alfalfa varieties once it is granted nonregulated status.

**3. Impose
Geographic
Restrictions**

In response to public comments submitted during scoping that described concerns about the gene movement between GE and non-GE plants, APHIS considered geographic restrictions based on regional growing practices of alfalfa or regional changes in pesticide use that may significantly affect the environment due to use of J101 or J163. In the regional analysis of production practices of alfalfa, no significant differences were detected at a regional level (see chapter 3), so this alternative was dismissed.

APHIS considered restricting the production of GT alfalfa based on production of non-GT alfalfa in organic production systems or production systems for GE-sensitive markets. State-level and county-level restrictions of GT alfalfa, as well as the establishment of GE-free alfalfa production zones, were rejected because GT alfalfa is unlikely to pose a plant pest risk (USDA-APHIS, 2009). Therefore, APHIS will have no regulatory authority over GT alfalfa and will be unable to impose regulatory restrictions on these GE alfalfa varieties.

**4. Impose
Testing
Requirement**

During the comment periods for other petitions for granting nonregulated status, and during the scoping period for this DEIS, some commenters have requested that USDA require and provide testing for GE products in non-GE production systems. However, there are no nationally established regulations involving testing or limits of GE material in non-GE systems. As a member of the Biotechnology Industry Organization (BIO), Monsanto and FGI are pledging to work with the framework of the new BIO Quality Management Program (www.bio.org). Additionally, because GT alfalfa is unlikely to pose a plant pest risk (USDA-APHIS, 2009), APHIS will have no regulatory authority over GT alfalfa, and will be unable to impose regulatory restrictions on these GE alfalfa varieties.

III. Affected Environment

A. Overview of Alfalfa

Alfalfa (*Medicago sativa* L.) is among the most important forage crops in the United States, with more than 20 million acres in cultivation. It is recognized as the oldest plant grown solely for forage. Conventional alfalfa (alfalfa that is not a GE variety and not grown using organic practices) has been used by farmers as livestock feed for decades because of its high protein and low fiber content. Alfalfa ranks fourth on the list of most widely grown crops by acreage, behind corn, soybeans, and wheat, and is ranked third among agricultural crops in terms of value. Because it is widespread and is typically grown as a perennial crop, alfalfa also provides important habitat for wildlife (Hubbard, 2008).

Dairy farmers would be the most likely users of glyphosate-tolerant (GT) alfalfa because they often depend on pure alfalfa stands that are free of weeds and grasses, whereas, beef cattle producers and horse owners typically feed their animals a mix of alfalfa-grass hay (Putnam, 2005). About 40 percent of U.S. alfalfa acreage is planted as pure stands, and about 25 percent is planted with grasses or another companion crop (Rogan and Fitzpatrick, 2004).

Alfalfa plants are also used for a variety of non-agricultural purposes. These uses include rehabilitation of overgrazed rangelands, erosion-control projects in interior forests, treatment of compacted soils, re-vegetation of areas damaged by wildfire, and erosion reduction in mined soils.

1. Uses of Alfalfa

The following discussion is in part taken from the technical report, *Effects of Glyphosate-Resistant Weeds in Agricultural Systems* (appendix G).

a. Seed

Humans consume alfalfa in the form of sprouts, dietary supplements, and herbal teas. The seed grown for sprouts is subject to more stringent restrictions for chemical applications during growing because the chemicals must be evaluated as food residues. Epidemiological (disease related) investigations have suggested that alfalfa seeds are the likely source in most, if not all, sprout-associated illness outbreaks. For these reasons, sprout seed and hay seed used for forage are usually grown separately (FDA, 1999).

In their Biotechnology Consultation, the Food and Drug Administration (FDA) concluded that the GT alfalfa events J101 and J163, and the feeds and foods derived from them, are not materially different in safety,

composition, or any other relevant parameter from alfalfa now grown, marketed, and consumed (appendix P). Thus, GT alfalfa is permitted for human consumption. However, Monsanto does not allow GT alfalfa to be planted for sprouts (Hubbard, 2008), a restriction that is enforced through signed agreements between Monsanto/Forage Genetics International (FGI) and purchasers of GT alfalfa.

b. Forage

Alfalfa is considered the “Queen of Forages” because of its high nutritional content for cattle and horses (Putnam et al., 2001). As alfalfa grows, yield increases until alfalfa yield peaks at full bloom. Nutritional content, however, is highest in young vegetative alfalfa plants and decreases as plants approach full flower. The highest quality alfalfa hay (bud stage) is generally used for dairy cows. Hay that is lower in protein and higher in fiber is fed to beef cattle, horses, heifers (too young to milk), and non-lactating dairy cows (Ball et al., 2001). Alfalfa for livestock feed is stored in a variety of forms such as hay (dry baled at 18- to 20-percent moisture); haylage (round bale silage, baled at 50- to 60-percent moisture and wrapped in plastic); and silage (chopped and blown into a silo or a truck).

c. Grazing

Grazing is sometimes used as an alternative to harvesting alfalfa. Grazing allows for high nutritional gains per animal, but the risks include animal losses due to gastro-intestinal bloating and difficulties in alfalfa stand maintenance if continuous grazing is present. Farmers may choose grazing for dormant-season alfalfa stubble, a substitute for early or late season cutting, and rotational grazing during the growing season (Orloff et al., 1997).

d. Other

Alfalfa and clover are common nectar sources for honey bee hives. Although alfalfa is not specifically grown for bees, both managed and wild bee hives are often associated with alfalfa fields (Hammon et al., 2007).

2. Biology of Conventional Alfalfa

a. Area of Adaptation

Alfalfa is recognized as a widely adapted crop, growing in all continental States, as well as Alaska and Hawaii. Alfalfa grows best in fertile, well-drained soils; however, because of its adaptability, it also survives outside of cultivation. Feral alfalfa populations, although sparse, occur throughout the United States (http://npdc.usda.gov/pdf/0105_npdc_brochure.pdf).

Little evidence exists to suggest that alfalfa is considered a weed (see appendices G and H), other than as a volunteer in agricultural settings. In correspondence with 13 weed control experts in Arizona, California, Idaho, Oregon, Pennsylvania, South Dakota, Washington, and Wisconsin, Monsanto found that none considered alfalfa a weed (Rogan and Fitzpatrick, 2004). In South Dakota and Wisconsin, it is encouraged to grow along roadsides.

b. Growth and Reproduction

Alfalfa is a deep-rooted and short-lived perennial. During establishment, alfalfa initially grows from seed, but after each harvest or winter, it re-grows from buds arising from the perennial root structure (the crown). Conventional alfalfa forage is grown in pure and mixed-species forage systems, or to a lesser extent, grazed in pasture or rangeland. The vegetative growth interval (i.e., harvest schedule) during most of the year is 22 to 40 days, and the crop is typically harvested for forage three to eight times per year, depending on location and seasonal climate. Fields grown for hay production are typically maintained for 3 to 6 years or longer in some areas. Most alfalfa in the United States is managed to limit growth to the juvenile (vegetative) state so that forage production (yield) and nutritional quality of the hay are optimized. Hay with open flowers or seed (late maturity) is of poor quality for feed and has low market value. In seed fields, flowering and seed production are promoted. In most fields, flower buds begin to form on stems approximately 4 to 6 weeks after field mowing during long-day photoperiods and warm weather. Flowering is not triggered under short days or cool weather (i.e., late summer through mid spring). Once flowering ensues, alfalfa flowers indeterminately, and its duration depends on moisture, temperature, and other factors (Rogan and Fitzpatrick, 2004).

Alfalfa is predominantly cross-pollinated and the flowers depend entirely on bees for cross-pollination. Wind cross-pollination in alfalfa does not occur (Viands et al., 1988). Alfalfa requires bees to physically “trip” flowers to release pollen for egg fertilization and seed production. In the United States, alfalfa seed production fields are pollinated primarily with leafcutter bees (*Megachile rotundata* F.) in the Pacific Northwest and honey bees (*Apis mellifera*) in California. Some growers in niche areas of southern Washington use alkali bees (*Nomia melanderi* C.), and certain seed producers use a blend of cultured species for pollination. Native bees, including *Bombus* spp., *Osmia* spp., *Agapostomen* spp., and *Megachile* spp., can be found visiting alfalfa in varying numbers. Other insect pollinators have not been shown to be effective for alfalfa (Rogan and Fitzpatrick, 2004).

c. Related Species

Alfalfa, of the genus *Medicago*, is in the tribe Trifolieae, which includes *Trifolium* (true clovers), *Melilotus* (sweetclover), and *Trigonella* (fenugreek). *Medicago* species do not hybridize (interbreed to form hybrid offspring) with these (or other) genera. The *M. sativa* complex has been successfully hybridized with 12 other perennial *Medicago* species (McCoy and Bingham, 1988). However, many of these interspecific hybrids have been successful only by using embryo culture of the hybrid in the greenhouse or laboratory (McCoy and Smith, 1986), making them highly unlikely to occur in nature. No perennial *Medicago* species are present naturally in the Americas, Australia, New Zealand, or South Africa, as it is native to the Middle East and Central Asia (Xu et al., 2004).

d. Susceptibility to Glyphosate and Other Herbicides

According to Crop Data Management System's (CDMS) Agricultural Product Label Service database, the herbicides 2,4-D, clopyralid, dicamba, glufosinate, glyphosate, and rimsulfuron-methyl were labeled for control of alfalfa. Independent research has demonstrated that dicamba, 2,4-D, tank mixtures of dicamba and 2,4-D, and clopyralid were often more effective than glyphosate for terminating alfalfa stands (Endres, 1999; Mayerle, 2002; Manitoba Agriculture and Food, 2002). Additional data demonstrated that early postemergence applications of herbicides (applied during the stage between the emergence of a seedling, and the maturity of the plant) used to control weeds in corn (Harness XTRA (acetochlor + atrazine), Degree (acetochlor), and Degree XTRA (acetochlor + atrazine) applied in tank mixtures with broadleaf herbicides Banvel (dicamba), 2,4-D, Marksman (atrazine + dicamba) and Hornet (clopyralid + flumetsulam) effectively controlled GT alfalfa in a GT corn crop. As expected, GT alfalfa events J101 and J163 were susceptible to herbicides typically used to control alfalfa² (Rogan and Fitzpatrick, 2004).

e. Susceptibility to Insect Damage and Disease

The major alfalfa diseases of economic importance in the United States are those pathogens that impact the foliar, crown, root, vascular, and seedling health of alfalfa plants. Alfalfa diseases are primarily caused by fungi; however, nematodes, bacteria, viruses, and other microbes also cause economic losses in alfalfa production (Leath et al., 1988). Diseases that occurred in the GT alfalfa test locations included, but were not limited to, seedling damping-off (caused by fungi such as *Pythium*, *Phytophthora*, *Aphanomyces*); foliar diseases (caused by fungi such as *Leptosphaerulina*, *Colletotrichum*, *Peronospora*, *Phoma*, *Stemphylium*,

² No unintended impacts or effects on other pest plant characteristics assessed by the manufacturers were found.

Cercospora, and stem nematodes like *Ditylenchus*); and root rots, vascular wilts and crown diseases (caused by fungi such as *Phytophthora*, *Verticillium*, *Fusarium*, *Phoma*, and bacterial wilt caused by *Clavibacter*) (Rogan and Fitzpatrick, 2004).

Insect pest species that are economically important in alfalfa vary widely among regions in the United States. The broad geographic distribution of the GT alfalfa test sites in the United States, and even broader exposure since deregulation in 2005, has exposed GT alfalfa to a wide range of naturally occurring insect pests. Insects that have an economic effect on the growing of GT and non-GT alfalfa included, but were not limited to potato leafhoppers (*Empoasca fabae*), aphids [pea (*Acyrtosiphon pisum*), blue (*A. kondoi*) and spotted alfalfa aphids (*Therioaphis maculata*)], alfalfa weevil (*Hypera postica*), lygus bugs (*Lygus species*), other plant bug species (family *Miridae*) and alfalfa caterpillars (various Lepidopteran species) (Rogan and Fitzpatrick, 2004).

f. Insertion of DNA Sequences

Monsanto and FGI has incorporated the gene sequence from a native soil microorganism, *Agrobacterium*, into the alfalfa genome in order to make alfalfa tolerant to glyphosate, the active ingredient in Roundup®, an herbicide Monsanto produces. As discussed in technical report, *Glyphosate-Tolerant Alfalfa Presence in Human Food and Animal Feed*, appendix Q), the expressed gene product in glyphosate-tolerant (GT) alfalfa is a protein, 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), derived from the CP4 strain of *Agrobacterium*, thus called CP4 EPSPS. The protein is a single polypeptide that is 455 amino acids long and structurally and functionally similar to the native plant EPSPS enzymes. The herbicide glyphosate inhibits an essential step in aromatic amine synthesis in plants by blocking the action of the natural EPSPS enzymes. However, the CP4 EPSPS protein is not inhibited by the herbicide glyphosate; thus any plant with the protein is resistant to glyphosate application. In other words, it is the insertion of this gene sequence and the production of the CP4 EPSPS protein that makes GE alfalfa events J101 and J163 tolerant to glyphosate and glyphosate herbicide formulations.

3. Feral Alfalfa

Since its introduction to the United States, alfalfa has occasionally become feral, or naturalized, by escaping agricultural fields and multiplying by natural regeneration. Settings where feral alfalfa can be found include air fields, canals, cemeteries, ditch banks, fence rows, highways, irrigation ditches, pipelines, railroads, rangeland, rights-of-way, roadsides, wasteland (Rogan and Fitzpatrick, 2004). Alfalfa plants that are not part of cropping systems generally have no regular external inputs like irrigation, herbicides, insecticides, and fertilizers; however, alfalfa was

found to survive and increase on rangeland in Utah for more than 10 years, and can reseed on sites with as few as 11 inches (28 cm) of precipitation per year (Sullivan, 1992).

Alfalfa that exists outside of cultivation is typically not targeted for control by herbicide. In some instances on lands where unmanaged or feral alfalfa now occurs, the planting was intentional (e.g., feral plants exist in relegated sown pastures, abandoned alfalfa fields, or on roadsides once sown with alfalfa seed, [Rogan and Fitzpatrick, 2004]). All feral alfalfa in the United States, like alfalfa under cultivation, originated from introduced varieties. Rogan and Fitzpatrick (2004) summarize the extent of feral populations in six major alfalfa-producing States, confirming that minor feral populations do exist in areas where alfalfa seed or forage is produced. In situations where control of feral alfalfa is desired, it can be controlled or discouraged just like cultivated alfalfa using cultural³ or chemical methods (Rogan and Fitzpatrick, 2004).

Sullivan (1992) reviewed alfalfa use for rehabilitation and disturbed sites. Some uses of alfalfa that can lead to feral alfalfa populations are:

- rehabilitation of overgrazed rangelands for improving wildlife habitat and livestock;
- erosion-control projects in interior forests;
- improvements of compacted soils (alfalfa has deep roots that grow vigorously in compacted soils);
- re-vegetation of areas damaged by wildfire (Oregon DFW, 2008); and
- erosion reduction in mined soils (Sullivan, 1992; Withers, 2002).

Survival without management inputs requires feral plants to have traits that may differ from those of cultivated plants. Bagavathiannan and Van Acker (2008) list the following traits that are common among the most successful feral species:

- variety of pollinators,
- continuous seed production,
- considerable seed output,
- seeds produced in several habitats,
- seed dispersal over short and long distances,
- seed dormancy (ability to form a seedbank),
- broad germination requirements,
- discontinuous germination,
- rapid vegetative growth,
- ability to withstand competition,

³ Cultural weed control methods include adding companion crops to the chief crop to smother or suppress weeds, applying a combination of mulches, or crop rotation.

- tolerance to unfavorable biotic and abiotic conditions, and
- rapid flowering.

Alfalfa has many of the above attributes and competes well with other native and introduced plants in a variety of settings. The *M. sativa* subspecies (purple-flowered alfalfa used in cultivation) has naturalized populations in all 50 States, while the *M. sativa* subsp. *falcata* subspecies (yellow-flowered or Siberian alfalfa) is naturalized in the northern and western States and is being promoted as a rangeland enhancer for grazing, as reported in the USDA, Natural Resources Conservation Service (NRCS), National Plant Data Center, PLANTS Database (http://npdc.usda.gov/pdf/0105_npdc_brochure.pdf).

B. Biological Environment at Risk

The terrestrial ecosystems potentially at risk from the application of glyphosate associated with GT alfalfa include the treated area and areas immediately adjacent to the treated area that might receive glyphosate drift or runoff, and might include other cultivated fields, fence rows and hedgerows, meadows, fallow fields or grasslands, woodlands, riparian habitats, or other uncultivated areas. The use of glyphosate is regulated by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) restrictions administered by the EPA, which mandates registration and use of all pesticides. APHIS has no regulatory authority over the use of glyphosate for any GT crop.

EPA includes instructions and restrictions on how glyphosate herbicides can be applied, and has determined that there is no unreasonable environmental risk if the user adheres to the directions when applying glyphosate herbicide formulations. Directions include application restrictions that minimize impacts on nearby environments. Violators of the regulations are liable for all negative consequences of their actions; therefore, farmers who use glyphosate are very likely to follow its label restrictions, and adverse impacts from the predicted increased glyphosate use will be minimized.

Aquatic ecosystems potentially at risk from glyphosate include water bodies adjacent to, or downstream from, the treated field, and might include impounded bodies such as ponds, lakes and reservoirs, or flowing waterways such as streams or rivers (this discussion is based on the concept that even in the context of FIFRA regulations and label restrictions that are legally required to be followed, there is a chance that glyphosate use might, nonetheless, result in environmental impacts). The proposed use sites may be located either near freshwater or saltwater habitats. For uses in coastal areas, an aquatic habitat also includes marine ecosystems with estuaries.

The above is discussed and reviewed throughout this section.

1. Glyphosate

a. In Roundup® Formulations

The discussion throughout this section is in part taken from the technical report, *Potential Impacts to Wildlife, Amphibians, Plants and Ecosystems from Increased Glyphosate and Other Chemical Usage* (appendix N).

Glyphosate was first introduced as an herbicide under the trade name of Roundup® by Monsanto in 1974. Glyphosate is a systemic, post-emergence herbicide widely used on both agricultural commodities (food uses) and non-agriculture sites (Cerdeira and Duke, 2006). Glyphosate is a substituted glycine, the simplest amino acid. The glyphosate molecule has a methylphosphono group bonded to the nitrogen atom of the amino group of glycine, as denoted in figure 3-1 below.

At normal temperatures, glyphosate is a white crystalline substance that is not volatile (is not likely to vaporize at normal pressure) and is highly soluble in water. Glyphosate salts serve as the source of the active ingredient *N*-(phosphonomethyl) glycine. To improve handling, performance, and concentration, the glyphosate acid is formulated as a salt compound. Several salts of glyphosate are currently marketed. The term acid equivalent (a.e.) refers to the weight of the glyphosate acid, which is herbicidally active, while the term active ingredient (a.i.) is the weight of the glyphosate acid plus the salt. While GT alfalfa could tolerate other herbicides formulated with glyphosate, there are five glyphosate herbicides recommended for use on GT alfalfa. These end use products (EUPs) are presented in table 3-1.

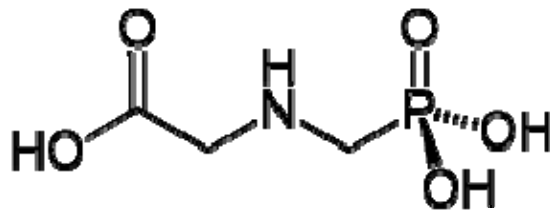


Figure 3-1. Molecular structure of glyphosate.

Table 3-1. Monsanto End Use Products Approved for Use on Glyphosate-Tolerant Alfalfa.

Product Name	% Salt	Glyphosate salt CAS No.	U.S. EPA PC Code	Surfactant	Year
Honcho®	41	Isopropylamine CAS: 38641-94-0	103601	Alkyl Tallow Ethoxylated Amines CAS 61791-26-2	2007b
Honcho Plus®	41	Isopropylamine CAS: 38641-94-0	103601	Trade Secret	2007d
Roundup Original MAX®	48.7	Potassium CAS: 70901-12-1	103613	Trade Secret	2007e
Roundup WeatherMAX®	48.8	Potassium CAS: 70901-12-1	103613	Trade Secret	2007f
Roundup Ultra MAX II®	48.8	Potassium CAS: 70901-12-1	103613	Trade Secret	2004

Glyphosate is a very effective non-selective herbicide (Cerdeira and Duke, 2006). Herbicide formulations in liquid form are generally considered trade secret. One formulation of glyphosate, Honcho®, has a tallow amine surfactant (Monsanto, 2007a). This and other surfactants (surface action agents that are soluble in organic solvents and water), such as polyethoxylated tallowamine (POEA), are added to the herbicide formulations to increase leaf penetration.

The Roundup® Ready Original MAX®, Roundup® WeatherMAX®, and Roundup® Ultra MAX II® products contain 48.8 percent of the phosphate salt of glyphosate, equivalent to 4.5 lbs of glyphosate equivalents per gallon (540 g glyphosate/L). The product is to be applied over-the-top (e.g., spot treatment, broadcast ground application) for pre-plant, preemergence, and post-emergence uses.

Typical single application rates of products containing glyphosate range from less than 1.5 pounds of glyphosate a.e. per acre up to 3.75 pounds of glyphosate a.e. per acre. Application rates were determined using specific product labels for each end use product recommended for use on GT alfalfa (Monsanto, 2007a; 2007f; 2007c; 2007d; 2005b; 2005c; 2004), and are calculated to minimize impact on nearby environments. Application rates of the five end use products recommended for use on GT alfalfa are presented in table 3-2. The maximum use rate (ground or aerial application) for a single application of glyphosate on GT alfalfa is 1.55 pounds of glyphosate a.e. per acre.

Table 3-2. Application Rates of EUPs Recommended for Use on Glyphosate-Tolerant Alfalfa.

Product	Single Use Application Rate	Reference
Honcho®	2.0 lb a.i./acre	Monsanto, 2007a; 2007e
Honcho Plus®	2.0 lb a.i./acre	Monsanto, 2007b; 2007f
Roundup Original MAX®	1.9 lb a.i./acre	Monsanto, 2007c
Roundup WeatherMAX®	1.9 lb a.i./acre	Monsanto, 2007d; 2005a; 2005b
Roundup Ultra MAX II®	1.9 lb a.i./acre	Monsanto 2005c; 2004; 2003

b. Chemical Fate and Transport of Glyphosate in Environment

Glyphosate exposure is possible due to spray drift, inadvertent direct overspray, or wind transport of soil particulates loaded with adsorbed glyphosate. Glyphosate has a low vapor pressure and Henry's law constant; thus, it has a low potential to evaporate from soil and water. Glyphosate is hydrophilic (bonds with and dissolves in water), therefore, it has low potential to accumulate in the tissues of animals. It has a high solubility in water and is not broken down by water (hydrolysis) or by exposure to light (photolysis). Due to glyphosate's strong adsorptive quality with soil (strong ability to collect and remain associated or bound with soil), it is not expected to contaminate groundwater; however, runoff water could contain particulates with adsorbed glyphosate (Giesy et al., 2000).

In soil, sediment, or natural water, glyphosate is primarily broken down by microbes, creating the major metabolic byproduct, aminomethyl phosphonic acid (AMPA). It can be further degraded to CO₂, although at a slower rate than the parent glyphosate (EPA, 1993). In a USDA monitoring study conducted on surface water, groundwater, and soil from 2001 to 2006, the metabolite AMPA was observed more frequently than the parent compound glyphosate (Scribner et al., 2007). The sample collections were from several U.S. Geological Survey (USGS) studies including the National Stream Quality Accounting Network Program; the National Water-Quality Assessment Program; and the Toxic Substances Hydrology Program. EPA determined that, based on toxicological considerations, AMPA need not be regulated (EPA, 2006c).

2. Toxicology and Environmental Risk

The discussion throughout this section is in part taken from the technical report, *Potential Impacts to Wildlife, Amphibians, Plants and Ecosystems from Increased Glyphosate and Other Chemical Usage* (appendix N).

Based on the EPA's toxicological and ecotoxicology and fate databases (EPA, 1993; EPA, 2006a), glyphosate is considered to be a toxicologically and ecologically low-risk herbicide (Cerdeira and Duke, 2006). Based on

the data available on glyphosate usage on GT alfalfa, chemical fate, and toxicity, and after a Tier 1 “high-end use case” scenario screening of hazard quotients, glyphosate is not expected to pose an acute or chronic risk to the following categories of wildlife:

- birds,
- mammals,
- terrestrial invertebrates,
- aquatic invertebrates, and
- fish.

a. Animal Toxicology

(1) Microorganisms and Soil Invertebrates

Microorganisms produce aromatic amino acids through the shikimate pathway, similar to plants. Since glyphosate inhibits this pathway, it could be expected that glyphosate would be toxic to microorganisms. However, field studies show that glyphosate has little effect on soil microorganisms, and, in some cases, field studies have shown an increase in microbial activity due to the presence of glyphosate (USDA–FS, 2003).

(2) Birds

Glyphosate is practically non-toxic to birds and was not found to cause reproductive effects. Toxicity in birds was assessed using single-dose, dietary, and reproductive toxicity studies. Toxicity was assessed by determining dose levels needed to kill 50 percent of a population of test animals. Glyphosate acute toxicity in the Bobwhite quail was slightly toxic. Dietary studies in the Bobwhite quail and Mallard duck are considered slightly toxic for both birds (EPA, 1993; EPA, 2006a). Reproductive studies did not indicate any effect after glyphosate treatment in Mallard duck or Bobwhite quail. Glyphosate tested as acid produced similar results in the Bobwhite quail and Mallard duck; studies with glyphosate tested as its isopropylamine (IPA) salt were not reported for review.

(3) Mammals

In terms of subchronic and chronic toxicity⁴ in rodents, one of the more consistent effects of exposure to glyphosate is loss of body weight. Glyphosate is a Group E carcinogen (cancer-promoting agent) which represents no evidence of carcinogenicity. Additionally, glyphosate does

⁴ Subchronic toxicity studies are those that study the effects on a small percentage of a subject's life span (e.g., up to 10%) while chronic studies continue for a longer period of the subject's lifespan.

not increase the frequency of mutations in an animals' DNA and was not found to cause reproductive or developmental effects in mammals.

Studies with lactating goats, laying hens, rats, rabbits, and cows fed a mixture of glyphosate and AMPA indicate that the primary route of elimination was by excretion (urine and feces).

(4) Amphibians

Glyphosate is slightly toxic to amphibians; however, amphibians exhibited greater sensitivity to Roundup® formulations than to glyphosate tested as an acid or IPA salt. This could be due to the surfactant (POEA) used in agricultural formulations. POEA is a surfactant used in many herbicide formulations (such as GLYFOS®) to increase the ability of active ingredients to penetrate leaf cuticles (Lajmanovich et al., 2003).

(5) Fish

Many studies have also been performed in a variety of species of fish to determine the acute toxicity of glyphosate formulations. In general, the glyphosate formulations (herbicide plus other chemicals) were more toxic to fish than technical glyphosate (herbicide only). The increased toxicity is due to the presence of a surfactant in glyphosate formulations (Giesy et al., 2000).

The most sensitive species to the formulations considered was rainbow trout when treated with formulations similar to Roundup® UltraMAX II® and Roundup® WeatherMAX® (Monsanto, 2004; Monsanto, 2005). In bluegill sunfish, channel catfish, and fathead minnow, formulations of glyphosate are much more toxic than technical grade glyphosate (Giesy et al., 2000). Interestingly, many salmon species studied were less sensitive to glyphosate formulations than to glyphosate.

(6) Terrestrial Invertebrates

Honey bees are the preferred species to assess the toxicity of herbicides on arthropods by EPA. Glyphosate is considered “practically non-toxic” according to EPA standards, based on the toxicity needed to kill 50 percent of the test animals (Giesy et al., 2000; Monsanto, 2005, 2006, 2007b, 2007d).

(7) Aquatic Species

Glyphosate is slightly toxic to aquatic invertebrates, but formulations with certain surfactants are considered very toxic. Several acute and lifecycle toxicity tests have been performed on a variety of fresh water aquatic

invertebrates for glyphosate and various herbicide formulations. The most sensitive species to glyphosate was the buzzermidge (*Chironomus plumosus*). The most sensitive species to glyphosate herbicide end-use formulations was the water flea (*Daphnia magna*). In the case of the water flea, glyphosate formulations are several orders of magnitude more toxic than technical glyphosate.

Per the EPA's 1993 Reregistration Eligibility Decision for Glyphosate, "since there is such an extensive data set for this chemical, the Agency can determine that glyphosate demonstrates low toxicity to fish and oyster species, and therefore is waiving the marine fish and oyster acute⁵ toxicity studies on the formulated product."

The saltwater and marine species tested for toxicity to glyphosate and glyphosate herbicide formulations for GT alfalfa were invertebrates. The most sensitive marine species to glyphosate was the tiny zooplankton, *Acartia tonsa* which is abundant in warm coastal and estuary water.

b. Plant Exposure to Glyphosate

Glyphosate is estimated to be equally toxic to both terrestrial and aquatic plants (USDA, 2003). EPA has evaluated glyphosate's toxicity to aquatic plants based on studies submitted for the registration of the chemical and additional studies are also available (USDA, 2003).

Most plant species, when exposed to glyphosate, experience high levels of toxicity. Vascular plants that use the shikimate pathway to produce aromatic amino acids will experience toxic effects as they metabolize glyphosate. These toxic effects could include the inability to photosynthesize, the inability to complete respiration, and the inability to synthesize nucleic acids. Although the effects can be slow to progress, all of these toxic effects could result in plant death. Spray drift is one of the pathways of concern for non-target plants; if aerial applications are minimized this risk to nontarget plants should be reduced. AMPA, the primary degradation product of glyphosate, seems to be equally or less toxic than glyphosate; therefore, a separate risk characterization was not evaluated (USDA, 2003).

c. Glyphosate Resistance in Weeds

Weeds can develop resistance to herbicides for the following reasons: frequent exposure to a particular herbicide, the spread of naturally resistant weed seeds, and the outcrossing of herbicide-tolerant genes from

⁵ Acute toxicity studies are those that study the effects of a single or short-term exposure to a substance.

plants, either GE plants or plants that naturally have herbicide tolerance genes, to weedy relatives.

Currently, GT weeds are on two million acres of farmland in the United States (Hubbard, 2008). Some of the glyphosate-resistant weeds may also produce copious amounts of seeds, which may lay dormant in the soil and germinate many years later, further compounding the problem of glyphosate-resistant weeds and complicating the containment efforts by farmers relying only on glyphosate for weed control. The most problematic glyphosate-resistant weeds in the United States include pigweed (waterhemp), horseweed (marestail), common and giant ragweed, and ryegrass (Hubbard, 2008).

d. Threatened and Endangered Species

Threatened and endangered (T&E) species occur in the major plant and animal ecosystems, such as terrestrial ecosystems (e.g., meadows, fallow fields, grasslands, woodlands, riparian habitats) and aquatic ecosystems (e.g., lakes, rivers, streams). Those T&E species that may be exposed to the gene product in GT alfalfa would be those T&E species that inhabit alfalfa fields and feed on GT alfalfa (e.g., seeds, leaves, roots) or T&E plant species that are sexually compatible with GT alfalfa.

T&E species may also be exposed to the application of glyphosate-based herbicides associated with GT alfalfa (see discussion in the Biological Impacts section and in appendix N). The species that could potentially be affected by the use of glyphosate on GT alfalfa are any that inhabit the terrestrial and aquatic ecosystems potentially at risk from the application of glyphosate associated with GT alfalfa. In this context, areas that could be potentially at risk include existing and planned GT alfalfa fields, as well as any other areas which may be suitable for GT alfalfa cultivation regardless of current use.

3. Gene Flow

Commercially cultivated alfalfa properly belongs to the *M. sativa* complex, a group of closely related subspecies that are reproductively compatible. The most commonly cultivated alfalfa in the world is *M. sativa* subsp. *sativa*, but subspecies *falcata* is also cultivated on a limited basis, primarily under rangeland conditions and in colder regions (e.g., Canada and Siberia). Other subspecies in the complex include subsp. *glutinosa*, subsp. *coerulea*, subsp. *x tunetana*, subsp. *x varia*, subsp. *x polychroa*, and subsp. *x hemicycla* (Quiros and Bauchan, 1988). Two other closely related species, *M. prostrata* and *M. glomerata*, can be considered capable of limited natural hybridization with alfalfa (Quiros and Bauchan, 1988); however, they do not occur naturally in North America.

Current native populations of members in the *M. sativa* complex to which cultivated alfalfa would hybridize, as well as other perennial *Medicago* species, exist particularly in Europe, Asia, the Middle East, and North Africa (Sinskaya, 1961; Lesins and Lesins, 1979; Ivanov, 1988). Based on a search for *Medicago* populations in the United States, 12 matches were found (see table 3-3) (<http://www.natureserve.org/explorer>). All of the 12 matches were to plants non-native to North America and were either conspecific (belonging to the same species) to *Medicago sativa* (two) or naturally sexually incompatible with *M. sativa* complex (ten).

Table 3-3. Members of the Genus *Medicago* Found in North America as Listed by NatureServe Explorer.

<i>Medicago</i> sp. in North America	Evidence for Natural Hybridization to <i>Medicago sativa</i> Complex	Range of Occurrence
<i>M. arabica</i> Spotted Medicago	No	CAN: BC, NB USA: AL, AR, CA, CT, DC, FL, GA, IL, LA, MA, ME, MO, MS, NC, NJ, OK, OR, PA, RI, SC, TX, VA, VT, WA
<i>M. laciniata</i> Cut-leaf Medicago	No	CAN: ON USA: MA, ME
<i>M. littoralis</i> Water Medicago	No	USA: NJ
<i>M. lupulina</i> Black Medicago	No. Reports of hand-cross hybrids are disputed and discounted as false hybrids by numerous experts.	CAN: AB, BC, MB, NB, NF, NS, ON, PE, QC, SK USA: AK, AL, AR, AZ, CA, CO, CT, DC, DE, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV, WY
<i>M. minima</i> Small Medicago –grass	No	USA: AL, AR, AZ, CA, CT, FL, HI, KS, LA, MA, MD, MI, MO, NC, NJ, NY, OK, OR, TN, TX, VA, WA
<i>M. monspeliaca</i> Hairy Medicago	No	USA: AL, ME, MD, NY
<i>M. orbicularis</i> Button Medicago	No	CAN: BC, ON USA: AL, CA, FL, GA, IL, LA, MD, MS, NC, NJ, OK, TN, TX
<i>M. polymorpha</i> Toothed Medicago	No	CAN: BC, NB, ON, QC, SK USA: AK, AL, AR, AZ, CA, CT, FL, GA, HI, ID, LA, MA, ME, MI, MO, MS, MT, NC, NE, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, TN, TX, UT, VA, VT, WA, WY
<i>M. praecox</i> Mediterranean Medicago	No	USA: CA, MA
<i>M. rugosa</i> Wrinkled Medicago	No. A single hybrid plant was produced via hand-pollination and embryo rescue; no viable progeny produced.	USA: HI
<i>M. sativa</i> Alfalfa	Yes, Conspecific	CAN: AB, BC, MB, NB, NF, NS, ON, PE, QC, SK, YT

<i>Medicago</i> sp. in North America	Evidence for Natural Hybridization to <i>Medicago sativa</i> Complex	Range of Occurrence
		USA: AK, AL, AR, AZ, CA, CO, CT, DC, DE, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV, WY
<i>M. sativa</i> ssp. <i>falcate</i> Yellow Alfalfa	Yes, Conspecific	CAN: AB, BC, MB, NS, ON, PE, QC, SK USA: AK, DE, IA, IL, KS, MA, MD, MI, MN, MS, MT, ND, NE, NJ, NV, PA, SD, UT, VA, WA, WY

Source: All data presented in NatureServe Explorer at <http://www.natureserve.org/explorer> were updated to be current with NatureServe's central databases as of October 6, 2007. This report was printed on November 11, 2007.

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Evolutionarily, *M. sativa* is very distantly related to the annual members of *Medicago*. However, *Medicago lupulina* (black medic), an annual (possibly a sometimes short-lived perennial) self-pollinating species, is known to occur throughout the United States and is the species that might be of most concern for hybridization. *M. lupulina* is considered a weed in lawns and waste places, and in forages because its seeds frequently contaminate forage legume seed crops. Successful hybridizations between *M. sativa* and *M. lupulina* have been reported (Southworth, 1928; Fryer, 1930; Schrock, 1943), but the validity of these past crosses has been disputed. According to Quiros and Bauchan (1988) and McCoy and Bingham (1988), no annual species are known to naturally hybridize with *M. sativa*.

Gene flow between alfalfa populations is a natural occurrence and bee-mediated cross-pollination among plants within a cultivar is necessary for commercial seed production. Alfalfa seed producers use spatial isolation to separate cultivars and manage bee and pollen flow between fields of different cultivars. The minimum isolation standard for foundation and certified seed fields more than 5 acres in size is 600 and 50 ft, and for fields 5 acres or less, the standard is 900 and 165 ft, respectively (Association of Official Seed Certifying Agencies (AOSCA), 2003). State seed certifying organizations that are members of AOSCA may adopt the same or more stringent local standards for certified alfalfa seeds. For example, Idaho Crop Improvement Association (2007) requires a greater isolation distance (900 ft) than AOSCA between certified seed fields when one field is conventional and the other is of a genetically modified type (e.g., GT).

In addition to field isolation, certified seed production applies standards for field history, known genetic origin of the stock seed, and in-crop volunteer control to maintain a variety true to type. Variety certification is distinct from organic certification of seeds—variety certification is a product-based certification wherein specified tolerances for off-types and impurities are recognized. USDA organic certification is a process-based certification only; organic seeds or products are not certified according to genetic purity. In a Web search of organic seed suppliers, none were found that offered organically grown seeds of a certified variety. This is discussed in technical report, *Glyphosate-Tolerant Alfalfa Presence in Human Food and Animal Feed* (appendix Q).

Alfalfa plants and alfalfa debris produce compounds that elicit an autotoxic reaction to germinating alfalfa seed. This autotoxic reaction and inter-plant competition severely limits germination and seedling vigor of alfalfa sown or dropped into existing or newly terminated alfalfa stands (Xuan et al., 2005).

4. Alfalfa Consumption by Livestock

Combs and Hartnell (2007) examined the effect of GT alfalfa forage on feed intake, milk composition and milk production in 16 multiparous (cows that than have given birth more than two or more times), lactating Holstein dairy cows. They concluded that milk production, milk composition, feed intake and feed efficiency were not different for dairy cows fed GT versus control alfalfa hay. GT alfalfa hay has also been used as feed extensively without incidence since deregulation in 2005. These results confirm those derived from previously conducted compositional analyses for GT alfalfa, where no differences were observed between GT alfalfa and the control, and further confirm the feed safety of glyphosate and the CP4 EPSPS protein.

C. Socioeconomics

1. Domestic Economic Environment at Risk – Conventional Alfalfa

This section addresses the topics of the economics of conventional (non-GE) alfalfa production and use, the economics of organic alfalfa production and use, the international trade in alfalfa seeds and hay, and the social environment of alfalfa farming and public perceptions regarding organic and genetically modified ingredients in food. The following discussion has come in part from technical reports, *Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa* (appendix K); *Impacts to United States Trade of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix R); *Economic and Social Impacts to Conventional and Organic Farmers of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix S); and *Downstream Effects to Organic Production and Marketing of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix T).

The economics of conventional (non-organically produced) alfalfa are presented below, broken into discussions of the production and demand for alfalfa hay, alfalfa seed, and alfalfa for human consumption. Each of these has its own particular market and production characteristics.

a. Conventional Alfalfa Farming For Forage

(1) Production of Alfalfa for Forage

The harvested acreage of alfalfa hay (dry) was almost 21 million acres in 2008, generating some 69.6 million tons of hay (including hay mixtures) at an average yield of 3.32 tons per acre (USDA-NASS, 2009). This yield corresponds to almost half the production of all hay that year (approximately 145.6 million tons). Statistics for acreage of alfalfa used as haylage (alfalfa baled at a higher moisture content than dry hay) for all States is only captured in the Agricultural Census; based on the most recent 2007 census and more recent USDA–National Agricultural Statistics Service (NASS) data available on 18 States, haylage acreage likely accounts for an additional 10 to 15 percent of alfalfa acreage grown for forage. Alfalfa is the fourth most common crop by acreage in the United States (USDA-NASS, 2008).

The alfalfa share of total hay production has been falling in recent years, as has absolute production of alfalfa hay (see table 3-5). In 2008, alfalfa production was at its lowest level (69.6 million tons) compared to a high of 84.4 million tons in 1999. Although it is a highly sustainable practice, alfalfa's use in crop rotation is declining in the United States because it demands different management, equipment, market channels, and labor schedules not common to other mainstream cropping systems (USDA-ERS, 2002). In certain locations, livestock to consume the hay may no longer be located in the vicinity, and transportation of the hay may be prohibitively expensive.

Alfalfa is grown for forage in almost all of the States (see figure 3-2), with farming conditions varying considerably depending on climate, rainfall, soil fertility, weed and disease prevalence, whether it is seeded in fall or in spring, for dairy or other use, among other factors. Hower et al., (1999) differentiated between four distinct regions in alfalfa farming: north-central, west, northeast, and south. The north-central region represented the highest acreage of alfalfa followed by the west. Together these two regions had 90 percent of the alfalfa acreage in the country. The west, however, had the highest yields, relatively high prices, the most seeding done in fall and relatively high rates of insecticide and herbicide use (50 percent of alfalfa hay acreage), while the north-central region had the lowest yields, lowest prices, most seeding done in spring and the lowest rates of insecticide and herbicide use (8.1 percent of alfalfa hay acreage).

A study conducted by Rogan and Fitzpatrick (2004) also found that western regions tend to have significantly higher yields than the larger overall acreage of the north-central area.

Hay Production Cost Studies

There have been a number of cost studies done by university cooperative extension services on the production of alfalfa hay and alfalfa haylage. APHIS believes that cost studies from four States—Nevada, Ohio, California, and Wisconsin—capture the costs of production associated with alfalfa hay farming in areas with distinct production challenges. Significant cost components varied in the studies. These studies show regional differences in the costs of inputs, including chemical use which varied from 9 to 22 percent of total operating costs in the cost studies. (Myer et al., 1997; The Ohio State University Extension, 2003). The cost studies did not show the cost of inputs for alfalfa hay production to be as significant a factor for returns as yield and quality.

The Integrated Pest and Crop Management Portal of the University of Wisconsin Plant Sciences outreach programs posts a “Roundup Ready® Alfalfa Calculator” (<http://ipcm.wisc.edu/WCMNews/tabid/53/EntryID/208/Default.aspx>). Table 3-4 shows the results of this calculator for costs of conventional hay in Wisconsin, which includes both establishment and production costs, as presented on the Web site. APHIS extended their analysis to include herbicide costs and the price of alfalfa hay (as discussed in technical report, *Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa* (appendix K)) and found that while a 40 percent increase in seed costs and herbicide costs have a less than proportional impact on profit, a 40 percent increase in alfalfa hay prices will more than triple the profit per acre. This implies that reductions in the costs of herbicides and seeds are less important in a producer’s choice than the possibility of obtaining higher quality alfalfa hay. As percentage changes in yield also seem to have a high impact on returns, it could be argued that farmers of conventional alfalfa face a trade-off between pursuing higher yields of alfalfa of lower quality, by harvesting a shared alfalfa-weed mix, or pursuing higher prices of alfalfa with lesser weed content.

**Table 3-4. Establishment and Production Cost of Conventional Alfalfa
Units Per Acre.**

Seed cost per 50-lb bag (\$)	\$200.00
Pounds of seed per acre	12
Technology fee per bag (\$/bag)	\$0.00
Yield in seeding year (t/a DM)	3.50
Herbicide cost (\$/acre/application)	\$20.00
Herbicide application cost (\$/acre)	\$10.00
Number of herbicide applications	1
Value of ease of roundup use (\$/acre)	\$0.00
Yield depression from pursuit/raptor (t/a DM)	0.30
Expected stand life (yrs including seeding year)	3
Value of hay (per ton DM)	\$100.00
Fixed costs per acre per year	\$180.00
Harvesting costs per acre per harvest	\$35.00
Number of harvests	2
Seeding Year Production Costs/Results	
Seed cost (prorated + tech fee) per acre *	\$16.00
Total seed and herbicide cost per ton of hay	\$14.38
Total Cost Per Ton of Hay Seeding Year	\$85.80
Profit per acre - seeding year	\$49.69

Source: Integrated Pest Crop Management, University of Wisconsin

Table3-5. Total U.S. Alfalfa Hay Acres and Value by Method of Production Practice (2002-2005).

Practice	Conversion Factor for Organic	2002	2003	2004	2005	Mean
Conventional						
All alfalfa dry hay, acres		22,923,000	23,529,000	21,707,000	22,439,000	22,649,500
Change in acres per year		--	2.64%	-7.74%	3.37%	-0.58%
Average production, tons/acre		3.19	3.24	3.48	3.39	3.33
Total production, tons		73,014,000	76,273,000	75,481,000	76,149,000	75,229,250
Value (\$ per ton, average		100	90.8	98.6	104	98.35
Value of production (\$)		7,137,469,000	6,724,537,000	6,973,371,000	7,342,000,000	7,044,344,250
Value (\$ per acre, average		311.37	285.8	321.25	327.2	311.4
Organic						
Organic alfalfa hay, acres		155,437	135,717	175,260	204,380	167,698
Change in acres per year		33.30%	-12.69%	29.14%	16.62%	16.59%
Organic (%) of total alfalfa acres		0.68%	0.58%	0.81%	0.91%	0.74%
Average production, tons/acre	0.8751	2,79125	2,835	3,045	2,96625	2,91375
Total production, tons		433,864	384,758	533,667	606,242	488,630
Value (\$ per ton, average	1.182	118	107.14	116.35	122.72	116.05
Value of production (\$)		51,195,896	41,222,939	62,092,121	74,398,040	56,705,517
Value (\$ per acre, average		\$329.37	\$303.74	\$354.29	\$364.02	\$338.14
Value-added per ton		\$18.00	\$17.94	\$33.04	\$36.82	\$26.74
Value-added per acre		\$50.24	\$50.87	\$100.59	\$109.21	\$77.92
Value-added per acre as percent of conventional		5.78%	6.28%	10.28%	11.25%	8.59%
Export						
Export alfalfa dry hay, tons (FAS)		1,176,208	1,260,450	1,253,130	1,125,363	1,203,788
Total production (%) of U.S. dry hay total		1.60%	1.70%	1.70%	1.50%	1.60%
Value (\$ of export (FAS)		180,917,000	192,993,000	202,372,000	193,789,000	192,517,750
Value (\$ per ton, average		153.81	153.11	161.49	172.2	160.16

¹ Based on Long et al. 2007 estimated 12.5% reduction in yield for organic alfalfa production

² Based on an estimated 18% price premium for organic alfalfa

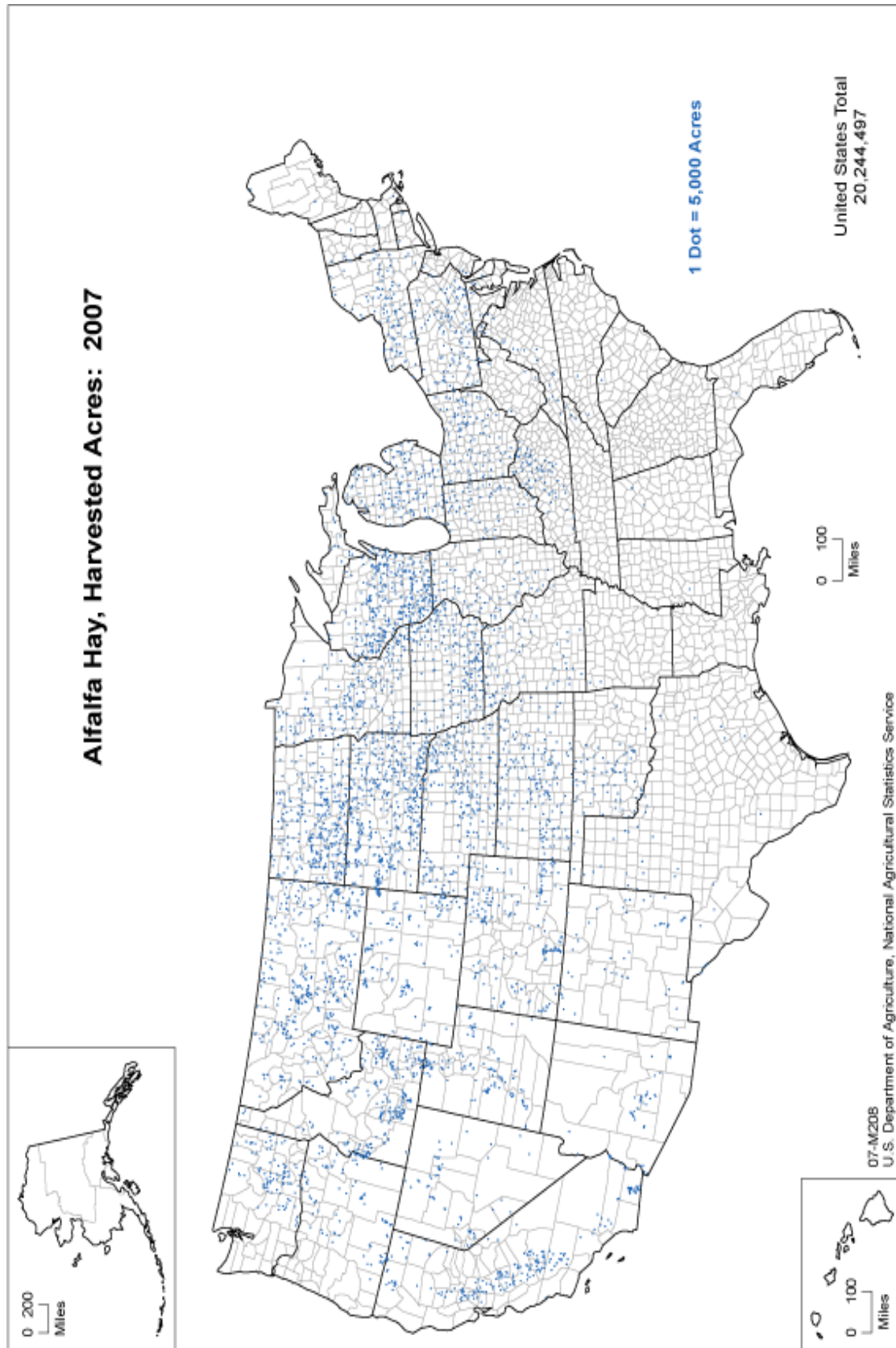


Figure 3-2. Geographic distribution of alfalfa forage acres, 2007 (USDA, 2007).

(2) Demand for Alfalfa Forage

APHIS was unable to locate complete and systematic data on alfalfa forage consumption in the United States (Klonsky et al., 2007); however, an approximate aggregate value of the demand for alfalfa hay can be obtained through production and trade statistics (assuming the accumulation of stored alfalfa hay over time is zero.). USDA–NASS estimates the value of alfalfa hay production in the United States was approximately \$9 billion in 2007. This number was obtained by multiplying average prices with volumes produced and does not correspond to actual sales. Actual sales were likely much less as, according to Klonsky et al. (2007), the majority of the alfalfa hay produced in the United States is produced on farms. This estimate is provided, therefore, for illustrative purposes only.

Discounting for this rough figure of \$9 billion, the \$171 million in alfalfa hay exports (see below for more information on alfalfa exports), and adding \$7 million in imports of alfalfa that occurred that year, the domestic market for alfalfa hay would be approximately \$8.8 billion in 2007. The same reasoning would lead to a domestic market of \$7.5 billion in 2006 and \$7.2 billion in 2005 (see table 3-6).

Table 3-6. Domestic Alfalfa Hay Market (1,000s of Dollars).

Item	2007	2006	2005
Production	8,972,483	7,668,870	7,342,000
Exports	170,925	165,192	165,087
Imports	6,800	3,613	2,430
Consumption	8,808,358	7,507,291	7,179,343

Sources: Production data from USDA NASS (2008a). Trade data from USDA Foreign Agricultural Service (FAS). Consumption calculated as production – exports + imports, and assuming change in alfalfa. Inventories is zero.

* Imports reported as alfalfa bales, not alfalfa hay.

APHIS was unable to find data on the national distribution of the consumption of alfalfa hay among its various uses. Putnam (2005) states that the three main domestic markets for alfalfa are dairy farms, beef farms and horse farms, with minor uses of alfalfa hay “for small ruminants (sheep, goats), alfalfa meal for processed feeds, and alfalfa pellets for pets and rabbits.” Of these, dairy farms are “by far” the main consumer. Klonsky et al. (2007) estimates dairy farms absorb between 75 to 85 percent of alfalfa hay in California, with another 10 to 15 percent consumed by horses and 5 to 10 percent used in the production of beef.

One indication of the role of dairy farms on alfalfa hay consumption can be found by multiplying the number of dairy cows in the United States by an estimate of alfalfa hay intake. Using alfalfa consumption estimates provided in Hoyt (2001) of an intake of 15 pounds of alfalfa hay per day per dairy cow, another 7 pounds a day for milk replacement heifers and another 3 pounds a day for dairy heifers under 500 pounds, and assuming

the proportion between milk cows, milk replacement heifers and heifers under 500 pounds is roughly 4:2:1, APHIS estimates consumption of alfalfa hay for dairy to be approximately 177 million pounds per day, or 32.8 million tons a year.⁶ This corresponds to roughly 46 percent of the domestic market estimated to be at 71.8 million tons in 2007 (72.6 million tons produced, minus exports, plus imports).⁷

The quality of alfalfa hay is determined by the presence of weeds, fiber content, protein content, and other factors such as color and mold presence (Klonsky et al., 2007). USDA's Agricultural Marketing Service uses the grades of supreme, premium, good, fair, and utility to regularly report average prices in various States. They describe each grade as follows:

- Supreme: Very early maturity, pre bloom, soft fine stemmed, extra leafy. Factors indicative of very high nutritive content. Hay is excellent color and free of damage.
- Premium: Early maturity, that is, pre-bloom in legumes and pre head in grass hays, extra leafy and fine stemmed-factors indicative of a high nutritive content. Hay is green and free of damage.
- Good: Early to average maturity, that is, early to mid-bloom in legumes and early head in grass hays, leafy, fine to medium stemmed, free of damage other than slight discoloration.
- Fair: Late maturity, that is, mid to late-bloom in legumes, head-in grass hays, moderate or below leaf content, and generally coarse stemmed. Hay may show light damage.
- Utility: Hay in very late maturity, such as mature seed pods in legumes or mature head in grass hays, coarse stemmed. This category could include hay discounted due to excessive damage and heavy weed content or mold. Defects will be identified in market reports when using this category (USDA-AMS, 2008).

Other sources note that alfalfa hay quality grades differ to some degree from State to State (McWilliams et al., 2005), or speak of high quality alfalfa as being "dairy-quality" (Klonsky et al., 2007). According to Klonsky et al. (2007), there is no clear cut classification for alfalfa hay quality.

Dairy cattle and horses both tend to have high forage quality requirements (Van Deynze et al., 2004). Most weeds are lower in forage quality or palatability (ability to appeal to animals as food) than alfalfa, and forage with high weed content can adversely affect milk production, as well as animal growth and health (Van Deynze et al., 2004). Forage quality

⁶ 9.2 million milk cows in 2007 (USDA ERS, 2008) x 15 lb = 138 million lb
4.6 million replacement heifers x 7 lb = 32.2 million lb
3.2 million heifers under 500 pounds x 3 lb = 9.6 million lb.

⁷ Production data from USDA ERS, 2007. Trade data from USDA FAS (online searchable database). Trade data is available in metric tons, transformed to short tons by multiplying by 1.10231.

requirements for sheep and goats are less rigorous. Beef producers in particular, facing relatively low margins, are apparently a market for lower quality (and cheaper) alfalfa (Klonsky et al., 2007).

Some States provide data on prices of different hay qualities. Table 3-7 below shows some of the historic price differences for different hay qualities in areas of California. The table also illustrates differences in prices depending upon location. As shown, prices can vary by more than 50 percent depending on quality and location. Distinctive regional alfalfa markets likely reflect the importance of transportation costs in limiting the trucking of relatively high volume, low value alfalfa hay across longer distances.

Table 3-7. Price Differences of Hay Qualities (\$/Ton), 10-Year Average, 1997-2006.

Region	Hay Quality Category			
	Supreme	Premium	Good	Fair
Southern California				
Imperial Valley	121	115.24	100.29	86.35
Blythe/Parker	120.14	114.52	99.38	82.56
Chino/LA	148.37	140.34	125.65	110.74
Mojave Desert	129.11	123.01	111.86	93.52
San Joaquin Valley				
Kern County	139.45	128.07	110.01	92.57
Tulare/ Visalia/ Hanford	163.54	149.42	129.83	109.13
Hanford/ Corcoran/ Tulare	146.25	132.62	113.75	94.08
Fresno/ Madera Counties	145.24	129.77	108.48	92.27
Los Banos/ Dos Palos	147.24	136.66	116.92	96.98
Escalon/ Modesto/ Turlock	161.69	148.94	130.23	109.20

Source: Klonsky et al. (2007)

(3) Alfalfa Forage as a Downstream Input to Human Food Production

This section briefly describes alfalfa feed as an economic input to its primary industries of use (dairy farms, beef cattle, and horses, with much smaller amounts being used for goat, sheep and small animal feed and other processed feeds).

Dairy Production

USDA estimated production costs for dairy farms in the United States based on the 2005 Agricultural Resources Management Survey (ARMS). According to this data, feed corresponds to 30 to 60 percent of total costs per hundredweight (100 pounds) sold, which includes one-time costs for establishment. The weight of feed on total costs is larger for smaller farms

given the lower productivity and relatively larger overhead. Looking at the share of operational costs (a subset of total costs) feed costs represent, roughly 70 to 85 percent, suggests the price of feed is a major determinant of the cost of dairy production for dairy farms (see table 3-8, below).

Table 3-8. Weight of Feed Costs in Dairy Farms.

Farm Type	Feed Costs/ Operational Costs	Feed Costs/ Total Costs
Conventional United States	73.3%	44.1%
Conventional California	79.7%	57.8%
Conventional Wisconsin	72.0%	40.4%
Conventional < 50 cows	73.4%	30.0%
Conventional 1000 cows or more	83.3%	44.1%
Organic United States	77.8%	41.9%
Organic < 50 cows	76.9%	33.7%
Organic 200 cows or more	79.6%	42.8%

Source: USDA-ERS, 2005

Alfalfa is likely a considerable share of feed costs. Short (2004) reports hay and straw, presumably mostly alfalfa, represents roughly a third of feed costs. Alfalfa may also be used in cubes or pellets. In some regions (Wisconsin, Minnesota) haylage is also a significant share of feed.

Beef Production

USDA-ERS produces cost estimates annually for a variety of farm products. According to the latest estimates available (2005–06), feed corresponds to an average of 56.8 percent of operational costs and 28.8 percent of total costs of cow-calf production (USDA-ERS, updated 2008). Harvested forages correspond to almost half of feed costs (46.9 percent). Other sources report a somewhat lower figure of 35 percent of operational costs and 20.8 percent of operational and ownership costs, with only between 10 to 20 percent of feed costs corresponding to purchased harvested forages (Short, 2001).

Alfalfa is likely a lower share of feed costs in cow-calf production than it is in dairy production since the main source for cow-calf production feed is grazing (Short, 2001). As cattle move on to feedlots (sometime through stocker operators) feed becomes mostly grain based ration.

Other Livestock, Pet Care, and Honey Production

Of the remaining potential sources of demand for alfalfa hay, the most important is horses. Putnam (2005) estimates that horses may consume between 5 to 15 percent of alfalfa hay in California. He also, however, describes the horse market for alfalfa hay as idiosyncratic, subjective, and supplemented by alternative hay such as timothy and grass.

The honey industry utilizes alfalfa fields for honey production. Alfalfa produces a large amount of nectar from which honey bees produce excellent crops of high quality honey (McGregor, 1976). The actual market demand for alfalfa hay fields by beekeepers appears to be small to non-existent; alfalfa seed producers usually contract for the bee keepers' services.

b. Conventional Alfalfa Farming for Seed

(1) Production of Alfalfa for Seed

Unlike alfalfa hay production, alfalfa seed production is largely concentrated both geographically and in the number of producers (see table 3-9). The latest complete information on alfalfa seed production comes from the 2007 Census of Agriculture, when 121,467 acres of alfalfa seed were harvested producing approximately 62 million tons of seeds at an average productivity of approximately 510 lbs/ acre. California was responsible for 31 percent of this production, Washington 17 percent, and Idaho 15 percent, with over 60 percent of production concentrated in those three States and the remaining also highly concentrated in Western States (Nevada, Oregon, Wyoming, Montana, and Utah). Mueller (Undated a) suggests California's share of production has fallen in recent years and a larger share is coming from the Northwestern States. In 2007, production came from 806 farms. This means that farming conditions for alfalfa seed production are likely more homogeneous than alfalfa hay farming. U.S. alfalfa seed growers also compete with their conventional seed producing counterparts in Canada, Australia, and elsewhere, where comparative production costs are significantly lower (e.g., USDA Docket 04-085-1; public comment by M. Wagoner,[December 12, 2004; comment P5]).

Alfalfa seed acreage and production increased between 2002 and 2007, reversing the trend of decreases in alfalfa seed production over the last few years. Similar economic, social, and competitive challenges face both U.S. alfalfa seed and forage growers. Mueller (2008) attributes recent reductions in alfalfa seed acreage in California to "changes in economics, environmental constraints, and regulatory issues." Mueller (Undated a) lists among difficulties of alfalfa seed farming in California scarcity of water for crop irrigation and lack of development of new chemicals for insect control due to high registration costs. However, between 2002 and 2007, California gained almost 10,000 acres of alfalfa seed production.

Some farmers allow existing alfalfa hay stands to go to seed at the end of the stand life or when there is little water. According to Mueller (2005b), this is the case for most of the seed produced in the Imperial Valley (California), about half of the non-certified seed produced in Utah, and

much of the dryland seed produced in Montana. This seed would typically not receive certification.

Despite the mixed purpose of many alfalfa fields that generate seeds, there are clear differences in best practices for managing forage alfalfa and seed alfalfa. Dense stands produce higher forage yields but lesser seed yields than thinner stands, as when alfalfa is planted in rows as opposed to solid planting, and certain chemicals used in seed production limit field use for forage (Mueller, 2008). Alfalfa seed farmers also have some costs that are not present in alfalfa hay farming: some insects are only important for alfalfa seed production (Mueller, Undated a), and costs associated with contracting with bee keepers for pollination services are considerable.

Table 3-9. State Production of Alfalfa Seed (2007 Census of Agriculture).

State	Farms	Seed Acres Harvested	Pounds of Seed Harvested
California	114	36,625	19,083,458
Washington	82	17,127	10,860,608
Idaho	92	12,788	9,346,709
Wyoming	62	10,548	5,915,816
Nevada	19	6,498	4,237,101
Montana	80	10,338	3,729,635
Oregon	32	4,959	3,183,375
Utah	54	3,803	2,077,813
Arizona	53	5,206	1,902,669
South Dakota	47	6,014	428,447
Oklahoma	29	2,004	281,121
Texas	24	546	79,885
Minnesota	17	611	63,461
Missouri	19	399	40,540
North Dakota	6	(D)	34,784
New Mexico	15	310	29,907
Kansas	5	342	22,430
Nebraska	29	545	21,216
Michigan	10	(D)	15,610
New York	3	27	6,180
Iowa	5	(D)	(D)
Ohio	1	(D)	(D)
Colorado	8	1,815	(D)

(D): Data withheld to avoid disclosing data for individual farms.

The presence of weeds may have a greater impact on costs in alfalfa seed production compared to alfalfa forage production. The separation of weed seeds from alfalfa seeds after harvesting is costly, so control of weeds in the fields is a more desirable method of seed quality control than post-harvest screening and separation (Mueller, Undated b). No primary or secondary noxious weeds⁸ are allowed for certified seed, with the removal of dodder seed of particular importance (Mueller, 2008). (See section

⁸ Primary noxious weeds cause harm wherever they grow and are an economic issue, while secondary weeds are designated at a local level for additional control.

below on Weeds in Alfalfa for more information on dodder and other alfalfa weeds.)

As discussed in technical report, *Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa* (appendix K), another important difference between alfalfa hay and alfalfa seed production is that the quality of seeds (germination, yield, dormancy, and other varietal properties) are not readily observable at the moment of purchase. To ensure quality, mechanisms come into place to offer clients (and breeding companies) assurance that seeds sold as one variety or another will perform as expected. State Crop Improvement Associations—or sometimes Seed Grower Associations—(all of these are members of the Association of Official Seed Certifying Agencies) provide certifications that seed production followed minimum standards, such as isolation between different alfalfa varieties, absence of prohibited noxious weeds in the field, inspection of conditioning (separation) facilities, maintaining traceability of seed lots, and seed testing.

Finally, an important cost in seed production is the seed itself. The development of crop varieties became a predominantly private activity in the past 30 years (Fernandez-Cornejo and Schimmelpenninck, 2004) and the Plant Protection Variety Act of the early 1970s simulated cultivar development in alfalfa (Bouton, 1998). Today almost all new alfalfa varieties are owned and patented.

Seed Production Cost Studies

There have been a number of cost studies related to the cost of producing alfalfa seed. The cost studies reviewed for this EIS deal with the economics of alfalfa seed production in three Western States—California, Nevada, and Idaho—due to the geography of seed production. A 1985 cost study found land rental to be the highest cost component (Sheesley, 1985). However, recent cost studies show pollination services (bees) account for the most significant cost component of alfalfa seed production, ranging from 18 to 30 percent of annual production costs. The second most significant cost component found in the recent cost studies was insect control, accounting for between 10 and 17 percent of total annual production costs. (Kettle, Myer and Breazeale, 1999a; Kettle, Myer and Breazeale, 1999b; Meister, 2004; Rimbey et al., 2005). Table 3-10 below shows the main cost items reported, with the last column showing the percentage total that each line item represents of the total costs.

Similar results were found in a 2005 cost study from the University of Idaho (Rimbey et al., 2005). The study assumes a farm with 150 acres of alfalfa seed over a three year period (the life of the stand) and found that pollination accounted for 25.1 percent of the operating costs, followed by

insecticides at 16.5 percent. Irrigation and herbicides are each just below 10 percent of total operating costs.

Table 3-10. Alfalfa Seed Production Costs.

Item	\$ Per Acre	Percent of Total Costs
Irrigation	35.81	7.88%
Insect Control	77.00	16.95%
Pollination	84.00	18.49%
Total Growing Period Costs	196.81	43.32%
Total Harvest Costs	108.18	23.81%
Land Rent	115.00	25.31%
Cash Overhead	34.30	7.55%
Total Cash Overhead Costs	149.30	32.86%
TOTAL CASH COSTS/ACRE	454.29	100.00%

Source: Meister, 2004

(2) Demand for Alfalfa Seed

The demand for alfalfa seed derives from the demand for establishing new stands of alfalfa hay, and to a much lesser extent from the demand for alfalfa products destined for human consumption. As in the case of alfalfa hay, the domestic alfalfa seed market can only be estimated using available data for production, exports and imports. The last year for which complete data is available is 2007, the year of the last Census of Agriculture.

The estimation presented in table 3-11 suggests the domestic demand for alfalfa seeds in 2007 was approximately \$63 million, up from \$52 million in 1997. Imports represented some 64 percent of domestic demand, although it is possible that some of these imports were re-exported.

Table 3-11. Domestic Alfalfa Seed Market (1,000s of Dollars).

	2007	2002	1997
Production	93,173	66,724	104,492
Exports	66,094	25,963	50,372
Imports	36,363	10,864	14,521
Consumption	63,442	51,625	68,641

c. Conventional Alfalfa Farming for Human Use

Some alfalfa seed is used to produce sprouts for human consumption. Seed for sprouting is produced throughout the world, but the major suppliers are in the United States, Canada, and Australia. Approximately 80 million pounds of alfalfa seed are produced each year in the United States. More than 85 percent of that is produced in six Western States—California, Washington, Idaho, Wyoming, Nevada, and Montana. The balance is from Oregon, Arizona, Utah, and other States. The primary market for that seed is planting stock to produce forage to support the livestock industry in the United States and throughout the world. Only a small fraction of the seed produced is used for sprouting (Mueller, Undated).

APHIS was unable to locate any publicly available sales data for alfalfa sprouts. In testimony given in a public meeting convened by the U.S. Department of Health and Human Services' Food and Drug Administration (1998), sprout industry expert Dr. Earl Hauserman noted that as of 1998 there were about 350 sprouters in the United States. He noted that green sprouts (alfalfa, broccoli, clover, mustard, onion, radish, sunflower, and other sprouts) amounted to about \$80 million a year in sales. Mr. Hauserman also stated that alfalfa sprouts account for about 75 to 80 percent of the green sprout market, or \$60 to \$64 million in annual sales. Hauserman stated that U.S. sprouters utilized approximately 125,000 to 150,000 pounds of alfalfa seed a month to produce about 5 to 6 million 4-ounce packages a month. On an annualized basis, Hauserman's testimony would imply that in 1998 alfalfa sprouters purchased 1.5 to 1.8 million pounds of alfalfa seeds, and produced 15 to 18 million pounds of alfalfa sprouts.

Dehydrated alfalfa leaf is commercially available as a dietary supplement in several forms, such as tablets, powders and tea. Alfalfa is also believed by some to be useful as an herbal or homeopathic medicine (Foster and Johnson, 2006). APHIS was unable to locate any publicly available sales data for alfalfa produced for dietary supplements, herbal remedies, or homeopathic medicines. Nelson (2008) reports an estimate that the total U.S. alfalfa supplement market could be satisfied with 10 tons of alfalfa hay production, which could be produced on 1 to 2 acres.

2. Domestic Economic Environment at Risk – Organic Alfalfa

a. Production of Organic Alfalfa for Forage

Between 2000 and 2005, the number of acres in certified organic alfalfa hay production fluctuated slightly, but overall showed an increasing trend. The percentage of total alfalfa hay acres certified as organic per year was between 0.51 to 0.92 percent nationally during this time period (see table 3-12). During 2005 (the most recent year for which certified organic alfalfa acres are reported), there were 204,380 acres in certified organic production, which was approximately 0.92 percent of the U.S. alfalfa dry hay total. Although the organic dairy and livestock industries are growing very rapidly, organic hay alfalfa acres may be growing at a slightly slower rate because many of the organic dairy and livestock producers are allowing more access to non-alfalfa (e.g., grass) organic pastures to avoid the high bloat incidence associated with grazing pure alfalfa. In contrast to conventional hay marketed mainly on forage quality grade, the main selling criterion for organic hay is often its organic status (USDA-AMS-LGMR, 2007).

Table 3-12. Organic Alfalfa Hay Harvested Acreage.

Acreage	2000	2001	2002	2003	2004	2005
Total	113,157	116,608	155,437	135,717	175,260	204,380
Share of Total U.S. Acreage	0.51%	0.49%	0.67%	0.58%	0.81%	0.92%

Source: USDA-ERS, 2005; USDA-NASS, 2007.

Organic alfalfa hay production is similarly distributed geographically to conventional hay. However, production of organic alfalfa hay is a more significant proportion of total alfalfa hay production in some States. In 2005, for example, more than 4 percent of all alfalfa hay acreage in Idaho was organic, compared to just 0.92 percent nationally. Organic alfalfa also seems to be grown in pockets, with 72 percent of organic acreage located in just 6 States—Idaho, Wisconsin, Minnesota, North Dakota, South Dakota, and California (see table 3-13). These 6 States only account for about 41 percent of total U.S. alfalfa acreage.

The increased price per ton of hay received by organic growers is partially offset by a reduction in forage quality (due to increased weeds in the hay) and an approximately 12.5 percent reduction of alfalfa yield per acre (Long et al., 2007).⁹ The 2005 national average yield per acre for alfalfa was 3.39 tons. Based on differences in organic and conventional alfalfa yield from Long et al.(2007), the total estimated U.S. organic hay production in 2005 was about 606,242 tons; the total U.S. production of alfalfa hay in 2005 was approximately 76,149,000 tons. This estimate is approximate, however, and is only presented here for illustrative purposes.

⁹ Estimates of 10 to 20 percent (or more) yield reductions were estimated by D. Putnam and D. Undersander, State Forage Extension Specialists from California and Wisconsin, respectively (Pers. Comm. No date).

Table 3-5 contains a comparison of total estimated U.S. organic and conventional alfalfa yields for 2002 to 2005.

(1) Demand for Organic Alfalfa for Forage

As in the case of non-organic alfalfa for forage, the demand for organic alfalfa derives mainly from the demand for organic dairy and beef (Butler, 2002). To be sold as organic in the United States, alfalfa hay must meet standards established by the Organic Foods Production Act of 1990 and the National Organic Program (NOP) that became effective in 2001. These standards require that organic dairy and meat products come from dairy cows and livestock fed with 100 percent organic feed, with exceptions for vitamin and mineral supplements (USDA-NOP, 2008). As shown in table 3-5 organic alfalfa hay represented 0.92 percent of total alfalfa hay acres harvested in 2005, up from 0.51 percent in 2000.

Prices and quality requirements are significantly different between organic and non-organic alfalfa hay. USDA-NASS reports the average conventional hay crop value (\$/ton); USDA-ERS reports the organic hay acreage but does not, however, report the value of organic hay, and therefore, it must be estimated. It is commonplace for certified organic feedstuffs to sell for a 10 to 30 percent price premium, depending upon demand and local supplies (Long et al., 2005; USDA-AMS-LGMN, 2006). The value-added price per ton for certified organic alfalfa hay is, on average, 18 percent greater than conventional hay. This price premium was calculated by comparing the mean sale prices of conventional and certified organic hay occurring within each sale location, within each forage quality grade and within each USDA hay market sale reporting period during 2006 (raw data was from USDA-AMS-LGMN, 2006). This price premium is generally supported by the University of California's 2007 *Organic Alfalfa Hay* report, which found that prices for organic alfalfa hay vary depending on season, market, and quality, but will be approximately 20 percent greater than prices for conventional hay, and 2007 USDA-AMS data for three counties in California, which found a slightly greater than 20 percent premium for organic alfalfa. The higher prices of organic hay would generally deter conventional livestock producers from using organic alfalfa when not necessary. Table 3-5 shows the value per ton, value per acre, and value added for organic alfalfa hay from 2002 through 2005 using this estimated 18 percent price premium.

Table 3-13. U.S. Alfalfa Hay (Dry) Acreage, Ranked by Number of Certified Organic Acres by State, 2005

Estimated 2005 Econ. Val.- added -- Certified Organic Hay Based on 18% Price Premium (\$)												
State	Total NASS 2005 Reported Alfalfa Hay (Acres)	Certified Organic ERS 2005 Reported (Acres)	Calculated Standard Practice (NASS - ERS) (Acres)	% Practice (Acres)	% Certified Organic Acres	Organic Practice State's National Rank by \$Val. (Rank)	NASS 2005 Production Yield (Tons/acre)	NASS 2005 Yield/State (1,000 Tons)	NASS 2005 Unit Price (\$/Ton)	Val. -- Total Production (\$1)	Estimated 2005 Econ. Val.- added -- Certified Organic Hay Based on 18% Price Premium (\$)	Estimated 2005 Econ. Val.- added -- Certified Organic Hay Based on 18% Price Premium (\$)
U.S. Total	22,439,000	204,380	22,234,620	99.09%	0.91%		2.45	76,149	104	7,342,000,000	12,037,080	0.16%
Idaho	1,140,000	49,497	1,090,503	95.66%	4.34%	2	4.2	4,788	112	536,256,000	4,191,044	0.78%
Wisconsin	1,550,000	29,389	1,520,611	98.10%	1.90%	3	2.4	3,720	112	416,640,000	1,421,967	0.34%
Minnesota	1,350,000	21,339	1,328,661	98.42%	1.58%	5	3.5	4,725	73	344,925,000	981,382	0.28%
North Dakota	1,850,000	20,614	1,829,386	98.75%	1.25%	18	2	3,300	55	181,500,000	408,153	0.22%
South Dakota	2,400,000	13,930	2,386,070	99.42%	0.58%	6	2.15	5,160	65	335,400,000	350,418	0.10%
California	1,040,000	13,246	1,026,754	98.73%	1.27%	1	6.9	7,176	136	975,936,000	2,237,341	0.23%
Iowa	1,250,000	9,193	1,240,807	99.26%	0.74%	4	4.1	5,125	80.5	412,583,000	546,132	0.13%
Colorado	800,000	8,943	791,057	98.88%	1.12%	7	3.7	2,960	101	298,960,000	601,563	0.20%
Nevada	1,250,000	8,192	1,241,809	99.34%	0.66%	14	3.7	4,625	50	231,250,000	272,777	0.12%
Nebraska	400,000	6,592	393,408	98.35%	1.65%	16	4.4	1,760	118	207,680,000	616,082	0.30%
Oregon	1,750,000	5,318	1,744,682	99.70%	0.30%	8	2.2	3,850	71	273,350,000	149,529	0.05%
Montana	260,000	3,000	257,000	98.85%	1.15%	20	4.8	1,248	120	149,760,000	311,040	0.21%
Nevada	400,000	2,488	397,512	99.38%	0.62%	22	3.5	1,400	99	138,600,000	155,159	0.11%
Illinois	600,000	1,726	598,274	99.71%	0.29%	25	2.6	1,560	75	117,000,000	60,597	0.05%
Wyoming	510,000	1,217	508,783	99.76%	0.24%	17	2.6	1,326	153	202,878,000	87,128	0.04%
Pennsylvania	450,000	1,180	448,820	99.74%	0.26%	23	2.7	1,215	102	123,930,000	58,485	0.05%
Missouri	450,000	1,140	448,860	99.75%	0.25%	10	5.2	2,340	112	262,080,000	119,508	0.05%
Washington	150,000	1,115	148,885	99.26%	0.74%	27	5.4	810	127	102,870,000	137,640	0.13%
Texas	510,000	1,030	508,970	99.80%	0.20%	13	3.6	1,836	130	238,680,000	86,784	0.04%
Ohio	540,000	925	539,075	99.83%	0.17%	15	4.2	2,268	96	217,728,000	67,133	0.03%
Utah	900,000	714	899,286	99.92%	0.08%	11	3.1	2,790	92	256,680,000	36,674	0.01%
Michigan	240,000	670	239,330	99.72%	0.28%	19	5.1	1,224	128	156,672,000	78,728	0.05%
New Mexico	850,000	661	849,339	99.92%	0.08%	12	4	3,400	74.5	253,300,000	35,477	0.01%
Kansas	340,000	597	339,404	99.82%	0.18%	21	3.8	1,292	112	144,704,000	45,697	0.03%
Indiana	260,000	487	259,513	99.81%	0.19%	9	8.4	2,184	124	270,816,000	91,307	0.03%
Arizona	11,000	345	10,655	96.86%	3.14%	37	2.7	30	167	5,010,000	28,284	0.56%
Maine	450,000	321	449,679	99.93%	0.07%	24	2.1	945	131	123,795,000	15,910	0.01%
New York	110,000	276	109,724	99.75%	0.25%	29	3.6	396	124	49,104,000	22,177	0.05%
Virginia	8,000	102	7,898	98.73%	1.27%	38	2.4	19	194	3,686,000	8,450	0.23%
Connecticut	320,000	90	319,910	99.97%	0.03%	26	3.7	1,184	97	114,848,000	5,814	0.01%
Oklahoma	40,000	28	39,973	99.93%	0.07%	30	3.9	156	169	26,364,000	3,263	0.01%
Maryland	260,000	13	259,987	100.00%	0.00%	28	3.2	832	118	98,176,000	884	0.00%
Kentucky	14,000	2	13,998	99.99%	0.01%	36	2.2	31	183	5,673,000	131	0.00%
Massachusetts	-	-	-	-	-	n/a	-	-	-	-	-	-
Alabama	-	-	-	-	-	n/a	-	-	-	-	-	-
Alaska	-	-	-	-	-	n/a	-	-	-	-	-	-
Arkansas	20,000	-	20,000	100.00%	0.00%	35	2.3	46	147	6,762,000	-	-
Delaware	5,000	-	5,000	100.00%	0.00%	41	3.6	18	169	3,042,000	-	-

Table 3-13. *continued*

State	Total NASS 2005 Reported Alfalfa Hay (Acres)	Certified Organic ERS 2005 Reported (Acres)	Calculated Standard Practice (NASS - ERS) (Acres)	% Standard Practice (Acres)	% Certified Organic Acres	Organic Practice State's National Rank by \$Val. (Rank)	NASS 2005 Production Yield (Tons/acre)	NASS 2005 Production Yield/State (1,000 Tons)	NASS 2005 Price (\$/Ton)	Val. -- Total Production (\$1)	Estimated -- Hay Based on 18% Price Premium (\$)	Estimated -- Certified Organic Hay Val.-added - 2005 Econ. Incremental Val.-added - Organic Hay (% of State Total)
Florida	-	-	-	-	-	n/a	-	-	-	-	-	-
Georgia	-	-	-	-	-	n/a	-	-	-	-	-	-
Hawaii	-	-	-	-	-	n/a	-	-	-	-	-	-
Louisiana	-	-	-	-	-	n/a	-	-	-	-	-	-
Mississippi	-	-	-	-	-	n/a	-	-	-	-	-	-
New Hampshire	8,000	-	8,000	100.00%	0.00%	40	2.1	17	197	3,349,000	-	-
New Jersey	25,000	-	25,000	100.00%	0.00%	34	2.7	68	150	10,200,000	-	-
North Carolina	11,000	-	11,000	100.00%	0.00%	39	2.5	28	130	3,640,000	-	-
Rhode Island	2,000	-	2,000	100.00%	0.00%	42	3	6	188	1,128,000	-	-
South Carolina	-	-	-	-	-	n/a	-	-	-	-	-	-
Tennessee	35,000	-	35,000	100.00%	0.00%	31	3.2	112	120	13,440,000	-	-
Vermont	45,000	-	45,000	100.00%	0.00%	32	1.8	81	161	13,041,000	-	-
West Virginia	35,000	-	35,000	100.00%	0.00%	33	2.8	98	108	10,584,000	-	-
Sources: Organic acres—USDA; Economic Research Service, based on information from USDA-accredited State and private organic certifiers; standard practice data from NASS; Most recent year (2005) for which both certified organic and U.S. total alfalfa hay acre data are available for direct comparison.												
** Estimate assumes equivalent yield per acre and equivalent forage quality grade for organic and standard practice hays. 18% price premium estimate based on median hay selling price for organic vs non-organic hays of the same quality group within the same geography of sale (USDA Livestock, Hay & Grain News, 2005 California Annual Hay Report.)												

b. Production of Organic Alfalfa Seed

APHIS was unable to locate data on U.S. organic alfalfa seed production. U.S. organic hay production in 2005 was roughly 0.92 percent of total alfalfa hay production. APHIS expects that stand establishment demand for organic alfalfa seed (expressed as a percentage of total alfalfa seed demand) would likely be in roughly the same proportion. However, for the reasons noted in above (i.e., the NOP-permitted use of non-organically produced seeds and foreign seed imports), the production of organic seed may be somewhat less than this percentage of the total.

(1) Demand for Organic Alfalfa Seeds

Demand for organic alfalfa seeds derives from the demand for organic alfalfa hay, as NOP requires the use of organic seeds to establish organic alfalfa stands (CFR Title 7, §205.204). However, as previously stated an exception is made to this requirement in cases where such seed is unavailable.¹⁰ In these cases, untreated conventional seeds from non-organically managed fields or conventional seeds treated with substances included in the national list of synthetic substances allowed for use in organic crop production are typically allowed.

APHIS was unable to estimate the demand for organic alfalfa seed, due to the lack of data on production of organic alfalfa seed, as well as on the organic seed trade. Some demand likely does exist and may be supplied by either domestic or imported production (imported seeds were approximately 21 percent of total domestic consumption in 2002¹¹). The Organic Materials Review Institute (OMRI), a nonprofit organization managed by the organic industry, reports three suppliers of organic alfalfa seed for forage in its seed database (<http://seeds.omri.org/index.php?dosearch=1&terms=alfalfa&submit=Go>). Some of this seed is imported from Canada. It is also possible that because non-organic seeds are permitted for use in the production of organic alfalfa hay, demand for organic alfalfa seed may remain low.

The main reason reported by organic certifiers to accept farmers' claims that organic seeds were not available was that organic seeds are not "equivalent" to non-organic available seeds in quality (Baker, 2008).¹² This may be an indication of an unfulfilled demand that, given the growth rates in organic alfalfa seed production, may stimulate the development of "equivalent" organic varieties that may now not be available.

¹⁰ This exception is not made for production of organic edible sprouts.

¹¹ Production data for U.S. domestic seed production comes from USDA Census of Agriculture (2002, 1997); Trade data for seed exports comes from USDA Foreign Agricultural Service.

¹² When asked what crop was most often claimed to not have available organic seeds, certifiers identified alfalfa.

(2) Demand for Organic Alfalfa for Human Consumption

Some alfalfa seed is used to produce sprouts for human consumption. Seed for sprouting is produced throughout the world, but the major suppliers are in the United States, Canada, and Australia; only a small fraction of the seed produced is used for sprouting (Mueller, undated). APHIS was unable to locate any publicly available sales data for organic alfalfa sprouts. Using data drawn from the U.S. Department of Health and Human Services' Food and Drug Administration (1998), it is estimated that in 1998 alfalfa sprouters purchased 1.5 to 1.8 million alfalfa seeds, and produced 15 to 18 million pounds of alfalfa sprouts. Presumably, organic sprout production in 1998 was some fraction of total sprout production.

Dehydrated alfalfa leaf is commercially available as a dietary supplement in the form of tablets, powders and tea, and is believed by some to be useful as an herbal or homeopathic medicine (Foster and Johnson, 2006). APHIS was unable to locate any publicly available sales data for alfalfa produced for dietary supplements, herbal remedies, or homeopathic medicines. Nelson (2008) reports an estimate that the total U.S. alfalfa supplement market could be satisfied with 10 tons of alfalfa hay production, which could be produced on 1 to 2 acres.

3. Trade Economics of Conventional and Organic Alfalfa

Certain official statistics for the tonnage of exported alfalfa hay data are highly mixed with and confounded by export statistics for other species crop hays (e.g., USDA-AMS-LGMR, 2007; Woodward, 2006; Putnam, 2005). USDA-FAS (2006) reports estimates for all alfalfa exports, which includes dry hay, cubes, pellets and meal. These hay data are reported by volume (tons), not by acres. Approximately 1.6 percent of the U.S. dry hay crop is exported (table 3-5). Most of this exported hay is grown in Washington and California, where average yield is 4.9 and 6.9 tons per acre, respectively, and relative to the national average, hay value per ton is high. Using the mean hay yield for these two States (5.9 tons per acre), the exported hay represents the equivalent production of approximately 204 thousand acres. It should be noted that an acre producing for the export market during one or more cutting periods likely produces hay for the domestic market at other times of the year (Putnam, 2005) (i.e., fields of alfalfa are not dedicated to the export market per se as they are in organic production). The number of acres from which exported hay is harvested annually is not known (Putnam, 2005).

On average, the FAS-reported selling price of exported hay is approximately \$160 per ton, which is similar to the price for domestically sold hay in the region of production (Pacific Northwest and California). However, using USDA-AMS-LGMN data, in 2006, within grade, within location, within month, the calculated price paid for export alfalfa hay was

approximately 0 to 6 percent lower per ton on average than the price for domestic cattle-use hay of the same grade (calculated from head-to-head comparison of selling prices reported by USDA-AMS-LGMN, 2006). Therefore, in general, export market hay has a similar selling price per ton as other locally available hay; it is not considered a value-added market per se although there is significant value in the ability to contract for a large volume of sales to a few importing customers ahead of harvest time. According to Shewmaker et al. (2006), “The export market helps support and stabilize[s] domestic forage prices in the [Pacific Northwest].” According to a National Alfalfa and Forage Alliance (NAFA) document addressing coexistence in the alfalfa export markets (NAFA, 2007) the export hay market is of key importance to certain producers in Washington, Oregon, and California, and coexistence strategies for minimizing comingling between GT and non-GT alfalfa may be effective (see table 3-14).

Annually, the export hay market is valued at approximately \$192 million (USDA-FAS, 2006) (table 3-5). It may be noted that, in general, hay sold into the export market channel is of “good,” “good/premium,” or “premium grade.” In 2006, no or few “supreme” grade hay lots were exported (USDA-AMS-LGMN, 2007). The highest quality grade hays always are in high demand domestically and locally. The export quality specifications, although affected by objective forage quality grade, can be more sensitive to highly subjective hay attributes (e.g., green color, dirt-free, animal/insect-free) (Putnam, 2005). Approximately three-fourths of U.S. alfalfa hay exports go to Japan each year; other key alfalfa hay export markets include the Republic of Korea (13 to 16 percent), Taiwan (5 to 7 percent), Canada and Mexico (table 3-15, hay exports; Woodward, 2006). More than 85 percent of alfalfa forage exports are hay/compressed bales, with approximately 13 and 1 percent exported as cubes or meal products, respectively (USDA-FAS, 2006).

Table 3-14. Alfalfa and Other Hay Exports from California, Oregon and Washington Ports (Tons), 2006.

Port	Destination		Total	%
	Japan	Other Countries		
California Ports	694,516	241,333	935,849	35%
Oregon-Washington Ports	1,246,055	486,495	1,732,550	65%
Total	1,940,571	727,828	2,668,399	100%

Source: United States Department of Commerce.

Table 3-15. U.S. Forage Export Markets (1000s of Metric Tons).

Forage Importing Country	2001	2002	2003	2004	2005	2006	6-year Ave. Market Share (%)
Japan	524,090	786,409	869,648	865,317	750,907	680,769	73.9%
Korea REP	122,475	133,935	127,657	109,634	100,796	128,331	11.9%
Taiwan	35,779	72,756	55,574	58,876	62,426	68,662	5.8%
Canada	41,251	47,517	64,683	65,113	62,114	39,447	5.3%
UAE	9,004	10,034	4,552	13,197	15,810	19,864	1.2%
Mexico	3,149	5,669	12,497	12,967	23,388	8,987	1.1%
Hong Kong	0	450	923	1,065	1,070	1,087	0.1%
China	982	880	611	127	251	420	0.1%
UK	4,310	2,175	1,602	418	776	407	0.2%
Singapore	0	0	85	55	327	314	0.0%
Other	2,127	6,996	5,396	9,820	2,839	2,309	0.5%
Total	743,167	1,066,821	1,143,228	1,136,589	1,020,704	950,597	100.0%

Source: Department of Commerce, U.S. Census Bureau, Foreign Trade Statistics.

a. Alfalfa Seed and Forage Farming

4. Social Environment at Risk

The following discussion is taken largely from a Monsanto report, *Impacts of Roundup Ready Alfalfa on Production Practices and Marketing of Alfalfa Seed and Hay* (appendix V).

Along with its primary value as a high quality livestock feed, alfalfa is a valued rotational crop in U.S. agriculture because it improves soil tilth, fertility and structure. It helps mitigate soil erosion and because alfalfa is a legume, successive crops benefit from residual nitrogen in the soil. Although it is a highly sustainable practice, alfalfa's use in crop rotation is declining in the United States because it demands different management, equipment, market channels, and labor schedules not common to other mainstream cropping systems (USDA-ERS, 2002). In addition, livestock to consume the hay may no longer be located in the vicinity. Alfalfa forage-cutting schedules, yield, quality, and persistence are challenged by weather and pests.

In general, alfalfa requires somewhat more complex management and more labor to produce per ton of bulk forage than alternative annual row crops, such as corn silage. This has occurred even though the alternative forage crop used is not as environmentally sustainable, is not as nutritionally complete for livestock, and is not as profitable in the long term for many farm systems. In part, because of several social and

economic reasons, risk-averse producers in much of the United States have reduced the number of acres planted to alfalfa. It may be noted that, in contrast to several alternative feedstuff crops, alfalfa crop prices are not directly managed or insured by government programs. Very little hay is transported cross country and almost none is imported to meet U.S. forage market shortfalls, although dairy and livestock producers require a constant supply. The crop is a perennial that peaks in yield during the second and third year. Relative to annual crops, alfalfa demand and supply are more prone to serious within-season imbalance, price volatility, and the selling price of the alfalfa crop is not known at planting time. Alfalfa growers face the risk of weather interacting with weed competition or herbicide application outcomes that can lead to unpredicted stand failure, stand depletion and or temporary or permanent loss of hay quality or stand yield potential.

In parallel and for several of the same reasons, the numbers of alfalfa seed growers and seed acres have declined in the United States. Most alfalfa seed is grown on highly valued irrigated land in the West where there is much competition for the limited number of skilled growers and suitable acres for alfalfa seed growing. U.S. alfalfa seed growers compete with their conventional seed producing counterparts in Canada, Australia, and elsewhere, where comparative production costs are significantly lower (e.g., USDA Docket 04-085-1; public comment by M. Wagoner [December 12, 2004; comment P5]).

Alfalfa seed yield is highly influenced by grower inputs (such as fertilizer, pesticides, herbicides, and/or irrigation), weeds and insect pests and seasonal weather fluctuations. The cost and availability of required cultured pollinator bees is highly variable (many cultured bees are imported from Western Canada). Similar economic, social, and competitive challenges face both U.S. alfalfa seed and forage growers. Weeds, for example, increase the costs for all alfalfa producers.

b. Consumer Demand and Preferences

(1) The Organic Segment of the Food Industry

The organic sector is rapidly growing both in the European Union (EU) and the United States (Dimitri and Oberholtzer, 2005). Together, consumer purchases in these two regions made up 95 percent of the \$25 billion in estimated world retail sales of organic food products in 2003 (Willer and Geier, 2005). In reporting the results of their annual manufacturer survey, the Organic Trade Association (2007) reports that U.S. organic food sales were estimated to be \$16.67 billion in 2006, up 22 percent from 2005 (see table 3-16).

The Organic Trade Association (2007) notes that organic foods have shown consistent annual growth rates of 15 to 21 percent since 1997, when fairly comprehensive data were first available. Moreover, they report growth rate data based on historical surveys and interviews with long-time participants in the organic foods business in a similar range of nearly 20 percent annually since 1990. Organic food sales are projected to continue growing at a similar pace through 2010 (table 3-16).

Table 3-16. U.S. Organic Food Sales and Sales Growth Forecasts.

Category of Food	Sales (Millions of \$)			Annual Sales Growth Rates (%)		
	2004	2005	2006	2004-2005	2005-2006	Forecasted Annual 2007-2010
Organic Dairy	1,731	2,140	2,668	24	25	20
Organic Meat	195	256	334	31	30	27
All Organic	12,460	13,831	16,673	11	22	18

Source: For 2005-2006, Organic Trade Association Manufacturers Survey (2007); For 2004, Organic Trade Association Manufacturers Survey (2006). Data rounded to the nearest integer value.

Of the total amount of 2006 organic food sales reported by the Organic Trade Association (2007), 16 percent were made up of organic dairy products, while another 2 percent came from organic meat. Moreover, organic dairy product sales in 2006 were reported to represent an increase of 25 percent over 2005 levels. Table 3-16 also provides recent trend sales data for organic meat, indicating an even faster growth rate than organic dairy products, though from a much lower base sales level. The Organic Trade Association (2007) notes that overall consumer purchases of organic foods in 2006 represented only 2.79 percent of total U.S. food sales, though this figure is up from 0.81 percent in 1997. The Organic Trade Association (2008) reports that while organic dairy sales in the United States represented 0.79 percent of all dairy sales in 1997, by 2006 that figure had increased to 4 percent of all dairy sales.

Organic production may be somewhat lagging behind the growth in demand; the Organic Trade Association (2006) indicated that 52 percent of respondent firms reported that a lack of dependable supply of organic raw materials has restricted their company from generating more sales of organic products. Willer et al. (2008) report that agricultural land under organic production systems represented 0.5 percent of all agricultural land in the United States in 2006, somewhat below the worldwide average.

There is evidence that consumer perceptions of organic food safety may be an important driver for consumer substitution of organic for conventionally produced food. In particular, Dimitri and Oberholtzer (2005) argue that changes in organic and conventional food demand are driven in part by “food scares.” They note, for example, that mad cow

disease (bovine spongiform encephalopathy (BSE)) considerably influenced the European organic livestock and dairy industry. Dimitri and Oberholtzer (2005) report that in response to news reports on BSE, many consumers substituted organic dairy and meat products (which consumers perceived as safer) for conventionally raised dairy and meat products. Dimitri and Oberholtzer (2005) report that other food scares that caused European consumers to substitute organic for conventionally produced food include episodes of contaminated chicken feed in Belgium in 1999, feed contaminated by dioxin in 2004, and more recently, carcinogenic food dyes in TV dinners in Ireland in 2005. However, Dimitri and Oberholtzer (2005) do not find evidence that U.S. consumers are as strongly affected by food scares.

(2) Consumer Sensitivity to GE Content in Food

Demand for GE foods or for foods free of GE content is very difficult to estimate. In the case of European countries this is because most European major food retailers do not carry GE foods in response to consumer concerns (Noussair et al., 2004). In the case of the United States, the absence of mandatory labeling for GE foods makes demand estimation difficult. Most U.S. consumers are unaware of the prevalence of GE material in the U.S. food supply (Anderson et al., 2006; Hallman and Hebden, 2005; Thomson and Dininni, 2005). Hallman et al. (2003) found that only one-fourth of U.S. residents believed that they had ever consumed food containing GE ingredients. There seems to be no estimate available of consumer demand for GE-free food products (Noussair et al., 2004).

However, in the last decade, there have been a considerable number of attempts to identify consumer preferences regarding GE foods, in and outside the United States, most of them based on consumer surveys done under various conditions asking consumers to express their preferences under hypothetical situations. The results overwhelmingly show lack of information regarding GE foods and some resistance towards their consumption (Hallman and Aquino, 2003).

A number of studies have implemented experiments in which consumers actually get to choose among products and benefit from their choices. Lusk et al. (2004) developed a meta analysis of 25 studies including 57 valuations of GE foods. Most of the studies analyzed are from the United States, a third are from Europe, and the remainder are from Asia, Canada and Australia. Seventeen of the studies are based on consumer surveys while 8 are based on experiments. These studies report that the willingness to pay for GE-free foods was positive, implying that consumers were willing to pay more for these foods.

A number of other studies have investigated whether the resistance to GE foods and the lack of information regarding biotechnology are correlated. Chern and Rickertsen (2002) conducted a student survey in four countries (United States, Japan, Norway and Taiwan) and a national phone survey in the United States and Norway. Willingness to consume GE foods increased when it was explained that GE foods could include benefits such as the reduced use of pesticides. Bertolini et al. (2003) compared attitudes towards GE foods in the United States, Japan, and Italy in random surveys of food shoppers. They also found a positive impact of familiarity with GE technology on acceptance. On the other hand, Hallman and Aquino (2003) conducted a survey of a random sample of U.S. households and found out that improved information on GE food did not necessarily mean increased approval. Those most knowledgeable of GE material tended to have more extreme opinions, in favor or against, than those less knowledgeable. Noussair et al. (2004) also found that prior beliefs regarding GE food had a stronger influence on consumer choice than information.

Studies also exist investigating how consumers value varying levels of GE content in their foods. In an experiment in France, where consumer surveys reveal very strong resistance to GE products, Noussair et al. (2004) found that 89 percent of consumers were willing to purchase a product with up to 1 percent GE content and 96 percent with up to 0.1 percent GE content. They also found that consumers differentiated between GE-free and 0.1 percent of GE-content. On the other hand, a nationwide study in the United Kingdom found that consumers did not distinguish between 0 and 0.5 percent GE levels in food and did not place a value in having products with 0 percent GE content as opposed to 0.5 percent (Rigby et al., 2004).

In response to consumer concerns, over 40 countries have adopted labeling regulations for GE products (Guère et al., 2007).¹³ In Europe, the main impact of labeling requirements has been the virtual disappearance of many GE products, given that the cost differentials in production are small (since often GE ingredients are a minor share of total ingredients in products) and the risk of loss of market share is high given the perceived consumer resistance (Guère et al., 2007). In addition, to the extent that labeling requirements require segregation of GE and non-GE products throughout the production process, labeling may imply considerable costs (Noussair et al., 2004).

United States

There is relatively little literature specifically assessing purchase motivations associated with GE foods in the United States. In their

¹³ Some of these regulations have not yet been implemented or only partially so.

summary of 25 valuation studies relating to GE food, Lusk and Rozan (2005) found that U.S. consumers are more receptive to GE foods than their European counterparts, although a preference for non-GE foods remains, suggested by various estimates of willingness to pay for GE-free foods.

Lusk and Rozan (2005) attribute differences in GE product receptivity by consumers in France and the United States, partially to differences in information about GE foods and partially to different levels of trust in the sources providing information. While the United States showed greater knowledge of GE foods, there was also greater trust in the institutions delivering the information (food regulatory agencies, universities, agribusiness).

There is some evidence that consumers support genetic engineering for use in crops to a greater extent than in animals from which dairy, meat, and other food products derive (Ganiere et al., 2006). Hallman et al. (2003) reported that one-half of U.S. residents surveyed approved of plant-based genetic engineering, while only one-quarter approved of it for use in animal agriculture. In fact, the survey by Lusk et al. (2003) found that consumers in the United States were more averse to hormone use than use of GE animal feed. Several studies have argued that even with the negative opinions Americans express about biotechnology in surveys, there has been little apparent effect on sales of food items that contain or are raised on GE ingredients or feeds (Fernandez-Cornejo and Caswell, 2006; Putnam, 2005).

In the case of organic foods, one of the unique attributes of organic foods, and one reason consumer demand for organic foods is increasing, is the intended absence of GE ingredients in the process of producing them (Anderson et al., 2006; Dhar and Foltz, 2005; Larue et al., 2004). USDA-NOP standards currently require that goods labeled “100 percent organic” must be produced and handled without the use of excluded methods, one of which is the form of genetic engineering used to produce GT alfalfa cultivars. Livestock standards applied to animals used for meat, milk, eggs, and other animal products call for animals to be fed 100 percent organic feed, with vitamin and mineral supplements excepted (USDA-NOP, 2008). At the present time, there is no policy regarding the unintended presence of GE material in organic products or food, consistent with the fact that the NOP is a process-based program for certifying a farm or production system as organic, and not a product-based program that tests or certifies individual products as organic.

D. Human Health and Safety

1. Risk from Gene Product

The U.S. Food and Drug Administration (FDA), the lead U.S. regulatory agency for review of the food and feed safety of GE crops, completed a voluntary consultation with Monsanto and FGI in 2004 regarding the safety of GT alfalfa (FDA, 2004b). FDA concluded that the CP4 EPSPS protein produced by GT alfalfa lines J101 and J163 was biochemically and functionally equivalent to CP4 EPSPSs produced by other Roundup Ready® crops, and to the family of EPSPS proteins that naturally occur in crops and microbiologically-based processing agents that have a long history of safe consumption by humans and animals. Specifically, FDA (2004b) made the following assertions: the soil bacterium used to create GT alfalfa is not a known allergen or pathogen (does not cause allergic reactions or diseases); the CP4 EPSPS gene and protein lack structural similarities to any allergen (it does not have the same structure as anything that causes allergic reactions); the CP4 EPSPS protein is only a small portion of alfalfa; and while acute toxicity in mice was observed, allergenic responses associated with Roundup Ready® crops have not been reported by farm workers or members of the general population since the commercialization of these crops in 1996. FDA (2004b) did not review studies on dermal or inhalation toxicity of the CP4 EPSPS gene or protein, nor were any available at the time of this analysis. Reviews on the nutritional quality of GE foods conclude that there is no significant nutritional difference in conventional versus GE plants for food or animal feed (Flachowsky et al., 2005).

2. Risk from Glyphosate and Other Herbicide Use

Herbicides used in conventional alfalfa farming can be divided into two major groups—herbicides that do not kill alfalfa and can be used to control weeds in alfalfa (2,4-DB, benefin, bromonoxynil, clethodim, diuron, EPTC, hexazinone, imazamox, imazethapyr, metribuzin, norfluzon, paraquat, pronamide, sethoxydim, terbacil, and trifluralin), and herbicides that kill alfalfa (2,4-D, dicamba, clopyralid, glyphosate, and picloram) and are used for alfalfa stand removal. Although more recent figures are not reported, in 1998 a University of Wisconsin weed control specialist reported that herbicides are applied to less than 17 percent of U.S. alfalfa hay acreage (Wilke, 1998).

A controversy exists over whether herbicide use overall has increased as a result of GT crops initially adopted in 1996. A few studies have claimed that the volume of herbicide use is greater due to GT crops (Benbrook, 2004), while other studies demonstrate a decrease on overall herbicide usage related to the increased use of herbicide resistant crops (Fernandez-Cornejo, 2006; Gianessi and Reigner, 2006; Sakula, 2006; Johnson et al., 2008; Hiemlich et al., 2000). Benbrook (2004) evaluated USDA-NASS data on GE crop acreage along with data on pesticide volumes used, from 1996 to 2004, and determined that GE corn, soybeans, and cotton have led

to a 138 million pound increase in herbicide use since 1996, which is a 5 percent increase. GT corn also shows a trend for increasing use of non-glyphosate herbicides, from 42 percent of acreage in 2002 to 55 percent of acreage in 2006. Benbrook (2004) attributes this increase to increasing weed resistance to glyphosate and reduction in glyphosate prices after the patent expired. Benbrook (2004) concluded that across all crops, genetically modified crops reduced pesticide use from 1996 to 1998, but from 1999 to 2004, pesticide use increased.

Others have indicated there has not been a significant increase in the amount of herbicide usage since the advent of GT crops. They noted that using glyphosate has resulted in the replacement of herbicides that are at least three times as toxic and persist almost twice as long as glyphosate, (Gianessi and Carpenter, 2000). Trewavas and Leaver (2001) conducted an analysis which revealed that 3.27 million kg of other herbicides have been replaced with 2.45 million kg of glyphosate in soybean fields in the United States. Carpenter and Gianessi (2003) concluded that the introduction of GT soybeans has resulted in a decrease in the total volume of herbicides used.

Gianessi and Reigner (2006) noted that an increase in glyphosate usage coincided with a decrease in total amount of herbicide usage by 61 million pounds (of active ingredient) between 1997 and 2002. Much of this reduction occurred in cotton and soybeans, where several herbicides were replaced by glyphosate. Johnson et al. (2008) evaluated the USDA-NASS database and concluded that herbicide use in 2006 was reduced by 100.5 million pounds of active ingredient, based on estimates of biotechnology-derived crop replacement of conventional crops.

Other studies showed a decrease in the overall amount of herbicide applied to herbicide-tolerant crops. For example, Sankula (2006) evaluated the impact of biotechnology-derived crops planted in the United States in 2005 and determined the following:

- Herbicide-tolerant canola used less herbicide active ingredient per acre than conventional canola, which represented a reduction of 0.69 million pounds of herbicide use in 2005.
- Herbicide-tolerant corn reduced herbicide use in corn by 21.8 million pounds in 2005, which corresponds to a grower cost savings of \$269 million. Compared to 2004, grower returns were 94 percent higher and pesticide use was 18 percent lower due to a 67 percent increase in the adoption of herbicide resistant corn (due to EU approvals).
- Herbicide-tolerant cotton reduced pesticide use by 18 million pounds and reduced production costs by \$39 million.

- On average, GT soybean programs used 1.03 pounds active ingredient per acre (lbs a.i./A) whereas conventional herbicide programs used an additional 0.32 lb a.i./A. This translates to a reduction of 39.4 million pounds of herbicide and a cost savings of \$134 million.

a. Glyphosate Toxicity

Glyphosate is among the most widely used pesticides by volume in the United States. While additional glyphosate products may be used, five products are recommended for use on GT alfalfa. The five herbicides are Monsanto products and include: Honcho®, Honcho Plus®, Roundup Original MAX®, Roundup WeatherMAX®, and Roundup Ultra MAX II®. Glyphosate products can be formulated to have different concentrations of glyphosate acid per gallon of product. However, in general, glyphosate is more environmentally and toxicologically benign than many of the herbicides that it replaces (Brookes and Barfoot, 2006).

APHIS has no regulatory authority over the use of glyphosate, and has no authority to restrict or otherwise regulate the amount of glyphosate that is used in the environment. That authority belongs to the EPA, pursuant to FIFRA.

The concern, for risk assessment purposes, is glyphosate residue and glyphosate's only known metabolite, aminomethylphosphonate (AMPA), which is not included in either the tolerance expression or the risk assessment (EPA, 2006). Although AMPA is a common environmental metabolite, only trace amounts of it are formed in mammals, with the remainder being excreted unchanged. For this reason, direct exposures to AMPA, as an endogenous metabolite in animals, are encompassed by the existing toxicity data on glyphosate.

Glyphosate acts on various enzyme systems and inhibits amino acid metabolism of EPSPS in plants. This enzyme is absent in mammals. "Glyphosate is particularly effective because most plants metabolically degrade it very slowly or not at all, and it translocates well to metabolically active tissues such as meristems" (Cerdeira and Duke, 2006). Based on EPA's toxicological, ecotoxicology, and fate databases, (EPA, 1993; EPA, 2006a) glyphosate is considered to be a toxicologically and ecologically low-risk herbicide (Cerdeira and Duke, 2006).

According to the Reregistration Eligibility Decision (RED) document for glyphosate (EPA, 1993), glyphosate is of relatively low oral and dermal acute toxicity to humans. For this reason, glyphosate has been assigned to Toxicity Categories III and IV for these effects (i.e., Toxicity Category I indicates the highest degree of acute toxicity, and Category IV the lowest). An acute inhalation study was waived by EPA because glyphosate is a

non-volatile solid and the studies conducted on the end-use product formulation are considered sufficient. With regard to subchronic and chronic toxicity, one of the more consistent effects of exposure to glyphosate is loss of body weight. Other general and non-specific signs of toxicity from subchronic and chronic exposure to glyphosate include changes in liver weight, blood chemistry (may suggest mild liver toxicity), liver pathology, and weight of the pituitary gland (USDA-FS, 2003). Glyphosate is not considered a carcinogen; it has been classified by EPA as a Group E carcinogen (evidence of non-carcinogenicity for humans) (EPA, 1993; EPA, 2006).

Various formulations of glyphosate contain POEA at a level of up to approximately 20 percent (200 g/L). Tallow contains a variety of fatty acids (e.g., oleic, palmitic, stearic, myristic, and linoleic acids), as well as smaller amounts of cholesterol, arachidonic, elaidic, and vaccenic acids. While surfactants are typically classified as “inert” components in herbicides, they are not toxicologically inert and in many cases they are found to be more toxic than the herbicide itself (USDA-FS, 2003).

Steckel et al. (2007) evaluated GT alfalfa for 3 years following glyphosate treatments ranging from 0.75 to 3 pounds of acid equivalent per acre (lbs a.e./acre) for crop injury and feed quality. Levels up to 9 lb a.e./acre over 3 years did not cause a reduction in yield or nutrition of the alfalfa in any of the forage quality measurements taken (e.g., protein, starch, sugar).

(1) Risk to Field Workers

There are two types of worker exposure scenarios. The first is the general worker scenario in which workers have chronic dermal exposure to glyphosate via one of three typical pesticide application methods: directed foliar, broadcast foliar, or aerial. An accidental exposure scenario was assessed as the second type of worker exposure scenario. This includes the two most likely types of accident scenarios—spills on arms and spills on legs. Based on conservative hazard estimates, workers in both types of exposure scenarios are not at risk of adverse health effects associated with acute or chronic dermal exposure to glyphosate. (Please see technical report, *Health and Safety Risks for Field Workers*, appendix M.)

(2) Risk to Public Health and Safety

Although the general public is not at a high risk of exposure to substantial levels of glyphosate under typical conditions (EPA, 1993; USDA-FS, 2003), the majority of exposures to glyphosate that may occur are via the oral and dermal route. The general public may be exposed to herbicides used on glyphosate-tolerant alfalfa if they consume crops that were grown near GT alfalfa fields. According to experimental studies, glyphosate is

not completely absorbed when administered orally. Much of the reviewed literature has revealed that only about 30 percent of glyphosate is absorbed from the gastrointestinal tract after oral exposure (USDA-FS, 2003). Furthermore, studies indicate that the majority of unabsorbed glyphosate remains in the gastrointestinal tract, while the absorbed glyphosate is widely distributed throughout the body (USDA-FS, 2003). The highest concentrations of glyphosate are found in the bone relative to other tissues, although glyphosate does not significantly concentrate or persist in any tissue (EPA, 1993).

Glyphosate is also poorly absorbed through the skin, according to two dermal absorption studies performed by Wester et al. (1991, 1996). In general, formulations contain more of the POEA surfactant than the active ingredient, glyphosate. The results of a USDA study (USDA-FS, 2003) indicated that glyphosate containing more of the POEA surfactant (i.e., the undiluted formulation) did not absorb more rapidly than a glyphosate formulation with a less concentrated solution of surfactant.

An APHIS review of health analyses conducted on infants, adults, and the elderly concludes that the majority of the population (analyzed under central and lower exposure estimates) is not at risk of adverse health effects associated with acute exposure to glyphosate (USDA, 2008). Based on upper estimates of exposure, however, infants consuming fruit and all age groups consuming vegetables may be at risk of adverse effects associated with acute exposure to glyphosate residues. The upper estimates of risk are based on highly conservative fruit and vegetable intake rates; thus it is anticipated that only a very small number of individuals will have this magnitude of exposure and therefore be at this level of risk. (Please see technical report, *Health and Safety Risks from Increased Glyphosate and Other Chemical Usage on Humans (Exclusive of Field Workers)*, appendix L.)

b. Other Herbicides

As discussed in the technical report, *Potential Impacts to Wildlife, Amphibians, Plants and Ecosystems from Increased Glyphosate and Other Chemical Usage* (appendix N), the 20 other herbicides used on alfalfa have varying chemical fates. In general, most were more persistent than glyphosate and were characterized by higher mobility in soils, making them more apt to continually contaminate surrounding water systems. Few were even considered compounds that could bioaccumulate, or accumulate in the tissues of plants and animals (e.g., clopyralid, EPTC, norfluzon, sethoxydim, and trifluralin).

Herbicides are used at three different phases in conventional alfalfa farming—stand establishment (to prepare ground), established stands (to

control weeds), and during stand removal (to kill alfalfa). The 16 herbicides that may be used for weed control in conventional alfalfa farming are summarized in appendix G. After 2 to 8 years alfalfa stands are usually thinning and vulnerable to weeds, so the stand is removed by killing the alfalfa by either plowing, herbicide application, or both (Rogan and Fitzpatrick, 2004). Herbicides that are used for stand removal or to control volunteer alfalfa (including GT alfalfa, except for glyphosate) include (Dillehay and Curran, 2006; Miller et al., 2006; Renz, 2007; Rogan and Fitzpatrick, 2004):

- 2,4-D,
- clopyralid,
- dicamba,
- dicamba and diflufenzopyr,
- glufosinate,
- glyphosate,
- primsulfuron-methyl,
- mixtures of dicamba, 2,4-D, and clopyralid,
- picloram,
- picloram and 2,4-D,
- halsulfuron and dicamba,
- acetochlor,
- acetochlor and atrazine,
- acetochlor and atrazine and dicamba,
- atrazine and dicamba, and
- clopyralid and flumetsulam.

Because GT Alfalfa cannot be removed using glyphosate, other herbicides are needed for alfalfa stand removal in GT stands. These herbicides are presented in table 3-17 along with their Environmental Impact Quotient (EIQ).

The EIQ metric was devised in 1992 and gives an indication of the effect of an herbicide on the environment in general (Kovach et al., 1992). It is calculated from a host of parameters and is the average of the farm worker, consumer and ecological components. For comparison, Glyphosate has an EIQ of 15.3, the lowest of the alfalfa-related herbicides in table 3-17.

Table 3-17. Calculated EIQs for Alfalfa-Related Herbicides.

Herbicide	EIQ
2,4-D	18.67
Atrazine (Atrazine)	22.9
Clpyralid (Stinger)	18.1
Dicamba (Dicamba)	28.0
Diflufenzopyr (Distinct)	17.5
Glufosinate-ammonium (Rely)	28.25
Glyphosate (Roundup®)	15.3
Halsulfuron methyl (Sanda)	17.0
Picloram (Pathway)	18.0
Primsulfuron-methyl (Beacon)	27.33

Source: Kovach et al., 2007

E. Land Use and Production Practices

Alfalfa is grown for forage, grazing, seed production (forage and sprouts), human consumption, and honey production. The most acreage is for dry hay forage, as discussed in chapter 3.C.1.. In the 2 years that GT alfalfa was on the market, ~200,000 acres were planted in 1,552 counties and 48 States with the exception of Alaska and Hawaii. In March of 2007 USDA published notice in the *Federal Register* that GT alfalfa is a regulated article and GT alfalfa seed sales and plantings were halted. GT alfalfa planted in the 2005 and 2006 growing seasons is still permitted to be harvested, but has court ordered stewardship practices to minimize potential of GT alfalfa being present in harvests of non-GT alfalfa harvests (Hubbard, 2008).

The following discussion comes in part from technical reports, *Effects of Glyphosate-Resistant Weeds in Agricultural Systems*, appendix G; *Effects of Changes in Farming Practices on Water, Soil and Air Due to Use of Glyphosate-Tolerant Alfalfa*, appendix J; and *Glyphosate-Tolerant Alfalfa Presence in Human Food and Animal Feed*, appendix Q.

1. Alfalfa Production Practices

Exact alfalfa production practices vary by location, season, and farmer preference, but in general, most alfalfa is sown in the spring, except in the western United States where fall planting is more common (Hower et al., 1999). Alfalfa can be sown anytime there is available moisture and a sufficient growth period for the seedling that is frost-free (about 6 to 8 weeks). Weeds are the most damaging pest during early stand establishment, especially for spring-sown alfalfa.

Based on an extensive survey¹⁴ performed from 1988 to 1992, herbicides are used much more often with seed fields (78.3 percent of total fields)

¹⁴ Data collected in the herbicide survey represented 90.1% of the 25.6 million acres produced annually from 1988-1992 as reported by the NASS.

than with hay fields (16.6 percent of total fields; 22 percent of acreage) (Hower et al., 1999). Mechanical and cultural methods for weed control (e.g., tillage and companion crops) were used for ~80 percent of the spring planted alfalfa and 18 percent of the fall planted alfalfa (Hower et al., 1999).

a. Seed

The following discussion comes in part from technical reports, *Effects of Glyphosate-Tolerant Weeds in Agricultural Systems*, appendix G; *Effects of Changes in Farming Practices on Water, Soil and Air Due to Use of Glyphosate-Tolerant Alfalfa*, appendix J; and *Glyphosate-Tolerant Alfalfa Presence in Human Food and Animal Feed* (appendix Q).

Nearly all alfalfa seed is used for the establishment of hay fields, with a minor amount used as seed field stock seed (variety increase) or for sprouting purposes. Alfalfa seed is not consumed as a grain and, therefore, not used directly as a food or feed product. Essentially all alfalfa planting seed produced in the United States is grown using insecticides and/or herbicides, the use of which precludes the seeds' use for food or sprouting purposes. The use of biologically contaminated canal waters, waste waters, or livestock manures to fertilize alfalfa sprout seed fields are also prohibited by food safety regulations. Therefore seed products for planting and sprouting are kept distinct from each other.

Bass et al. (1988) estimated that 7 percent of U.S. alfalfa seed is used for sprouting, but this has not been confirmed. Acreage or production of sprout-destined seed is not reported and field locations for such production are not recorded, therefore, they are not known officially. It is believed that most of the sprout seeds are imported because economic alfalfa seed production in the United States generally requires the use of some food-prohibited practices.

Alfalfa seed production occurs exclusively in niche areas of the Western United States on approximately 100 to 120 thousand acres under intensive management and irrigated field conditions (see table 3-9). Alfalfa seed production requires a long growing season with a very warm temperature, very low humidity during seed ripening, and specialized equipment. Most professional seed producers use cultured bees and specialized equipment associated with bee culture.

As seen in table 3-9, within the seed producing states seed production is localized to certain counties. In the most recent USDA-NASS Census of Agriculture (2007), during 2002 and 2007, 1,234 and 806 farmers grew alfalfa seed on 110.6 and 120 thousand acres, respectively. This is a small number of growers in comparison to those growing alfalfa for forage (i.e.,

344,000 and 290,000 alfalfa hay growers in 2002 and 2007, respectively). During 2007, 90 percent of the U.S. seed crop tonnage was grown by 304 seed growers operating farms with at least 100 acres of alfalfa seed (USDA-NASS, 2009). Therefore, most of the alfalfa seed production is managed by a relatively small number of large professional seed producers. Nearly all large growers have at least one proprietary seed production contract with one of the four national alfalfa seed production companies.

Cultural practices used to produce seed are distinct from those used to produce forage. Professional seed growers usually grow seed under terms of a two or three year term seed company contract, by variety name. The contracting seed company supplies the stock seed (e.g., foundation seed) to the seed producer and the genetic source variety of the seed is documented. In contrast, seed companies purchasing or growing “common seed” or “catch crop” seed typically use lower management and inputs, the genetic identity of the stock seed is often unspecified /unknown and the resultant product quality is highly variable and cannot be certified as to cultivar or variety identity.

Typically, seed fields are planted in the fall and clipped back in late spring so that bloom within the field is uniform, synchronous and optimally timed for the warm dry season and optimal pollinator activity. Weed and in-crop volunteer controls (herbicides and cultivation) are applied mainly prior to the start of pollination or after seed harvest. Flowering begins in approximately mid June. Insecticides (primarily for *Lygus* control) and other pesticides are applied prior to bee release to avoid insecticide damage to the bees. At approximately 50 percent flower (early to mid July), cultured bees are gradually moved into the seed field for pollination with their domicile or hive for local shelter. The field is actively pollinated for approximately one month, allowed to ripen seed for approximately 4 weeks more, and then, chemically desiccated or swathed several days prior to combining the seed. At the end of the pollination period and just prior to desiccation, the pollinating generation of bees is either at the end of their lifecycle (i.e., leafcutter or alkali bees), or are transported by the honeybee keeper to a different location to forage on fall-flowering plant species. Seed is harvested in mid August to late September depending on geography. In long-growing season regions, the cool-season alfalfa forage growth between seed crops is sometimes mechanically harvested or grazed.

Usually, stands of alfalfa grown for seed production only are maintained for an average of three production seasons. Seed production contracts and AOSCA variety certification standards generally predetermine the length of the seed stand. Because most seed production is planted in widely spaced rows and are not cut monthly, relative to forage stands, weeds in

seed fields have more time and open area to proliferate and compete with the alfalfa. Therefore, weeds, insects, and pests are intensively managed in seed production systems. Weed seeds and weed debris in grower seed lots directly reduce the purity and yield of alfalfa seed and drive up growers' costs to remove them.

b. Forage

Due to climate and other differences, farming practices differ regionally. However, some farming characteristics are shared among growing regions. Alfalfa stands have two growing phases, establishment of seedlings (first year) and established alfalfa fields (two to eight years). Weed management differs for each phase (Orloff et al., 1997). Well-established alfalfa that is not thinning has fewer weeds because established alfalfa is a good competitor. Alfalfa is typically harvested (mowed) every 22 to 40 days depending on growth conditions in the region, local weather patterns, and alfalfa variety. In most of the growing regions, alfalfa is only cut three to four times a year, but in the Southwestern United States, growers can cut up to 10 or 11 times per year (Putnam et al., 2001).

To determine when to harvest, farmers balance yield and nutritional content. Yield increases as plants grow and peaks at 100 percent bloom, but nutritional content is highest in young vegetative plants and decreases until full flower. There is no optimal harvest schedule, because farmers make different decisions based on changing market demand. Farmers typically harvest between late bud stage and full bloom. The highest quality hay (bud stage) is generally used for active dairy cows, whereas, hay that is lower in protein and higher in fiber is fed to beef cattle, horses, heifers (too young to milk) and non-lactating dairy cows (Ball et al., n.d.). Alfalfa for livestock feed can be stored in a variety of forms:

- hay—dry baled at 18-20 percent moisture;
- haylage—round bale silage, baled at 50-60 percent moisture, wrapped in plastic; and
- silage—chopped and blown into a silo or a truck.

Alfalfa grown for hay is sometimes grown with a companion crop to act as weed control and to prevent soil erosion. These crops, such as oats, spring wheat or peas, tend to grow much quicker than alfalfa, and out-compete any weeds while alfalfa is becoming established. Once the companion crop begins to compete with the alfalfa for nutrients, water, and space, the companion crop can be harvested, and serves as extra profit for the farmer (Smith et al., 1998). At this point, the alfalfa is established enough to compete against any weeds on its own. Oats are the most popular companion crop to alfalfa because they are the least competitive, with alternatives such as peas also in wide use, but exact companion crop habits

depend on farmer preference and region (McCordick et al., 2008; Smith et al., 1998). Studies have found that companion cropping in alfalfa can suppress weed growth more than herbicide treatments, but that the crop then competes with the alfalfa, reducing yield (McCordick et al., 2008).

Companion crops are different from nurse crops in that nurse crops are a specific type of companion crop. Nurse crops do not compete with alfalfa for nutrients, but rather are removed or killed with herbicide early in development. This can result in both effective weed control and little impact on alfalfa yield (McCordick et al., 2008). Nurse crops can also help reduce wind, water and soil erosion and provide early groundcover like other companion crops (Hall, 2004). Other types of companion cropping include using a cover crop, used during dormant seasons to protect the soil, or a barrier crop, used as pest management strategy by serving as a refuge and distraction for pests.

2. Alfalfa Farming Practices

Alfalfa farming practices are broken into three categories: organic, conventional, and GT alfalfa.

a. Organic Farming

Organic production includes only those cropping systems that fall under the USDA-NOP definition of organic farming and are certified organic production systems. In organic systems, the use of synthetic pesticides, fertilizers, and genetically engineered crops is strictly limited. A list of NOP approved substances for organic farming inputs can be found on the USDA Web site (<http://www.ams.usda.gov/AMSV1.0/>). Neither glyphosate nor GT alfalfa is permitted in organic systems.

In organic systems, where herbicides are not permitted, the area to be seeded with alfalfa is tilled for weed management and allowed to sit for seven to ten days. Two or more passes to turn the soil with discs may be necessary if weed germination is observed. It is recommended that the field be treated with nutrients, such as compost and boron, and left for a week to check for further weed germination. Further, composted manure fertilizer can be used to kill weed seeds (Canevari et al., 2007). Planting may occur once weed growth potential is minimized (Guerena and Sullivan, 2003).

According to USDA-NOP standards, the following inputs can be used as herbicides or weed barriers, as applicable, to control weeds¹⁵: 1) soap-based herbicides for use in farmstead maintenance (roadways, ditches, right of ways, building perimeters) and ornamental crops; 2) mulches-newspaper or other recycled paper, without glossy or colored inks; plastic

¹⁵ Insecticides and substances to control plant diseases are also included on the NOP list, but are not listed here because they are beyond the scope of this Report.

mulch and covers (petroleum-based other than polyvinyl chloride (PVC)) (<http://www.ams.usda.gov/AMSV1.0/getfile?dDocName=STELPRDC5068682&acct=nopgeninfo>).

b. Conventional Farming

Conventional farming includes any farming system where synthetic (manufactured) pesticides or fertilizers are used. The definition of conventional farming usually includes the use of GE crops, but genetically engineered GT alfalfa is considered separately for this report (Harker et al., 2005). Conventional farming covers a broad scope of farming practices, ranging from farmers who only occasionally use synthetic pesticides and fertilizers to those farmers whose harvest depends on regular pesticide and fertilizer inputs. The 16 herbicides that may be used in conventional alfalfa farming are discussed in *Effects of Glyphosate-Resistant Weeds in Agricultural Systems* (appendix G; table 2-1) (based on OMAFRA, 2008; Canevari et al., 2007; Rogan and Fitzpatrick, 2004; Loux et al., 2007).

c. GT Farming

GT alfalfa can be integrated into conventional farming practices. Farming GT alfalfa is mostly the same as farming conventional alfalfa, with two important exceptions:

- (1) Weeds can be controlled by the application of glyphosate directly on top of growing alfalfa;
- (2) When alfalfa stands reach the end of their life cycle, typically after 3 to 8 years depending on growing region, glyphosate cannot be used to kill the stand to prepare for another rotation (Miller et al., 2006).

In GT alfalfa, herbicides other than glyphosate combined with tillage are required to obtain 100 percent removal. Several of the recommended GT alfalfa stand removal herbicides result in restrictions regarding what crops can be planted next, so careful crop rotation plans are necessary when using GT alfalfa (Miller et al., 2006).

Another important difference is that non-GT crops cannot be used as companion crops for GT alfalfa. This difference is important for farmers that traditionally interseed companion crops like small grains (e.g., oats) with alfalfa; it does not affect farmers that plant pure alfalfa stands. Companion crops may possibly benefit stand establishment by weed control, increased forage yield during the seedling year, and wind and frost protection for young alfalfa seedlings (Orloff et al., 1997). However, it is important to carefully monitor the seeding rates to avoid excessive competition of companion crops with the alfalfa. Companion crops can

increase overall forage yield but may decrease hay quality (McCordick et al., 2008).

3. Weeds in Alfalfa

The following discussion is based in part on the technical report, *Effects of Glyphosate-Resistant Weeds in Agricultural Systems* (appendix G).

Healthy, productive stands of alfalfa require attention to manage pests (including weeds), fertilizer inputs, irrigation (if applicable), and harvest timing. Weeds can be a problem in alfalfa, but once alfalfa is established, it acts as a suppressor of weeds and is commonly used in rotations for weed reduction. For example, prior rotation in alfalfa can reduce weed densities in sunflower to the same level as herbicide treatment and alfalfa in corn rotations has also been observed to benefit corn yield and suppress weeds (Clay and Aguilar, 1998).

Several years after sowing when plants weaken and stands become thin, weeds become more competitive with the alfalfa and can contribute to a significant decline in alfalfa yield and forage value. Well-established alfalfa fields or fields undergoing stand renovation are sometimes used for the disposal of livestock manures. Weed seeds present in livestock manure can contribute to an accumulation of weed seeds in the soil and weed problems in alfalfa production systems. Certain weed species found in alfalfa stands are particularly difficult to control (Hower et al., 1999), are poisonous to livestock, negatively affect palatably or livestock performance, impart off flavors to milk products, and may be noxious regulated species (e.g., dodder).

Farmers are concerned about glyphosate-resistant weeds (Johnson and Gibson, 2006). One hundred and twenty-nine weeds are known to infest alfalfa, some of which have already shown glyphosate resistance. Since 1998, nine new GT weeds have been found in the United States. Eight out of the 14 new GT weeds known globally are also known to be weeds in alfalfa stands. At least 21 weeds that have natural resistance to glyphosate exist. Ten of these naturally glyphosate-resistant weeds are known to be a problem in alfalfa. See *Effects of Glyphosate-Resistant Weeds in Agricultural Systems* (appendix G; table 4.1) for a list of weeds that are known to be glyphosate resistant in general or have glyphosate resistant biotypes, both since 1998 and historically.

Weeds are controlled in conventional alfalfa with chemicals (herbicides), cultural methods (rotation, mowing, companion crops, monitoring), and mechanical methods (tillage). The cultural and mechanical methods are permitted for organic farmers. GT systems allow for the use of one additional herbicide, glyphosate.

a. New Glyphosate-Resistant Weeds

Glyphosate-resistant biotypes have recently been identified for the following eight weeds that are also common in alfalfa: common ragweed, horseweed, Italian ryegrass, Johnsongrass, Palmer Amaranth, buckhorn plantain, goosegrass, and junglerice. (*Effects of Glyphosate-Resistant Weeds in Agricultural Systems* (appendix G; section 4.1.1) briefly discusses each.)

b. Traditionally Glyphosate-Resistant Weeds

Ten weeds that are common in alfalfa and historically have some resistance for glyphosate include bermudagrass, burning nettle, cheeseweed, common lambsquarters, field bindweed, filaree, large crabgrass, morningglory, nutsedge, and purslane. (*Effects of Glyphosate-Resistant Weeds in Agricultural Systems* (appendix G; section 4.1.2) briefly discusses each.)

c. Weed Management Options

Weed management strategies in organic alfalfa systems, conventional alfalfa systems, and glyphosate-tolerant alfalfa systems differ. Management options for conventional systems include (Nandula et al., 2005; Guerená and Sullivan, 2003):

- Chemical (see appendix G; table G-6)
 - Alternating herbicides with different modes of action
 - Tank mixing herbicides
 - Sequences of herbicides
 - Application timing
- Cultural
 - Rotation between GT cultivars and non-GT cultivars
 - Winter crops in rotation
 - Mowing
 - Companion crops/co-cultivation/interseeding/nurse crop)
 - Cover crops (smother crops) (prior to planting alfalfa)
 - Field scouting for early detection
 - Monitor for weed species and population shifts
 - Mechanical
 - Tillage cultivation

Cutting intervals affect weed infestation. For example, if alfalfa is cut too frequently (20 to 25 days) there is not enough time for roots to build up a sufficient storage of carbohydrates so growth after cutting is not vigorous enough and weeds have a competitive advantage. However, sometimes early harvest can rescue a heavily weed-infested new stand if the weeds

are beyond the stage of successful herbicide treatment (Canevari et al., 2007). Alternating long and short intervals between cuttings enables alfalfa to maintain root reserves so plants can recover from defoliation quickly and more vigorously compete with weeds (Canevari et al., 2007).

Crop rotations can help maintain soil fertility, reduce soil erosion, avoid pathogen and pest buildup, adapt to weather changes, avoid allelopathic effects (effects to reduce the growth of one plant due to chemicals released by another) and increase profits (Peel, 1998). Alfalfa is also used in crop rotation because it provides nitrogen to the soil, which decreases fertilizer inputs in other rotations. It can be economically advantageous to include alfalfa in rotations (Mends and Dobbs, 1991). Perennials and annuals promote and restrict different weeds, so rotating perennials with annuals helps control weeds in general. It is also advisable to rotate alfalfa because mature alfalfa is autotoxic to seedling alfalfa (Xuan et al., 2005). Monsanto recommends that alfalfa can be rotated to grass crops (corn and cereal crops) or broadleaf crops, and that alfalfa should not be rotated with other GT crops (Monsanto, 2008). This limits some options for farmers, as GT corn and GT soybean are both popular rotation crops for alfalfa. Typical rotation crops include wheat, oats, barley, potato (*Solanum tuberosum* L.), sugar beet (*Beta vulgaris* L.), and corn. Appropriate weed management practices reduce the probability of weeds developing glyphosate resistance (Rogan and Fitzpatrick, 2004).

d. Distribution of Glyphosate-Resistant Weeds

Table 3-18 shows that currently 19 U.S. States are affected by glyphosate-resistant weeds. The majority of new glyphosate-resistant weeds are located in the Southeast and Midwest. The overlap with the major alfalfa producing states in the Intermountain regions seems to be minimal at this point (see also table 3-20).

Table 3-18. Glyphosate-Resistant Weed Infestations by State.

State	Weed species	~ Number of Sites in State Infested	~ Number of Acres in State Infested	Situation	Year Reported
Arkansas	<i>Conyza canadensis</i> Horseweed	6-10 increasing	1,001-10,000 increasing	Cotton	2003
	<i>Ambrosia artemisiifolia</i> Common Ragweed	1	11-50	Soybean	2004
	<i>Ambrosia trifida</i> Giant Ragweed	6-10 increasing	101-500 increasing	Soybean	2005
	<i>Amaranthus palmeri</i> Palmer Amaranth	1 increasing	unknown	Soybean	2006
	<i>Sorghum halepense</i> Johnsongrass	1	unknown	Soybean	2007
California	<i>Lolium rigidum</i> Rigid Ryegrass	11-50 increasing	1,001-10,000 increasing	Almonds	1998
	<i>Conyza Canadensis</i> Horseweed	1	unknown	Roadside	2005
	<i>Conyza bonariensis</i> Hairy Fleabane	2-5	unknown	Roadside	2007
Delaware	<i>Conyza canadensis</i> Horseweed	101-500	10,001- 100,000	Soybean	2000
Georgia	<i>Amaranthus palmeri</i> Palmer Amaranth	101-500 increasing	100,001- 1,000,000 increasing	Cotton Soybean	2005
Illinois	<i>Conyza canadensis</i> Horseweed	1,001-10,000 increasing	10,0001- 1,000,000 increasing	Soybean	2005
	<i>Amaranthus rudis</i> Common Waterhemp***	1 increasing	51-100 increasing	Corn Soybean	2006
Indiana	<i>Conyza canadensis</i> Horseweed	2-5 increasing	101-500 increasing	Soybean	2002
	<i>Ambrosia trifida</i> Giant Ragweed	1 increasing	11-50 increasing	Soybean	2005
Kansas	<i>Conyza canadensis</i> Horseweed	51-100 increasing	10,001- 100,000 increasing	Cotton Soybean	2005
	<i>Ambrosia trifida</i> Giant Ragweed	2-5 increasing	501-1,000 increasing	Soybean	2006
	<i>Amaranthus rudis</i> Common Waterhemp	2-5 increasing	101-500 increasing	Soybean	2006
	<i>Ambrosia artemisiifolia</i> Common Ragweed	1 increasing	11-50 increasing	Soybean	2007
Kentucky	<i>Conyza canadensis</i> Horseweed	2-5 increasing	51-100 increasing	Soybean	2001
Maryland	<i>Conyza canadensis</i> Horseweed	6-10 increasing	501-1,000 increasing	Soybean	2002

State	Weed species	~ Number of Sites in State Infested	~ Number of Acres in State Infested	Situation	Year Reported
Michigan	<i>Conyza canadensis</i> Horseweed	1 increasing	51-100 increasing	Nursery	2007
Minnesota	<i>Ambrosia trifida</i> Giant Ragweed	2-5 increasing	101-500 increasing	Soybean	2006
	<i>Amaranthus rudis</i> Common Waterhemp	2-5 increasing	51-100 increasing	Soybean	2007
Mississippi	<i>Conyza canadensis</i> Horseweed	101-500 increasing	1,001-10,000 increasing	corn, cotton, rice, and soybean	2003
	<i>Lolium multiflorum</i> Italian Ryegrass	Unknown	1,001-10,000 increasing	Cotton Soybean	2005
Missouri	<i>Conyza canadensis</i> Horseweed	101-500 increasing	10,001-100,000 increasing	Cotton	2002
	<i>Ambrosia artemisiifolia</i> Common Ragweed	1	11-50	Soybean	2004
	<i>Amaranthus rudis</i> Common Waterhemp**	1 increasing	1,001-10,000 increasing	Corn Soybean	2005
New Jersey	<i>Conyza canadensis</i> Horseweed	6-10 increasing	101-500 increasing	Soybean	2002
North Carolina	<i>Conyza canadensis</i> Horseweed	2-5 increasing	6-10 increasing	Cotton	2003
Ohio	<i>Conyza canadensis</i> Horseweed	101-500 increasing	1,001-10,000 increasing	Soybean	2002
	<i>Conyza canadensis</i> Horseweed*	2-5 increasing	101-500 increasing	Soybean	2003
	<i>Ambrosia trifida</i> Giant Ragweed	2-5 increasing	101-500 increasing	Soybean	2004
Oregon	<i>Lolium multiflorum</i> Italian Ryegrass	1 stable	1-5 stable	Orchards	2004
Pennsylvania	<i>Conyza canadensis</i> Horseweed	2-5 increasing	101-500 increasing	Soybean	2003
Tennessee	<i>Conyza canadensis</i> Horseweed	501-1,000 increasing	>2,000,000 increasing	Cotton Soybean	2001
	<i>Amaranthus palmeri</i> Palmer Amaranth	2-5 increasing	101-500 increasing	Cotton	2006
	<i>Ambrosia trifida</i> Giant Ragweed	101-500 increasing	1,001-10,000 increasing	Cotton Soybean	2007

* Resistant to chlorimuron-ethyl, cloransulam-methyl, and glyphosate.

** Resistant to acifluorfen-Na, cloransulam-methyl, fomesafen, glyphosate, imazamox, imazethapyr, and lactofen.

*** Resistant to chlorimuron-ethyl, glyphosate, and imazethapyr

Source: Heap et al., 2008.

4. Crop Rotation in Alfalfa

For weed, insect, and disease management, it is recommended that alfalfa be used in rotation with other crops. It is also advised to rotate alfalfa because mature alfalfa produces allelochemicals which are autotoxic to seedling alfalfa. Autotoxicity is the primary problem for alfalfa seeded after alfalfa.

Table 3-19 presents rotation recommendations for control of several common alfalfa pests.

Table 3-19. Recommended Rotations for Pest Reduction.

Pest	Recommended Rotation
Root knot nematode	1 year rotation with cotton
Stem nematode	3-4 year rotation with small grains, beans, cotton, corn, sorghum, lettuce, carrots, tomatoes, or forage grasses.*
Disease Bacterial wilt Anthracnose Spring blackstem Common leafspot Stagonospora	3-4 year rotation with small grains, beans, corn, sorghum, forage grasses.*
Winter weeds	A minimum of 1 year (preferably longer) in crops such as small grains, wheat, oats, winter forage grasses that allow the use of selective herbicides that are not registered in alfalfa.
Summer weeds	A minimum of 1 year (preferably longer) in crops such as small grains, beans, cotton, corn, sorghum, summer forage grasses that allow the use of selective herbicides that are not registered in alfalfa.
Dodder	At least 2 years with cotton or other nonhost crops such as small grains, beans, corn, sorghum, or forage grasses. Avoid rotations with crops such as tomatoes, onions, and carrots that also serve as a host for this weed.
Nutsedge	Two year rotation with corn or sorghum rotation that includes application of herbicide to control nutsedge.

* Three to four-year rotations give satisfactory results. A rotation for fewer years will provide minimal suppression.

Source: Goodell, 2006

The major regional differences for growing alfalfa forage are due to different climatic regions and the adaptation of different varieties to these climatic regions. The major factors involved in variety adaptation are winter temperatures and rainfall. The areas of alfalfa adaptation for the United States are shown in figure 3-3. These regions are recognized by the USDA–Plant Variety Protection Office and the National Alfalfa and Miscellaneous Legume Variety Review Board (Rogan and Fitzpatrick, 2004).

5. Regional Differences in Production Practices

The adaptation of alfalfa varieties to winter temperatures is based on their winterhardiness, which ranges from very dormant and more winterhardy to extremely non-dormant and less winterhardy (Teuber et al., 1998; Rogan and Fitzpatrick, 2004). Dormancy is a condition where physiological activities associated with growth temporarily cease. For alfalfa, dormancy is thought to be brought on by shorter day length and possibly colder temperatures in the autumn. The alfalfa plants reverse this

process in the spring with the onset of warmer temperatures and longer day lengths. The more dormant varieties require numerically more and warmer days along with longer day lengths for vigorous growth to begin again. In regions where winter temperatures are less severe and the length of the growing season increases, the need for winterhardiness decreases resulting in more harvests per year and increased yields per acre per year (Rogan and Fitzpatrick, 2004).

Rainfall influences soil moisture, soil pH, and humidity, which in turn, affects the prevalence of disease, weed, nematode, and insect problems. Therefore, throughout the 1900's, many alfalfa varieties were first developed with varying levels of winterhardiness, and then later for resistance levels to various diseases, insects and nematodes (Melton et al., 1988).



Figure 3-3. Areas of alfalfa adaptation in the United States (Rogan and Fitzpatrick, 2004).

a. Seed Production

Most of the high quality alfalfa seed is grown under irrigation in the western states as noted in tables 3-13 and 3-20 with California, Washington, and Idaho being the top three seed production States. Small acreage seed growers located mainly in the Plains primarily produce uncertified seeds (e.g., for the past several years, South Dakota Crop Improvement has not certified any alfalfa seed production although much alfalfa seed is produced). Overall, approximately 8 and 58 percent of the dormant and non-dormant seed crops are exported, respectively (table 3-18). The States that export the most nondormant and dormant alfalfa variety seeds are California and Idaho (table 3-20).

Table 3-20. Alfalfa Forage and Seed Production by State.

State	Acres by State				Hay and Haylage			2007 FAS Report			
	(1000s)				Harvested			2002-06 Mean			
	Dry Hay 2006	Hay and Haylage 2006	Average Yield T/A	Harvested Tons	Seed Production Acres	Average Yield (lbs/A)	Seed Lbs Harvested	Seed Dormant	Harvested ND/SD	Seed Export	
Southwest											
AZ	250	250	8.3	2,075	4	500	2,000,000	0	2,000,000	1,000,000	
CA	1,050	1,070	6.9	7,426	38	550	20,900,000	209,000	20,691,000	12,885,713	
NM	220	234	5.1	1,184	2	400	800,000	0	800,000	0	
Total	1,520	1,554		10,685	44		23,700,000	209,000	23,491,000	13,885,713	
PNW											
ID	1,180	1,230	4.5	5,523	28	700	19,600,000	18,302,000	1,568,000	2,500,000	
NV	270	270	5.1	1,377	5	600	3,000,000	3,000,000	0	0	
OR	430	430	4.4	1,892	5	650	3,250,000	3,250,000	0	150,000	
WA	440	455	4.9	2,239	15	750	11,250,000	10,125,000	1,125,000	2,847,247	
Total	2,320	2,385		11,031	53		37,100,000	34,677,000	2,693,000	5,497,247	
Inter-Mountain											
CO	780	780	3.8	2,964	0.6	200	390,000	390,000	0	0	
MT	1,550	1,550	2.1	3,255	5.5	200	3,025,000	3,025,000	0	500,000	
UT	560	560	4	2,240	2.2	200	1,320,000	1,320,000	0	100,000	
WY	500	500	2.8	1,400	7.5	400	4,125,000	4,125,000	0	1,094,738	
Total	3,390	3,390		9,859	15.8		8,860,000	8,860,000	0	1,694,738	
Plains											
KS	950	965	3.8	3,677	0.5	200	100,000	100,000	0	0	
NE	1,250	1,265	3.3	4,212	0.4	200	80,000	80,000	0	0	
OK	380	380	2.1	798	0.4	200	80,000	80,000	0	0	
TX	150	160	4.4	707	1	400	400,000	40,000	360,000	0	
Total	2,730	2,770		9,394	2.3		660,000	300,000	360,000	0	
North Central											
IA	1,180	1,230	4	4,908	0	0	-	-	0	0	
MN	1,350	1,500	3.6	5,460	0	0	-	-	0	0	
ND	1,450	1,450	1/2	1,740	0	0	-	-	0	0	
WI	1,650	2,400	3.9	9,336	0	0	-	-	0	0	
SD	1,800	1,820	1.6	2,930	7	250	1,750,000	1,750,000	0	0	
Total	7,430	8,400		24,374	7		1,750,000	1,750,000	0	0	

Table 3-20, continued

2006 National Agricultural Statistics Service Data											2007 FAS Report	2002-06 Mean
State	Acres by State (1000s)			Hay and Haylage Harvested			Average Yield (lbs/A)	Seed Production Acres	Seed Lbs Harvested	Seed Dormant	Harvested ND/SD	
	Dry Hay 2006	Hay and Haylage 2006	T/A	Average Yield	Forage Tons	Seed Production						
East Central	7	7	2.1	15							0	
CT	5	5	3.9	20							0	
DE	440	460	4.2	1,918							0	
IL	360	360	4.1	1,476							0	
IN	10	10	1.9	19							0	
ME	40	40	3.9	156							0	
MD	13	13	2.3	30							0	
MA	830	980	4	3,940							0	
MI	390	400	3	1,184							0	
MO	8	8	2.4	19							0	
NH	25	25	2.5	63							0	
NJ	370	610	3.3	2,019							0	
NY	470	550	4	2,195							0	
OH	500	660	3.8	2,515							0	
PA	1	1	3	3							0	
RI	45	90	3.6	322							0	
VT	3,514	4,219		15,894		0		0	0	0	0	
Total												

b. Forage Production

The north-central region has the most acres devoted to alfalfa forage production, followed by the east-central region and the intermountain region. The least amount of forage production occurs in the southeast region. Less than 1 percent of alfalfa hay produced is exported. Nearly 100 percent of exported alfalfa hay is produced in the Pacific Northwest and Southwest regions.

As a percentage of acres produced, the north-central, east-central and southeast regions use most of the hay on the same farm on which it is grown. For the southwest and Pacific Northwest, most of the forage sold is used for dairy farms (USDA-NASS, 2002). (See tables 3-20, 3-21 and 3-22 for more details on forage production.)

c. Weediness and Weed Control

Weeds and their control have a major impact on the management practices in alfalfa seed and forage production. Weed control measures vary by farm within a region as much as among regions. The plant species that are considered weeds in alfalfa production are also affected by the different climates in which alfalfa is grown; thus, different weeds can be expected to vary in their importance in the different alfalfa growing regions. Since each herbicide has a fairly definite array of weeds that it can control without causing major damage to the alfalfa, the use of the different herbicides varies among the regions. Herbicide use depends on the weeds that are causing the most concern on each farm, stage of growth of alfalfa and weeds, potential damage to the crop, forage versus seed production, the potential carry-over for injuring the following crop in their crop rotation, as well as the price-value relationship of each herbicide.

Because alfalfa seedlings grow slowly, they are especially susceptible to weed competition, especially in the spring (Peters and Linscott, 1988; Hower et al., 1999). Extension weed specialists and forage specialists indicate that the best weed control in an established stand of alfalfa is achieved by establishing and maintaining a dense healthy stand of alfalfa. Important factors in establishing a dense healthy stand include proper soil fertility and pH, seedbed preparation, varietal selection, appropriate cutting schedules, insect control and good weed control in the seeding year (Undersander et al., 2004). Stringent weed control during the first 60 days after alfalfa emergence is critical for high quality forage from first harvest, and to prevent stand loss due to early weed competition (Leep et al., 2003). The use of companion crops, such as oats, depends on the relative competitiveness/tolerance to competition of the companion crop plants, alfalfa seedlings, and the weeds. These attributes of competitiveness and tolerance to competition are greatly affected by the appropriate soil

fertility, seed bed preparation, moisture availability and timing of clippings/harvests.

Tillage practices during cultivation of crops impact the soil and water, and can influence such factors as weed control, crop rotations and yields. Tillage is most often used between crops in order to remove the traces of the previous crop and as weed control in preparation for the next crop. Excessive tillage causes soil erosion, but reducing tillage through use of herbicide improves soil nutrients, increases moisture content, benefits soil microbes, decreases runoff, and reduces atmospheric pollutants (Fawcett and Towery, 2002).

Perennial weed species in forage crops become an increasing problem without tillage (Peters and Linscott, 1988). Dandelions, plantain, cinquefoils, docks and thistle species are among the perennials infesting alfalfa (Peters and Linscott, 1988). Other perennial weed problems in alfalfa are quackgrass, nutsedges, white cockle, yellow rocket, Johnsongrass, and bermudagrass.

The cultural methods used to control weeds in the seedling year are clipping, companion crop, flash grazing (where fields are briefly and heavily stocked with grazing animals), and early harvest for spring seeding and fall seeding, with one exception. Early harvest was not noted for fall seeding (Hower et al., 1999). Mowing or cutting is performed frequently (3-10 cuttings per year) in alfalfa as a natural part of the harvesting process. Multiple cuttings for hay harvest each year, for several consecutive years, will impact the weed population and species present in alfalfa. Mowing is beneficial in preventing weed seed production and further infestations, such as annual broadleaf weeds in new alfalfa stands or weeds such as Canada thistle and Johnsongrass in established stands of alfalfa (Peters and Linscott, 1988). Annual grasses cannot be controlled effectively by mowing because growth is regenerated from crown buds near the soil surface below the point of mowing, and mowing is not effective for controlling quackgrass because of its growth patterns.

For organic alfalfa hay growers, these cultural methods are still the only means of controlling or reducing weeds in alfalfa hay fields. For organic alfalfa seed growers (none of which have been identified to date in the United States), insecticides, fungicides, and herbicides cannot be used. The use of these chemicals can increase the harvest of economically viable yields of alfalfa seed, and therefore this lack of pesticide use in organic crops could be a contributing reason for the scarcity of organic alfalfa seed produced in the United States.

d. Seeding and Harvesting

Good establishment is required for a long-lived productive stand of alfalfa. Seeding failures can be the result of poor seedbed preparation, seeding too deep, low moisture availability, freezing, diseases, insects, excess competition for light and nutrients from other alfalfa seedlings, companion crop or weeds, damage from herbicides or insecticides, and excess straw from the companion crop. For seeding, slight differences may be in the equipment used (some farmers may use drills, while others may broadcast the seed and some may even aerial broadcast). Seeding time during the year varies from region to region (the far northern areas will generally seed in the spring to avoid major freezing damage of young seedling plants whereas other areas will seed in the fall), but recommended seeding times are based as much on the previous crop and soil water availability throughout the year as on time of year. The recommended soil preparations are very similar in all regions unless no till planting is used and no-till planting can be used in all regions. For fertilizing, any differences that occur are in the composition of the fertilizer used because of the different soil types in the different regions, but all of the regions generally recommend good availability of phosphorus and potassium. Nitrogen fertilizer is generally not recommended unless considerable refuse from the previous crop exists.

Alfalfa grown for forage can be used for grazing or harvested as silage or hay. Different equipment is used for each type of harvesting. The only major difference for harvests among regions is the total number of harvests per year, with the far northern regions having up to two to three harvests per year due to a shorter growing season than the southern regions, which can have six or more harvests per year. The major differences are in the adaptation of different varieties to the different climates in the United States, and differing levels of various pests (weeds, diseases and insects), which have effects on the pesticides that might be used.

6. Distribution and Acreage (by State and County)

The number and location of alfalfa forage acres are closely associated with livestock operations, especially dairy. In the United States in 2008, approximately 21 million acres were grown for forage production (figure 3-2). The alfalfa acreage in the United States has declined gradually over the past 40 years from a high of approximately 30 million acres (Rogan and Fitzpatrick, 2004).

Table 3-20 summarizes 2006 total hay (and seed) acreage as the sum of “alfalfa dry hay” and “alfalfa hay and haylage” categories, and presents acreage and yield per acre summaries by region and state. Multi-year national statistics for conventional, organic and exported alfalfa dry hay acres and values are presented in table 3.5 for the 4-year period from 2002

to 2005.¹⁶ During the period 2002 to 2006, the number of conventional acres grown for alfalfa forage was relatively stable, with an average of 3.33 tons dry hay per acre

Alfalfa seeds of each variety type are grown in their respective area of adaptation: dormant varieties in the north and, non-and semi-dormant varieties in the southwest, especially California (tables 3-9, 3-13, and 3-20). According to USDA-NASS statistics for 2006, 122 thousand acres were harvested for alfalfa seed, total production was 72 million pounds, and the average yield was approximately 590 lbs per acre (weighted average) (table 3-20).

Table 3-21 presents the U.S. states in order of percentage of alfalfa harvest (in 2005). For each state, the growing region, the percentage of the total national harvest of all alfalfa are presented for 2002, 2005, and 2007; and the percentage of the national organic certified harvest are presented for 2002 and 2005. In 2005, the most recent USDA organic harvest report, 22,439,000 acres of dry hay alfalfa were harvested and 204,380 (0.9 percent) of those acres were certified organic. The number of acres harvested in a state does not indicate the quantity of the harvest. For example, as shown in table 3-22, because of the growing season length, California ranks top in production (in 2007, ~11 percent of the national harvest and ~7 million pounds) and South Dakota ranks second (in 2007, ~6.8 percent of the national harvest and ~4 million pounds) even though South Dakota has ~2 million acres and California has less than 1 million acres of alfalfa. In addition, even though the northeastern states rank low in the percentage of acres and quantity of harvest, alfalfa is the number one crop for several of those states (NAFA, 2007).

Table 3-21. Alfalfa Growing Regions and Percentage of Dry Hay Harvest by State.

State	Growing Region	Percent of harvest acres			Percent of organic harvest	
		2002	2005	2007	2002	2005
South Dakota	North Central	10.57	10.70	9.86	8.58	6.82
Montana	Winter Hardy Intermountain	6.76	7.80	9.23	3.66	2.60
North Dakota	North Central	6.13	7.35	7.20	11.22	10.09
Wisconsin	North Central	7.32	6.91	7.50	16.34	14.38
Minnesota	North Central	5.59	6.02	4.67	6.40	10.44
Iowa	North Central	5.16	5.57	4.10	6.11	4.50
Nebraska	North Central	5.92	5.57	5.36	2.71	4.01
Idaho	PNW-Intermountain	4.57	5.08	5.12	24.69	24.22

¹⁶ 2005 is the most recent year for which organic alfalfa acreage data is available from USDA. Therefore, 2005 is used as the year of comparison for the relative size of organic, export and domestic markets. Dry hay values are used in table 3-21 because exported hay is dried before sale or processing.

State	Growing Region	Percent of harvest acres			Percent of organic harvest	
		2002	2005	2007	2002	2005
California	Moderate Winter Hardy Intermountain/Southwest	5.19	4.63	4.88	2.92	6.48
Michigan	East Central	3.56	4.01	3.45	2.07	0.35
Kansas	Great Plains	4.14	3.79	3.92	1.40	0.32
Colorado	Winter Hardy Intermountain	3.40	3.57	4.25	3.45	4.38
Wyoming	Winter Hardy Intermountain	2.16	2.67	3.33	0.19	0.84
Utah	Moderate Winter Hardy Intermountain	2.48	2.41	2.71	0.60	0.45
Ohio	East Central	2.71	2.27	2.16	1.89	0.50
Pennsylvania	East Central	2.96	2.27	2.35	0.96	0.60
Missouri	East Central	1.77	2.01	1.46	0.23	0.58
New York	East Central	2.90	2.01	2.22	1.34	0.16
Washington	PNW-Intermountain	2.37	2.01	2.22	1.19	0.56
Illinois	East Central	1.84	1.78	1.59	0.80	1.22
Oregon	PNW-Intermountain	2.15	1.78	2.12	0.42	3.23
Indiana	East Central	1.41	1.52	1.19	0.03	0.29
Oklahoma	Great Plains	1.54	1.43	1.65	0.00	0.04
Kentucky	East Central	1.37	1.16	1.33	0.00	0.01
Nevada	Moderate Winter Hardy Intermountain	1.34	1.16	1.35	1.25	1.47
Arizona	Moderate Winter Hardy Intermountain/Southwest	1.03	1.16	1.27	0.91	0.24
New Mexico	Moderate Winter Hardy Intermountain	0.83	1.07	1.17	0.14	0.33
Texas	Great Plains/Southwest/Southeast	0.72	0.67	0.76	0.18	0.55
Virginia	East Central	0.62	0.49	0.44	0.31	0.14
Vermont	East Central	0.20	0.20	0.16	0.00	0.00
Maryland	East Central	0.25	0.18	0.20	0.00	0.01
Tennessee	East Central	0.13	0.16	0.10	0.00	0.00
West Virginia	East Central	0.23	0.16	0.14	0.00	0.00
New Jersey	East Central	0.12	0.11	0.10	0.00	0.00
Arkansas	East Central	0.07	0.09	0.06	0.00	0.00
Massachusetts	East Central	0.07	0.06	0.05	0.00	0.00
Maine	North Central	0.06	0.05	0.05	0.00	0.17
North Carolina	Southeast	0.10	0.05	0.05	0.00	0.00
Connecticut	East Central	0.04	0.04	0.04	0.00	0.05
New Hampshire	East Central	0.04	0.04	0.03	0.00	0.00
Delaware	East Central	ND	0.02	0.02	0.00	0.00

State	Growing Region	Percent of harvest acres			Percent of organic harvest	
		2002	2005	2007	2002	2005
Rhode Island	East Central	0.01	0.01	0.01	0.00	0.00
Florida	Southeast	0.02	0.00	0.03	0.00	0.00
Georgia	Southeast	0.01	0.00	0.01	0.00	0.00
Louisiana	Southeast	0.03	0.00	0.01	0.00	0.00
Mississippi	Southeast	ND	ND	0.02	ND	ND
South Carolina	Southeast	0.01	0.00	0.02	0.00	0.00
Alabama	Southeast	0.04	ND	0.04	0.00	ND
Alaska		0.00	ND	0	0.00	ND
Hawaii		ND	0.00	0.00	0.00	0.00
ND = no data provided by USDA						

Table 3-22. Alfalfa Dry Hay Harvest 2007 Census of Agriculture.

State	# of Farms	Acres Harvested	Lbs. Harvested	Farms Irrigated	Acres Irrigated	% of Acres	% of lbs.	Avg. Acres per Farm
United States	290,726	20,244,497	65,349,074	56,390	6,556,652	100.0	100.0	70
California	3,587	986,982	7,057,014	3,488	963,086	4.9	10.8	275
South Dakota	12,653	1,996,599	4,414,338	716	75,913	9.9	6.8	158
Idaho	8,817	1,037,520	4,254,543	7,605	861,092	5.1	6.5	118
Nebraska	14,820	1,085,921	3,955,881	4,405	389,516	5.4	6.1	73
Montana	9,711	1,868,756	3,936,445	5,444	703,960	9.2	6.0	192
Wisconsin	30,810	1,517,522	3,673,619	171	8,809	7.5	5.6	49
North Dakota	8,985	1,457,604	3,072,682	240	21,773	7.2	4.7	162
Iowa	22,040	830,440	3,054,729	62	1,198	4.1	4.7	38
Kansas	9,643	793,140	2,986,134	1,115	207,455	3.9	4.6	82
Colorado	8,648	861,053	2,887,865	7,347	707,234	4.3	4.4	100
Minnesota	20,398	944,775	2,671,173	384	15,603	4.7	4.1	46
Washington	4,294	448,588	2,192,001	2,822	334,005	2.2	3.4	104
Utah	7,780	548,570	2,172,218	7,413	507,798	2.7	3.3	71
Arizona	943	257,407	1,968,043	920	257,263	1.3	3.0	273
Oregon	3,569	428,812	1,777,894	3,043	380,679	2.1	2.7	120
Michigan	16,431	698,595	1,707,036	291	8,080	3.5	2.6	43
Wyoming	4,007	674,284	1,696,438	3,357	471,126	3.3	2.6	168
Pennsylvania	14,402	475,873	1,357,225	109	462	2.4	2.1	33
Ohio	15,354	437,658	1,256,174	17	536	2.2	1.9	29
Nevada	1,128	274,004	1,217,586	1,128	274,004	1.4	1.9	243
New Mexico	4,272	236,103	1,176,242	4,091	222,018	1.2	1.8	55
Illinois	12,913	322,339	1,138,512	47	906	1.6	1.7	25

State	# of Farms	Acres Harvested	Lbs. Harvested	Farms Irrigated	Acres Irrigated	% of Acres	% of lbs.	Avg. Acres per Farm
Oklahoma	3,781	334,990	1,131,938	294	33,000	1.7	1.7	89
New York	7,707	450,144	1,119,421	31	901	2.2	1.7	58
Missouri	8,229	295,021	782,847	63	1823	1.5	1.2	36
Texas	2,391	153,763	721,303	1,154	98,831	0.8	1.1	64
Indiana	10,775	241,129	665,767	139	2,185	1.2	1.0	22
Kentucky	10,538	269,610	524,565	109	1,210	1.3	0.8	26
Virginia	3,063	89,213	233,807	76	679	0.4	0.4	29
Maryland	1,429	40,576	120,402	49	712	0.2	0.2	28
Vermont	571	31,769	68,624	2	(D)	0.2	0.1	56
West Virginia	1,185	28,465	62,484	5	(D)	0.1	0.1	24
New Jersey	728	20,310	51,483	39	799	0.1	0.1	28
Tennessee	1,655	20,074	45,819	28	(D)	0.1	0.1	12
Arkansas	278	11,732	28,647	15	932	0.1	0.0	42
Maine	246	10,089	23,876	0	0	0.0	0.0	41
Massachusetts	406	9,921	22,537	1	(D)	0.0	0.0	24
Connecticut	349	8,343	18,441	0	0	0.0	0.0	24
Alabama	340	7,526	16,944	13	91	0.0	0.0	22
North Carolina	758	10,322	16,755	67	360	0.1	0.0	14
Florida	141	6,951	14,993	13	1,071	0.0	0.0	49
Delaware	177	3,687	13,530	22	421	0.0	0.0	21
New Hampshire	218	5,373	13,475	5	(D)	0.0	0.0	25
South Carolina	143	4,070	8,860	20	274	0.0	0.0	28
Mississippi	159	3,931	7,113	4	35	0.0	0.0	25
Georgia	134	1,655	4,810	18	243	0.0	0.0	12
Louisiana	52	2,164	4,768	2	(D)	0.0	0.0	42
Rhode Island	63	1,035	1,806	1	(D)	0.0	0.0	16
Hawaii	5	89	267	5	89	0.0	0.0	18

D = data withheld to protect identity of individual farms

Source:

http://www.agcensus.usda.gov/Publications/2002/Volume_1,_Chapter_2_US_State_Level/st99_2_026_026.pdf

Other differences in alfalfa farming are revealed by examining the number of farms that grow alfalfa and the number of farms that irrigate. Comparison of California and Wisconsin (table 3-22) shows that in California ~97 percent of the farms irrigate, whereas in Wisconsin only 0.5 percent of the farms irrigate. Farmers that irrigate can maintain soil moisture at near optimum levels and can withhold irrigation before harvesting, giving farmers greater control of harvest timing (Orloff et al.,

1997). In areas where irrigation is uncommon, farmers rely on rain, which has natural variations that greatly influence alfalfa growth and the harvest schedule.

Another difference is farm size. The average farm size in California is much larger than in Wisconsin. It should be noted that the average farm size calculation is a bit misleading because in California some very large farms (4,000 acres) skew the average. In general, because farm size does not fit a normal distribution, the average farm size does not give an accurate picture of farm sizes. However, average farm size does relay the general trend of farm size in a state. Like any census, these data may not include all alfalfa farms.

G. Physical Environment

1. Soils

Like other legumes, alfalfa forms a symbiotic relationship with the nitrogen-fixing bacterium *Sinorhizobium meliloti*. The result is the conversion of atmospheric nitrogen to fixed nitrogen in the soil, resulting in a net increase in available nitrogen to the soil (USDA-FS, 2003).

Studies show that glyphosate does not move deep into the soil, does not get transported at high levels to or through groundwater, and does not persist long in the soil (Major, 2003; Milleret al., 1995; Torstensson, 2005). It is highly adsorptive and remains in the soil until mineralizing bacteria breaks it down; the primary route of degradation (Gimsing et al., 2004). The major byproduct of this process is aminomethyl phosphonic acid (AMPA), which further degrades in the soil to form carbon dioxide. Soil composition does have an effect on glyphosate adsorption, with presence of minerals increasing adsorption (lessening movement of the glyphosate) and the presence of soil organic matter inhibiting adsorption (Getenga and Kengara, 2004; Vereecken, 2005). See section 'Glyphosate' above for details on glyphosate chemical fate and transport in the environment.

2. Climate and Air Quality

Herbicides can pollute air either through drift, the movement of herbicide through the air to unintended sites or evaporation into the air (volatility). Glyphosate is essentially not volatile at 77°F and has not been reported as an atmospheric contaminant (Cerdeira and Duke, 2006). When glyphosate is applied directly to plant leaves, the risk of drift is low, but when glyphosate is applied broadly to a field, the risk of drift increases (Owen, 1998).

The use of glyphosate as a post-emergence herbicide leads to an increase in no-till farming, which can lead to a decrease in tractor use (Fawcett and Towery, 2002). In fact, emissions related to global warming, ozone depletion, summer smog and carcinogenicity, among others, were found to

be lower in GT crop systems than conventional systems (Bennett et al., 2004). In addition, because the soil is not mechanically disturbed, no-till also results in less dust than tillage, which improves air quality.

3. Water

a. Surface Water

Glyphosate and its metabolite AMPA adsorb to soil particles that become suspended in runoff water and can potentially contaminate surface waters when this soil erodes. Once in surface water, glyphosate and AMPA are not readily broken down by water or sunlight (EPA, 1993), but can be removed through standard water purification processes and disinfection processes such as ozonation and chlorination (Speth, 1994).

In a U.S. Geological Survey (USGS) monitoring study of surface water, groundwater, and soil conducted from 2001 to 2006, the metabolite AMPA was observed more frequently than the parent compound glyphosate (Scribner et al., 2007). The sample collections were from several USGS studies including the National Stream Quality Accounting Network Program, the National Water-Quality Assessment Program, and the Toxic Substances Hydrology Program. Additionally, glyphosate and its metabolite AMPA were found in surface water more frequently than groundwater. Groundwater and surface water contamination by glyphosate is limited because of glyphosate's tendency to adhere to variable-charged soil minerals and because of microbial degradation of glyphosate in soils (Borggaard and Gimsing, 2007). Higher occurrences of glyphosate and AMPA in ground and surface waters were observed when samples were taken near agricultural areas that experienced a rain event shortly after glyphosate application (Scribner et al., 2007). (Please see section 'Glyphosate' above for additional discussion on glyphosate fate in surface water.)

b. Groundwater

Due to glyphosate and AMPA's strong adsorptive characteristics, they are not likely to leach to groundwater from the soil, and compared to most herbicides, leaching is very limited (Cerdeira and Duke, 2006; Grunewald et al., 2001). (Please see section 'Glyphosate' above for additional discussion on glyphosate fate in groundwater.)

IV. Environmental Consequences

This chapter evaluates the potential effects of the preferred alternative (the proposed action of granting nonregulated status to GT alfalfa lines J101 and J163 without restrictions), and the no action alternative detailed in chapter 2 of this EIS. The effects on plant genetics and gene flow, threatened and endangered species, socioeconomic implications, human health and safety impacts, implications for land use and production practices, soil, climate, air quality, and water are considered in this chapter.

A. Methodologies and Assumptions Used in Analysis

1. Models, Risk Assessment, Cause and Effect

The risk characterization used in this chapter to analyze biological impacts of glyphosate use integrates the results of exposure and ecotoxicity assessments to evaluate the likelihood of adverse ecological effects. The means by which this integration occurs is referred to as the quotient method. In this method, risk quotients (RQs) are first calculated by dividing exposure estimates by acute¹⁷ and chronic¹⁸ ecotoxicity values ($RQ = \text{Exposure}/\text{Toxicity}$). RQs are then compared to the EPA's levels of concern (LOCs), which are used by EPA's Office of Pesticide Programs to analyze both potential risk to nontarget organisms and the need to consider regulatory action on pesticides.

Effects of glyphosate exposure to nontarget terrestrial organisms were estimated using the Tier 1 T-REX (Terrestrial Residue Exposure) simulation model (version 1.2.3) based on the maximum application rate, re-application interval, and the default foliar dissipation half-life of 35 days at a rate of 1.99 lb a.i./acre (pound of active ingredient per acre), applied four times at 30 day intervals. Residues on various terrestrial food items ranged from 60.53 to 968.42 mg/kg diet (EPA, 2005). This spreadsheet-based model calculates the residues on avian and mammalian food items along with the dissipation rate of a chemical applied to foliar surfaces (for single or multiple applications) in order to estimate acute and reproductive risk quotients (EPA, 2005).

Glyphosate exposure to aquatic species was estimated using GENEEC (Generic Estimated Exposure Concentration) Version 2.0 (EPA, 2001b) as the Tier I simulation model. GENEEC estimates the peak value which occurs on the day of a single large rainstorm event as well as multiple day averages over periods of 4, 21, 60 and 90 days. The magnitude of the peak concentration is the result of how fast the chemical dissipates in the

¹⁷ Acute toxicity studies are those that study the effects of a single or short-term exposure to a substance.

¹⁸ Chronic studies are those that study the effects of exposure on a large percentage of a subject's life span, such as daily exposure received by workers.

field. The multiple day average over periods of 4 to 90 days reflect the dissipation of the chemical that takes place in the water body. These peak and average concentrations are then compared with the appropriate toxicity tests for aquatic plants and animals. The estimated environmental concentrations for aquatic organisms were based on the application rates proposed in the labels for uses on glyphosate-tolerant (GT) alfalfa. It was assumed that glyphosate was applied in four sequential applications; at least 7 days apart to an annual total maximum of 7.98 lbs glyphosate acid equivalent (a.e.) per acre and that each single application is assumed to be 1.99 lbs glyphosate equivalents per acre. The maximum single use application of 1.99 lbs glyphosate a.e./acre was based on Honcho and Honcho Plus products containing 41 percent of the isopropylamine salt of glyphosate, equivalent to 3 lbs of glyphosate equivalents per gallon (356 g glyphosate/L). This application rate and a minimum reapplication period of 7 days was used to estimate high-end use of glyphosate on GT alfalfa in efforts to quantify the risk to ecological organisms. The maximum single application rate of glyphosate on GT alfalfa is 1.55 pounds a.e./acre, thus, this analysis is highly conservative.

APHIS has no authority under the Plant Protection Act to regulate herbicide use associated with GT plants that are granted nonregulated status. The use of glyphosate is regulated by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) restrictions administered by the EPA, which mandate registration and use of all pesticides. EPA includes instructions and restrictions on how glyphosate herbicides can be applied, and has determined that there is no unreasonable environmental risk if the user adheres to the directions. Directions include application restrictions that minimize impacts on nearby environments. Violators of the regulations are liable for all negative consequences of their actions; therefore, farmers who use glyphosate are very likely to follow its label restrictions, and adverse impacts from the predicted increased glyphosate use will be minimized. The information is provided to help inform the agency decision maker and the public of the risks associated with glyphosate use. Glyphosate is currently undergoing the reregistration process with EPA.

2. Assumptions a. Data Gaps and Uncertainties

The CEQ regulations recognize that many Federal agencies confront limited information and substantial uncertainty when analyzing potential environmental impacts of their actions under NEPA (40 CFR §1502.22). Accordingly, the regulations provide agencies with a means of formally acknowledging incomplete or unavailable information in NEPA documents.

If the information relevant to reasonably foreseeable significant adverse impacts cannot be obtained because the overall costs of obtaining it are exorbitant or the means to obtain it are not known, the agency shall include within the environmental impact statement:

(1) A statement that such information is incomplete or unavailable; (2) a statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment; (3) a summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment, and (4) the agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community. For the purposes of this section, "reasonably foreseeable" includes impacts which have catastrophic consequences, even if their probability of occurrence is low, provided that the analysis of the impacts is supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason. (40 CFR §1502.22.b).

Some of the data on the effects of the deregulation of GT alfalfa are incomplete. Where a complete evaluation of reasonably foreseeable environmental impacts on the human environment that could result from the proposed action and alternatives are precluded by a lack of data that cannot be obtained except at an exorbitant cost or by unknown means, APHIS has complied with the regulations mandated by the CEQ. In these cases, APHIS acknowledges incomplete and unavailable information where the agency is unable to precisely estimate the potential environmental impacts that may result from the preferred alternative.

B. Plant Genetics and Gene Flow

1. Gene Flow Due to Pollen Transfer and Pollination

Preferred Alternative

The discussion throughout chapter 4.B is formed in the context of the preferred alternative. The discussions under each sub-topic are not broken down into both a preferred alternative and a no action alternative discussion, but instead, the no action alternative impacts discussion comes at the end of this section. Unless explicitly defined, all of the following considerations are in relation to the preferred alternative.

Gene flow is a measure of the exchange of genes between populations, and it occurs naturally between alfalfa populations. Review of information previously provided by Monsanto and FGI, information in the Petition 04-110-01p, as well as in the technical report, *The Potential for Gene Flow from Glyphosate-Tolerant Alfalfa (Medicago sativa L.) to Related Species* (appendix I) concludes that alfalfa does not naturally

hybridize with any wild relatives in North America. Having established that there are no related, sexually compatible wild relatives in the United States, movement of the *CP4 EPSPS* gene can only occur to cultivated or feral alfalfa populations through pollination by bees.

Agricultural farmers manipulate bee colonies to control pollination of their crops. For alfalfa seed production, cultured alfalfa leafcutter bees, *Megachile rotundata* (F.), are used primarily in the cooler Pacific Northwest and honey bees (*Apis mellifera* L.) are used primarily in the irrigated valleys of the Desert Southwest (California, Arizona, etc.). In certain niche geographies where suitable climate and soil beds exist (e.g., southern Washington), permanent colonies of the ground-nesting alkali bee, *Nomia melanderi* Cockerell, contribute significantly to commercial alfalfa pollination, and are estimated to contribute 20 percent pollination for alfalfa seed fields proximal to an alkali bee bed. However, alkali bee pollination is often augmented by adding cultured leafcutter bees. Occasionally, some seed producers use a blend of two managed cultured bee species for pollination to increase the rate of seed set or shorten the pollination period.

Hammon et al. (2007) studied alfalfa fields in Colorado and collected data on the insects observed visiting the alfalfa. That list is in table 4-1, in order of abundance, followed by estimated ranges collected from various sources.

Alfalfa farmers purposely stock bees only in seed farming, as they do not want or need pollination of hay fields. Because most regions that cultivate alfalfa seed do not have naturally occurring populations of effective alfalfa pollinators, farmers must produce, introduce and manage these pollinators to ensure pollination (Rogan and Fitzpatrick, 2004). Alfalfa leafcutter bees, a typical managed species for alfalfa seed production, are established next to the target crop of alfalfa. The release of these bees can be controlled by directing incubation temperatures, which signal the bee developmental processes. Alfalfa seed farmers judge when blooming of the crop will be at a peak, and will time the incubation and subsequent release of the bees accordingly. Once the released bees have completed their season and die, the larvae laid throughout the season are collected and cleaned, then stored at a temperature that keeps them in a pupating stage until the desired release time next year. Honey bee colonies, which are not typically used for alfalfa seed production as leafcutter and alkali bees are more effective pollinators (Mueller, 2008), may be moved from field to field because the hives are highly portable and because the bees stay with their queen. Honey bees also tend to forage at much larger distances, and this increases the chances of pollen being spread from one location to another (Strickler and Freitas, 1999; Bosch and Kemp, 2005).

Table 4-1. Pollinator Foraging Distance.

Pollinator (Species)	Forage Distance from Nest
Alfalfa leafcutter bee (<i>Megachile rotundata</i>)	300-600 feet ¹
Honey bee (<i>Apis mellifera</i>)	Measured up to 6.21 miles away, average distance depends on availability of pollen/nectar, typically 1.86 miles ²
Alkali bee (<i>Nomia melanderi</i>)	Will forage up to 4 or 5 miles away; typical pollination within 2 mile radius ³
Long-horned bee (<i>Melissodes</i> sp.)	Data not found
Mud/Digger bee (<i>Anthophora</i> spp.) (2)	Data not found
Bumblebee (<i>Bombus morrisoni</i>)	Data not found
Bumblebee (<i>Bombus griseocollis</i>)	Data not found
Sweat bee (<i>Lasioglossum sisymbrii</i>)	Data not found
Sweat bee (<i>Halictus tripartitus</i>)	Data not found
Sweat bee (<i>Halictus confusus</i>)	Data not found
Leafcutter bee (<i>Megachile texana</i>)	Data not found
Mason bee (<i>Osmia laticulcata</i>)	Data not found

¹ Source: McCaslin et al. (2000)

² Source: Beekman and Ratnieks (2000)

³ Source: USGS, 2008

Bee habits vary based on range and climate. In general, bees will forage where they need to in order to collect pollen and nectar. If there is an abundant source of both close to the nest, then their average foraging distances will be lower than if the bees must forage further to find adequate pollen and nectar. Both honey bees and alfalfa leafcutter bees will increase their foraging distance as the distance to high-reward resources (high nectar and pollen amounts) increases, and as closer resources become scarce (Strickler and Vinson, 2000). Patchiness of the environment also affects this foraging distance, as bees can prefer certain flowers over others (depending on the species and season), and might need to travel through or around obstacles in the environment, so they will adapt foraging habits accordingly (Greenleaf et al., 2007).

It is highly unlikely that physical contact between bees in the hive would result in passive transfer of pollen, which could hypothetically lead, rarely if at all, to a subsequent pollination event and gene flow (Mueller, 2005). According to Johansen (1980 Personal Communication as cited by V. Marble), "...bees clean themselves quite thoroughly back at the hive or nest, concluding that little pollen remained to contaminate a new area of [bee] forage when the bees do not return to the same area of a field on the subsequent trip." This suggests that there is near zero potential for gene flow that might result from passive pollen transfer among cohabitating bees and very little accumulation of viable pollen on the surface of bees that make repeated foraging trips to an alfalfa field or feral grouping of plants. There would be essentially no potential of within-nest transfer of

pollen between bees for most of the native bee species because they are solitary nesting bees.

- 2. Gene Flow Due to Secondary Seedlings** Secondary seedlings (seedlings that are not planted directly by the farmer but rather sprout unintentionally) are an unlikely avenue for effective gene flow into existing solid-seeded alfalfa plantings since alfalfa plants and alfalfa debris produce compounds that elicit an autotoxic reaction to germinating alfalfa seeds. The autotoxic reaction and inter-plant competition severely limit germination and seedling vigor of alfalfa sown or dropped into existing or newly terminated alfalfa stands. Cultivated fields do not successfully self-seed. Attempts to thicken existing alfalfa stands by deliberately inter-planting new seed into them typically fail, which is why most agronomists do not recommend the practice (Canevari et al., 2000).

A portion of seed growers plant their fields in rows instead of solid plantings. In these situations, in-crop volunteers from dropped seeds occur and the resulting seedlings could be a means of gene flow to subsequent crops. However, in order to maintain required variety and purity of the alfalfa crop, these seed growers routinely control germinating alfalfa seedlings and weeds using irrigation and/or soil-active herbicides that do not impact the pre-established, alfalfa crop. The high likelihood of autotoxicity is one reason why alfalfa growers must rotate to a different crop for at least 1 full year following stand take-out.

- 3. Seed Purity** Seed farmers are concerned with the purity of their seed stock, and follow state and federal-mandated standards in order to produce seed of certified purity. Isolation distances between fields and threshold amounts of other varieties that are allowable in a crop vary by state, but in general, seed stock must be 99 percent of the variety or varieties stated on the label. Alfalfa seed production occurs mainly in the West and Northwest United States. California produces the most alfalfa seed in the country, in both pounds and acreage. This is discussed in chapter 3 and in the technical report, *Glyphosate-Tolerant Alfalfa Presence Human Food and Animal Feed* (appendix Q).

In California, in order to cultivate *foundation* alfalfa seed (seed of the highest purity) alfalfa must not have grown on the land in the previous 4 years, and for *certified* seed (seed of the second highest purity), 1 to 2 years, depending on the intervening crops (http://ccia.ucdavis.edu/seed_cert/alfalfa_seedcert_standards.htm). All volunteer plants and noxious weeds must be eradicated and definite boundaries to the field set before field use. Foundation seed fields must be isolated from alfalfa of different varieties by 900 feet, while certified fields must be isolated by 165 feet. However, the 10 percent rule is followed for certified fields, where if 10 percent or less of the certified

field is in the 165 foot isolation zone, the entire field is considered certified, but if more than 10 percent is in the isolation zone, then that part of the field must be separated and not harvested as certified seed. Most states have identical guidelines, with only slight variations, and purity standards remain high. As shown in table 4-2, which shows seed purity standards for California, Idaho, Wisconsin, and Montana, at least 99 percent of each seed harvest must contain the pure seed variety, and there are strict limits on the allowable amounts of other crops, weeds and inert matter as well.

Table 4-2. Seed Purity Standards by State.^{1,2,3,4}

State	Type of Seed	Pure Seed (min %)	Other Crops (max %)	Other Varieties (max %)	Other Material (max %)	Isolation Distance, < 5 acres (ft)
California	Foundation	99.5	0.1	0.1	0.5	900
	Certified	99.5	0.1	0.2	0.5	165
Idaho	Foundation	99	0.1	0.0	1.1	900
	Registered	99	0.1	0.0	1.2	450
	Certified	99	0.25	1.0	1.25	330*
Wisconsin	Foundation	99	0.2	0.1	0.85	900
	Certified	99	0.75	0.25	0.95	165
Montana	Foundation	99.5	0.1	0.1	0.6	1320
	Registered	99.5	0.1	0.25	0.7	660
	Certified	99.5	0.1	1.0	0.8	330

¹ <http://ag.montana.edu/msga/Seed%20Standards/alfalfa%20standards.pdf>

² <http://www.idahocrop.com/standards.aspx>

³ <http://www.wisc.edu/wcia/2008StandardW.pdf>

⁴ http://ccia.ucdavis.edu/seed_cert/alfalfa_seedcert_standards.htm

After seed crops have been evaluated by seed labs, they are tagged with seed labels in accordance with law. Seed labs perform multiple tests mandated by the AOSCA (Association of Official Seed Certifying Agencies) on a representative sample from each submitted crop.

Assuming that the contaminating variety has the same germination (the process of a seed beginning to sprout) and fitness (a measure of survival and reproduction) as the certified variety, one can calculate the number of plants in an acre that would be off-type.¹⁹ A thriving alfalfa hay field can have 15 plants per square foot (Orloff et al., 1997), which equals 653,400 plants in an acre (0.5 percent of 653,400 is 3,267). If the contaminating variety is mixed evenly in the seed batch, then there might be an off-type plant every 13.3 square feet. In older stands where plant density may be closer to five plants per square foot, there might be an off-type plant every 40 square feet. FGI's 2000 to 2002 field studies (Fitzpatrick et al., 2002), which assayed 30,000 non-GT alfalfa seedlings, detected 0.000 percent gene flow with a 99.9 percent confidence interval.

¹⁹ Only 60% of the seeds germinate and emerge and only 40% of emerged seedlings survive the first year (Orloff et al., 1997).

This means there could be a 0.01 percent cross-fertilization between non-GT alfalfa and a GT variety, which is one seed in 10,000, or one plant in 667 square feet at a stand density of 15 plants per square foot.

Because of alfalfa seed purity concerns, FGI has expanded the required isolation distances typically used in States that follow the AOSCA standards when growing GT and non-GT alfalfa for seed production. FGI changed the isolation distances for contractors growing alfalfa seed based on scientific studies examining the travel distance of different alfalfa pollinators. FGI's Best Practices, described in more detail below and are a part of the mandatory stewardship program for licensed GT alfalfa seed growers (alfalfa hay growers follow the mandatory stewardship program as described by the Monsanto Technology/Stewardship Agreement), states that when farmers contract with FGI to grow and produce alfalfa seed and use leafcutter bees for pollination, the distance between GT and non-GT alfalfa seed production fields must be greater than or equal to 900 feet. When using Alkali bees, the isolation distance must be greater than or equal to 1 mile, and when honey bees are used as a pollinator, the isolation distance must be greater than or equal to 3 miles. FGI has validated their Best Practices for seed production and believes they can produce non-GT alfalfa seed reliably with >99.5 percent purity (FGI, 2007). To put this in context, one seed in 200 could be from an off-variety, such as GT alfalfa seed in conventional alfalfa seed.

4. Gene Flow to Other Alfalfa Crops and Wild Relatives

Gene flow (the movement of genes from one population to another) occurs naturally among alfalfa in hay fields, seed fields, feral and other alfalfa populations via bees and secondary seedlings. Potential environmental impacts due to gene flow from GT alfalfa to cultivated or feral (free living) alfalfa are considered by APHIS to be no different from cultivation of conventional alfalfa and the resulting potential for gene flow from conventional alfalfa. In the event that GT alfalfa plants were no longer regulated under 7 CFR part 340, we do not believe that the natural flow of genes and traits between alfalfa populations in the United States amounts to a significant impact on the human environment for the following reasons:

- No *Medicago* species are native to the Western Hemisphere; hence, there will be no impact on the natural genetic resources of these species from release in the United States (Sinskaya, 1961; Lesins and Lesins, 1979; Ivanov, 1988).
- If GT individuals did arise through intraspecific hybridization (between two sub-species of the same species), tolerance to glyphosate would not confer any competitive advantage to these plants unless exposed to glyphosate. This would only occur in managed ecosystems where glyphosate is applied for broad-spectrum weed control or in

plant varieties developed to exhibit glyphosate tolerance and in which glyphosate is used to control weeds.

- As with GT alfalfa volunteers, these individuals, should they arise and where they require control, could be controlled using other available chemical and/or mechanical means. Undesired crosses, if they developed, would not be controlled by the use of glyphosate and control would require use of non-glyphosate vegetation management practices. Currently, glyphosate is not widely used to control unwanted alfalfa vegetation (Rogan and Fitzpatrick, 2004).

The following section discusses the factors that influence gene flow between alfalfa fields and potentially increase or decrease the chances of gene transfer between alfalfa plants.

As previously discussed (see chapter 3), there is no evidence for existence of any sexually compatible, free-living or cultivated relatives of *Medicago sativa* in the United States or North America. Thus, possible movement of the transgene via pollen from GT alfalfa events J101 and J163 to other members of the *Medicago* genus would not occur in the United States, or it would only occur following the introduction and establishment of a reproductively compatible, non-native species near GT alfalfa events J101 and J163. It is reasonable to predict that hybridization between rangeland *falcata* subspecies and GT alfalfa varieties with mostly *sativa* parentage would result in hybrids with more rangeland hardiness than the original GT alfalfa, but less rangeland hardiness than the *falcata* parent.

The three alfalfa populations discussed in this section are defined as follows (based partly on Bagavathiannan and Van Acker, 2008):

- *Hay field population*: agricultural field that is intentionally planted with alfalfa and is harvested for hay (may also include some grazing).
- *Seed field population*: agricultural field that is intentionally planted with alfalfa and is harvested as seed stock.
- *Feral and other alfalfa*:
 - *feral*—alfalfa growing on any non-agricultural land (including roadsides, fences, waste lots) that reproduces without intentional human inputs, including reseeding. This is considered the “naturalized” population in the United States because alfalfa was introduced to the continent at least 200 years ago (Putnam et al., 2001).
 - *habitat/rehabilitation/erosion control*—alfalfa that is intentionally sown (most likely in a seed mix), but is not managed after planting.
 - *rangeland*—seed may be sporadically sown for grazing, but land is not mowed for regular hay harvest, populations are mostly self sustaining.

- *volunteer*—alfalfa growing unintentionally, out of rotation in an agricultural field with another crop (e.g., corn).
- *escaped volunteer*—alfalfa from seed that escaped from an agricultural field (this is the first generation of a feral population). Escaped volunteers may not persist past a generation or two, depending on conditions.

There are several factors that influence the probability of gene flow between these fields. The following is a list of factors adapted from Putnam (2006):

- probability of synchronous flowering (e.g., the percentage of days where several plants flower simultaneously);
- availability of pollen (e.g., the percentage of bloom during each day of synchronous flowering);
- pollinator activity on days of synchronous flowering and placement of bee hives (e.g., influenced by timed bee release and weather);
- distance between fields (alfalfa populations);
- probability of seed maturation; and
- probability of seed germination.

Considering the various factors mentioned above, table 4-3 below presents the relative potential of gene flow between hay fields, seed fields and feral and other alfalfa, under the possible nine scenarios of gene flow. This topic is also discussed in the technical report, *Glyphosate-Tolerant Alfalfa Presence in Human Food and Animal Feed* (appendix Q).

Gene flow between and into alfalfa seed fields is of higher concern than gene flow into alfalfa hay fields, whether maintaining the purity of a GT variety or a non-GT variety. This is primarily because hay fields are typically harvested before 10 percent of plants reach full flower (before they can be pollinated), so even if pollen from a GT alfalfa arrives at a non-GT hay field, propagation of seed is highly unlikely.

Even in instances where weather or equipment failures delay harvesting of GT or non-GT alfalfa hay fields, there is little risk of GT gene flow into alfalfa production if it is not wanted (Van Deynze et al., 2008). Alfalfa must bloom, be cross-pollinated by insects, set fruit, and then dehisce seed in order to successfully transfer genes from one plant to another. Alfalfa requires at least four weeks of appropriate environmental conditions (temperature, sunlight, nutrients, and water) before forming reproductively mature floral buds, and an additional 4 to 6 weeks after that to form mature seeds after pollination (Rogan and Fitzpatrick, 2004). Alfalfa hay normally is harvested at or before first flower, 6 to 9 weeks before the ripe seed stage (Putnam, 2006).

Table 4-3. Relative Potential for Gene Flow Between Populations of Alfalfa (requires that viable seed is produced).

<i>Pollen Donor</i>	<i>Pollen Acceptor</i>		
	Seed field	Hay field	Feral and other alfalfa
Seed field	Between adjacent fields with synchronous flowering, gene flow would be expected to exceed 1% which is not acceptable for foundation or certified seed. The largest data set collected under actual seed production conditions using FGI Best Practices found a range of gene flow from 0.00 to 0.18 percent. Thus, FGI Best Practices that include distance between fields can manage cross-fertilization to below 0.5 percent which is FGI's goal.	Lowest risk of gene flow because hay is cut before seed is produced.	Feral populations should be controlled near seed fields to preserve seed purity. However, if feral plants are present, they will likely be cross-pollinated by seed field pollen.
Hay field	Less likely than seed to seed gene flow. The percent bloom at harvest will influence how much pollen could potentially be transported to seed fields. Mowing hay prior to 10 percent bloom and distance (350 to 600 feet) from seed fields can manage cross-fertilization to below 0.01 percent.	Lowest risk of gene flow out of the nine scenarios. Even in fields that bloom, hay is cut before seed is produced.	The percent bloom at harvest will influence how much pollen could potentially be transported to feral populations. Mowing hay prior to 10 percent bloom can reduce pollen availability. Seed farmers will need to be aware of seeding practices in neighboring rangelands because falcata (yellow-flowered alfalfa) may become increasingly adopted for rangeland forage improvement and the Falcata seed is available commercially ¹ .
Feral and other alfalfa	Feral populations need to be controlled near seed fields, or purity of GT and non-GT varieties can be compromised. (Or the seed field edges can be harvested as a separate crop.) Seed farmers will need to be aware of seeding practices in neighboring rangelands because falcata (yellow-flowered alfalfa) may become increasingly adopted for rangeland forage improvement and the Falcata seed is available commercially.	Lowest risk of gene flow because hay is cut before seed is produced.	Gene flow between feral individuals that are close to each other is likely. Gene flow between feral populations depends on proximity, pollinators, flowering timing, and environmental stresses. The GT trait is not expected to impart increased fitness in feral alfalfa.

Source: Van Deynze et al. (2008)

¹ <http://www.windriverseed.com/15212%20-%20Falcata.pdf>

Thus, there are realistic measures that non-GE alfalfa farmers can employ that will effectively reduce or prevent gene flow from neighboring GE alfalfa crops. As stated by Van Deynze et al. (2008):

“Growers who wish to avoid gene flow (e.g., those who produce hay for markets that reject GE crops) should pay attention to flowering habits (avoiding simultaneous flowering) and harvest schedules, and disallow or remove commercial beekeepers’ hives. Although the hay harvest date can be delayed a week or more by wet weather or equipment failure, harvesting before the ripe seed stage is possible in all but the most extreme circumstances.”

In those extreme weather circumstances, rainfall or snow during the ripening time will cause decreased seed yield and reduces seed quality (e.g., reductions in seedling vigor and reduced percent germination because of fungal pathogen infection of the seed, or seed will sprout prematurely and die while it is still in the pod) (Rincker et al., 1988), further reducing the likelihood of gene flow. Additionally, viable alfalfa seeds that fall near adult alfalfa have a harder time growing because they must compete for nutrients with the already established adults, and adult alfalfa plants secrete an autotoxic substance into the soil that inhibits root growth in seedlings (Xuan et al., 2005). In fact, reseeding fields to fill gaps from dead plants is not recommended, as the new plants do not compete efficiently enough to survive (Orloff et al., 1997).

Feral alfalfa is a concern if it is not managed near seed fields. Feral alfalfa near GT alfalfa hay fields may receive the GT trait, but the trait’s survival in the feral population depends on whether there is pressure from the environment to select for plants that maintain the trait, or chance. The GT trait is not expected to enhance feral alfalfa fitness; there is no difference between GT and non-GT alfalfa in terms of alfalfa’s ability to reproduce or persist in an environment (USDA-APHIS, 2009).

Rangeland alfalfa (*falcata* subspecies) populations may be growing as ranchers intentionally seed *falcata* into rangeland to increase forage quality and soil nitrogen (Waggener, 2007; High Plains Midwest Ag Journal, 2008). The potential for gene flow between GT alfalfa and *falcata*, as well as the effect of hybridization between GT alfalfa and the *falcata* subspecies is unstudied.

Factors Decreasing Probability of Gene Flow

FGI and Monsanto have developed mandatory stewardship programs to address concerns regarding gene flow (FGI, 2007).²⁰ Seed growers

²⁰ The stewardship programs also address other concerns such as weediness potential and glyphosate-resistant weed formation.

undergo training and have to be licensed to grow GT alfalfa seed. Any farmer who purchases GT alfalfa seed for producing hay is required to sign a Monsanto Technology/Stewardship Agreement (MTA). The FGI (Forage Genetics International) Best Practices for alfalfa seed growers is the primary mechanism for limiting gene flow. Features of the MTA and FGI Best Practices are as follows (FGI, 2007):

- GT alfalfa seed producers may not sell seed to any party other than FGI and growers may not save seed for any purpose.
- Bee hives cannot be moved out of GT alfalfa fields until pollination is finished for the year. This prevents pollen being carried via hive between GT and non-GT alfalfa. Grower must indicate main pollinator species on the FGI Seed Grower Contract.
- Isolation through distance from other alfalfa fields is required. For pollination with leafcutter bees the distance must be greater than or equal to 900 feet, for Alkali bees greater than or equal to 1 mile, for honey bees greater than or equal to 3 miles.
- FGI reports seed field location and planting date to local seed certifying organizations, which GE-sensitive farmers can refer to in order to certify isolation distances.
- Stand removal and volunteer management must be sufficient to allow seed certification inspectors to validate stand removal. Stand removal date and method must be reported to FGI and verified.
- Cleaning requirements for equipment are included in the FGI Best Practices.
- The Monsanto MTA requires alfalfa hay growers to harvest at or before 10 percent bloom.

Additional factors that could further decrease the potential for gene flow include:

- *Barriers between fields*—Types of barriers can include bodies of water, or other, more attractive plants for bee foraging in between fields. A border of plants at field edges has the benefit of being a buffer zone, as pollen would be deposited in the border population before leaving a GT alfalfa field. If the border were also alfalfa, this would ensure that pollinators would not preferentially avoid the border area. However, the border would need to be treated as GT alfalfa, and if it starts out as non-GT alfalfa, then the spread of genes from that population to the GT alfalfa could adversely affect the cultivation of GT alfalfa seeds by reducing seed purity. If the border were not alfalfa, but a different plant, this would prevent bees from traveling far from the field, and fewer GT genes would be spread. However, this could be difficult if the border plant has different growing and management requirements from the alfalfa, or if it is an attractive plant to pollinators, which would discourage the alfalfa pollinators from

pollinating the alfalfa, and could encourage distant bees to forage there, increasing long-distance pollen flow. Seeds produced by a non-alfalfa plant could also contaminate the purity of the alfalfa seed crop (Amand et al., 2000; Rogan and Fitzpatrick, 2004).

- *Competition for resources*—Volunteer alfalfa plants must establish themselves and compete for nutrients against adult plants.

Given proper adherence to FGI Best Practices and Monsanto's MTA, the risk of cross-fertilization is well below FGI's goal of less than 0.5 percent (unintended or unplanned presence of GT alfalfa).

Factors Increasing Probability of Gene Flow

Certain factors have the potential to increase gene flow between alfalfa crops, as has been discussed in the technical report, *Glyphosate-Tolerant Alfalfa Presence in Human Food and Animal Feed* (appendix Q). If GT alfalfa is deregulated, there would be no restrictions or permits required to grow GT alfalfa. Factors that may increase gene flow between alfalfa populations include, but are not limited to the following:

- *Feral alfalfa creates gene flow corridors*—If feral alfalfa grows between fields of GT alfalfa and non-GT alfalfa, then it could provide a corridor for gene flow, or a strip of growth that can serve as a reservoir for the GT gene, between these fields. It could act as a stepping stone for pollinators that would be more likely to travel between flowers that are closer together than between distant fields.
- *Pest management strategy*—Some farmers use a pest management strategy which allows for a strip of uncut alfalfa during hay harvest. This alfalfa strip can act as a reserve for insect predators. If these alfalfa strips are not harvested at the same time as the rest of the field, they would have the chance to flower, receive pollinators, and set seed. If the strip was GT alfalfa, this would result in a low risk of pollinators mediating the distribution of the GT trait, potentially including feral populations if they occur nearby (Mueller, 2005).
- *Seed field proximity can increase gene flow between the fields*—The seed fields are generally found in a compact geographic area, and with pollinators that have the potential to forage over miles (honey bees, for instance), this creates the potential for cross-pollination in non-GT alfalfa seed fields (Hubbard, 2008).
- *Presence of volunteer alfalfa*—As with any agricultural crop, there is the possibility of volunteer alfalfa growing in the field during other crop rotations. If these volunteer plants were GT, normal glyphosate-based herbicide routines would not eradicate them, creating a possibility that the volunteer plants would flower, set seed, and be a source of pollen for gene flow (Altieri, 2000). Also, alfalfa produces “hard seeds”, which have hard coatings that prevent moisture from

germinating the seed. It is possible that these seeds can remain dormant through growing seasons and germinate at a later time, creating the possibility of adventitious presence even after alfalfa is no longer produced in a field (Hubbard, 2008).

- Movement of honey bees from crop to crop could increase the chance of transferring pollen from one field to another.
- If farmers release too many bees to pollinate one alfalfa seed field, this can lead to unintended and wide dispersal of the bees. This is because bees respond to the competition at one field, and if there are too many in one field, they will forage to find nectar and pollen or to establish nests at alternate sites where there is less competition. This might happen before they visit any flowers of the target field, or they might visit the target field before traveling, increasing the potential of gene flow from the target field (which may be GT alfalfa) to other fields (possibly non-GT alfalfa) (Bosch and Kemp, 2005).

If alfalfa farmers take these factors into consideration and employ measures to counter these factors, such measures should also help alfalfa farmers effectively reduce or prevent gene flow between neighboring alfalfa crops. Combined with the measures discussed above that can be employed to decrease the probability of gene flow between alfalfa fields and crops, we do not believe that the potential for flow of genes and traits between alfalfa populations in the United States should amount to a significant impact on the human environment.

5. Weediness and Increased Glyphosate Resistance

Weed management is an important aspect of alfalfa production. Some of the negative effects of weeds include the following (Canevari et al., 2007; Canevari et al., 2006; Van Deynze et al., 2004; Loux et al., 2007; Miller et al., 2006; Orloff et al., 1997):

- competition with weeds can reduce yield and cause thinning in the stand;
- weeds can lower the nutritional quality of alfalfa hay because many weeds are lower in protein (50 percent less protein than alfalfa) and higher in fiber compared to alfalfa;
- poisonous weeds containing toxic alkaloids (a type of chemical) can make alfalfa hay unmarketable (e.g., common groundsel, fiddleneck, yellow starthistle, and poison hemlock);
- under some conditions weeds can accumulate toxic nitrate concentrations (e.g., lambsquarters, kochia, and pigweed);
- some weeds with a spiny texture can cause mouth and throat ulcerations in livestock (e.g., foxtail, wild barley, cheatgrass, and bristlegrass);
- weeds that are unpalatable to livestock result in less feeding and, therefore, less productivity (of either beef or milk);

- some weeds can contribute to off flavors in milk (e.g., wild celery, Mexican tea, creeping swinegrass, and mustards); and
- weeds that contain higher moisture content than alfalfa (e.g., dandelion) can cause bale problems such as mold, off-color hay, and high bale temperatures, which are a fire hazard.

Without weeds, alfalfa can grow at a density of about 12 plants per square foot. Heavily weed-infested stands can have less than one alfalfa plant per square foot (Canevari et al., 2007). In California, if weeds are not effectively controlled, they can represent up to 76 percent of the first cutting yields (Gianessi et al., 2002).

Farmers are very interested in effective weed control, and GT alfalfa allows the use of glyphosate to eradicate weeds without damaging the crop. However, although relying on glyphosate alone as the only weed removal herbicide may influence the number of weed species that may become glyphosate-resistant (weeds that inherit the ability to survive and reproduce following glyphosate applications that are normally lethal) (Puricelli and Tuesca, 2005; Stoltenberg and Jeschke, n.d.), it is not the only factor involved in the evolution of glyphosate resistance in weeds.

A number of genetic, biological/ecological, and operational factors are involved in determining if a weed species will evolve a resistance to any herbicide (Georghiou and Taylor, 1986; Neve, 2008). Genetic factors include the frequency of genes in a weed species that promotes resistance to a particular herbicide, the ability and rate of changes to genes to cause resistance, the way genes for resistance are passed down to offspring, and the fitness of the plant (and these genes) in the presence and absence of a herbicide. Biological and ecological factors include how the weed species reproduces (selfing or outcrossing), seed production capacity, seed bank turnover, and amount of gene flow within and between populations (Maxwell and Mortimer, 1994; Jasieniuk et al., 1996; Neve, 2008). The genetic factors and biological/ecological factors involved highlight that different species may present different risks of resistance, depending of the genetics of the weed and the biology of the plant. Operational factors involved in the evolution of weed resistance include the type of chemistry and how the herbicide kills plants, frequency the herbicide is applied, and dose and pattern of herbicide application. For many of the genetic, biological/ecological, and operational factors that influence the evolution of herbicide resistance in weeds, accurate measurements are difficult, or impossible, to obtain experimentally (Jasieniuk et al., 1996).

Modeling has been used, but because of the difficulty in obtaining accurate information on the factors indicated above, the use is limited (Jasieniuk et al., 1996). Neve (2008) has used simulation modeling to examine the evolution of glyphosate resistance in weeds. Of the many

assumptions in the model, an important one is that the model only accounts for the evolution of glyphosate resistance in weeds in an annual crop, like herbicide-tolerant corn, where the weeds are only removed when the crop is harvested at the end of the growing season. Alfalfa, on the other hand, is a perennial crop, and when produced as forage, is regularly harvested by mowing during the growing season. Harvesting forage alfalfa has the added benefit of also mowing weeds, which may not have had time to produce flowers, pollen or even seed. Thus, although the genetic factors of a weed species growing in a corn and alfalfa field would likely be the same, the biological and ecological factors may be quite different because of potential reduction in reproductive capability, seed bank formation, and the amount of gene flow within and between the weed species in the alfalfa field compared to the corn field. Neve (2008) modeled the influence of seed bank turnover and seed production characteristics in a continuous glyphosate resistant crop rotation over a 10-year period. At year 10 in the simulation, lower seed bank turnover and low seed production capacity, which may be comparable to the environment in a GT alfalfa forage system, can drastically reduce or even eliminate the probability of weeds becoming glyphosate resistant.

Operational factors also play an essential role in determining the risk of glyphosate use resulting in the evolution of glyphosate-resistant weeds. Neve (2008) found that in year 3 of the simulation, in an annual, glyphosate resistant crop that used five applications of glyphosate at different points during the growing season (before crop seeding, at crop seeding, at pre-emergence of weed, and two post-weed emergence applications), there was a 100 percent probability that a weed species would evolve resistance to glyphosate. In contrast, for GT alfalfa forage production, glyphosate is applied, at most, 4 times a year. In fact, the comments submitted in January and February 2008 to the Notice of Intent for this EIS indicate that no more than two applications of glyphosate are used on GT alfalfa for forage. Furthermore, the application rate for GT alfalfa (1.55 pounds of glyphosate a.e. per acre) is reduced by half compared to the full field application (3.85 pounds of glyphosate a.e. per acre) in other GT crops. Thus, the operational factors for GT alfalfa forage production may decrease the probability of weeds evolving resistance to glyphosate.

Currently, there is no concrete data, information, or models that provide a prescriptive determination on if or how many weed species may evolve resistance to glyphosate, or how many years it may take for a single weed species to evolve resistance, or which management strategy will completely prevent the evolution of weed resistance to glyphosate, or which management strategy will result in all weed species evolving resistance to glyphosate. APHIS is not aware of any models that simulate

the evolution of weeds resistant to glyphosate in a GT alfalfa production system.

There is potential for an overall decrease in total herbicide use due to increases in glyphosate use (see *Glyphosate and Herbicide Use and Comparative Toxicity*, below, and *Potential Impacts to Wildlife, Amphibians, Plants, and Ecosystems from Increased Glyphosate and Other Chemical Usage*, appendix N). However, if there is an increase in glyphosate-resistant weeds due to the adoption of GT alfalfa, there could be a corresponding increase in the amount of other herbicides used for stand removal for non-GT alfalfa.

Weediness Potential of Alfalfa

Under the preferred alternative, GT alfalfa with the inserted CP4 EPSPS gene can be introduced in cropping systems just like cultivated alfalfa. APHIS has previously reviewed information submitted to the agency by Monsanto and FGI on the weediness characteristics of GT alfalfa and have determined that the transformation process and insertion of the CP4 EPSPS gene in GT alfalfa events J101 and J163 have not altered the weediness potential of alfalfa (USDA-APHIS, 2009). Although volunteer crops can become problem weeds in some settings, Rogan and Fitzpatrick (2004) conclude that GT alfalfa will not be any more of a problem weed in a non-agricultural setting than non-GT alfalfa.

Information submitted relating to the use of glyphosate for control of feral alfalfa indicates that feral alfalfa is rarely controlled with herbicide and if controlled, glyphosate is not the herbicide of choice for control. Thus, the GT trait does not provide a competitive advantage to feral alfalfa, and other herbicides are available to control alfalfa that may be tolerant to glyphosate (Rogan and Fitzpatrick, 2004).

Less than 100 percent alfalfa stand termination can result in volunteer alfalfa plants in the following crop. Therefore, good stand termination procedures would still be a good method of eliminating volunteer GT alfalfa plants. Non-glyphosate herbicides and tillage are recommended for effective GT alfalfa stand removal (Orloff et al., 1997).

Monsanto's guidance for GT alfalfa stand removal is summarized in the technical report, *Effects of Glyphosate-Resistant Weeds in Agricultural Systems* (text box 3.1 in appendix G). Based on the available information on this subject, alfalfa is not an important weed in the United States, but care should be taken with other GT crops that may be chosen to follow GT alfalfa in a crop rotation.

Use of GT Alfalfa for Weed Management

The following discussion of GT alfalfa and weed management was based largely on the technical report, *Effects of Glyphosate-Resistant Weeds in Agricultural Systems* (appendix G).

GT alfalfa can be used by farmers for weed management in alfalfa crops. Its unique characteristics allow for effective weed control throughout the growing season of an alfalfa crop, and compared to other GT crops that are commercially available, alfalfa and alfalfa farming practices have characteristics that will aid in the suppression of the development of glyphosate-resistant weeds. Alfalfa's perennial nature, autotoxicity, and nitrogen fixing ability are different from other GT crops, and reduce the likelihood of glyphosate-resistant weed development. Crop rotations with plants that can follow alfalfa, such as annuals (plants that sprout and die each year, and do not regrow from the same seed the next year) or plants that need high amounts of nitrogen in the soil and regular mowing to remove weedy plant mass also help to minimize glyphosate-resistant weeds. These factors are explained below.

Alfalfa produced for forage purposes (e.g., hay and silage in either GE, conventional or organic production systems) is mowed regularly at a recommended cutting height of 3 inches. This removes all plant material higher than 3 inches, including weeds (Orloff et al., 1997), which may not have had time to produce flowers, pollen or even seed. This regular removal of all plant mass above 3 inches of the soil surface, including all weed material, greatly suppresses or eliminates seed production in weed species, and is especially effective in controlling annual weeds.

In a GT alfalfa farming system for forage, the combination of broad spectrum weed control from glyphosate (which should lead to more vigorous alfalfa competition), and regular mowing, which reduces the likelihood that any glyphosate-resistant weeds in the GT alfalfa field have had time to produce pollen or set seed, greatly decreases the probability of the development of glyphosate-resistant weeds. In seed production, mowing only occurs once, as one crop is removed each year; thus, there is a potential for greater weed seed production compared to alfalfa forage production. However, in order to maximize yield for a seed crop, alfalfa seed production currently receives significantly higher herbicide inputs to reduce weed cover than in alfalfa forage production. The additional herbicides with other modes of action may also work to reduce weed seed production and minimize glyphosate-resistant weeds in the seedbank of GT alfalfa grown for seed.

The ability for alfalfa to fix nitrogen encourages the decision to follow alfalfa in the rotation with a crop that requires additional nitrogen, such as

the annual grasses of corn and various cereal crops. These subsequently rotated crops can tolerate a spectrum of herbicides substantially different from the herbicides used in alfalfa. This encourages rotation of crops and herbicides, both of which are highly recommended for reducing the probability of developing herbicide resistant weeds.

All other commercially available GT crops are annuals. As discussed above, simulated modeling indicates that the biological/ecological factors and the operational factors for annual GT crops, point to the potential for faster evolution of glyphosate resistance in annual weeds compared to GT alfalfa. Likewise, perennial conventional alfalfa produced for several years in the same location could favor an increase in perennial weeds if the weeds have the ability to survive repeated mowing; however, no experimental data or modeling specific to GT alfalfa is available to substantiate this prediction.

The use of GT alfalfa for weed control and management may not be appropriate in the following situations (Dillehay and Curran, 2006):

- alfalfa-grass mixtures and alfalfa seeded with companion/nursery crops;
- fields that have a history of low weed populations; and
- fields that are rotated between alfalfa and other GT crop varieties (e.g., Roundup Ready® soybeans).

Van Deynze et al. (2004) reported that in field trials when Roundup® (a glyphosate-based herbicide) was applied during alfalfa stand establishment at the 3 to 4 leaf stage, weeds were controlled and usually no second application was needed. Early applications allowed for late germination of weeds while later applications allowed weeds to compete with alfalfa. If glyphosate is sprayed early enough, alfalfa plants containing the GT trait will fill in gaps left by dead weeds and non-GT alfalfa that was killed (Van Deynze et al., 2004).

Nineteen states have records of glyphosate-resistant weeds (Heap et al., 2008), and all of these states produce alfalfa. The likelihood that glyphosate-resistant weeds will appear in a GT alfalfa field increases with both the number of sites of glyphosate-resistant weeds in a state (Heap et al., 2008) and the acreage planted to alfalfa in a state (USDA-NASS, 2009). The greatest potential for overlap between glyphosate-resistant weeds and GT alfalfa fields occurs in the states of Kansas, Ohio, Illinois, and Missouri. These four states have more than 100 sites of glyphosate-resistant weeds, and each state has over 200,000 acres planted to alfalfa. Although California also has more than 200,000 acres of alfalfa, it has a slightly lower likelihood of overlap between glyphosate-resistant weeds and GT alfalfa because there are less than 70 sites with glyphosate-

resistant weeds. Similarly, Indiana, Michigan, Minnesota, Kentucky, Oregon, and Pennsylvania also have greater than 200,000 acres planted to alfalfa, but each State only has 10 or fewer sites of glyphosate-resistant weeds. The remaining States with records of glyphosate-resistant weeds (Arkansas, Delaware, Georgia, Maryland, Mississippi, New Jersey, North Carolina, and Tennessee) have from 10 to over 500 sites of glyphosate-resistant weeds; however, these States do not have large acreages devoted to alfalfa. Rotation between perennial and annual crops along with the application of glyphosate on the GT alfalfa, alfalfa's natural autotoxicity, and the farming practice of mowing (in forage production) or intensive management practices (in seed production) decreases the probability of a single weedy species surviving these major stresses to become a glyphosate-resistant weed.

Weed Shifts in GT Alfalfa and GT Alfalfa Weed Management Options

The limiting factor for weed control in non-GT conventional alfalfa is that by the time alfalfa reaches the stage of growth that is tolerant to herbicides, weeds are also beyond the stage when they are easily killed with herbicides (Gianessi et al., 2002). Adopting new weed control strategies eventually leads to shifts in composition and/or distribution of the weeds that are of greatest concern.

Weed shifts can occur in GT alfalfa due to tillage, irrigation, soil fertility, planting date, crop rotation, and herbicide use (Hilgenfeld et al., 2004). Changing production to a no-till system results in a more diverse seedbank. Within weedy species variations in characteristics such as seed dormancy, emergence patterns, growth plasticity (the variation in the growth of the plant), life cycle, life duration, shade tolerance, late-season competitive ability, seed dispersal mechanisms, and morphological (physical form) and physiological (biological functioning) variations, help weeds escape or tolerate weed management (Hilgenfeld et al., 2004).

Factors that influence weed shifts in GT agricultural production systems include:

- composition of the weed seedbank in the soil,
- glyphosate application, and
- rotation patterns in a site-dependent manner.

The studies described below exemplify how the above factors affect weed community shifts. If the weed seedbank is largely composed of dormant seed, weed shifts may not be apparent for years, depending on the weed species present. If glyphosate-resistant weeds already occur in an area with a GT crop, glyphosate applications will promote the appearance of more glyphosate-resistant weeds in a field, causing a shift toward a

glyphosate-resistant weed community. Crop rotation between GT and non-GT crops and the use of non-glyphosate herbicides can reduce the populations of glyphosate-tolerant weeds, thus alter weed shifts in GT crops.

- *Composition of weed seedbank and surrounding sources of weeds*—Weed seedbanks in the soil can contain large reservoirs of dormant weed seed; thus, short-term studies (a few years) might not detect the full potential shift in weed communities (Harker et al., 2005). However sometimes weeds shift can be observed within a few years. In a field trial in an established GT alfalfa stand in the Southwest (San Joaquin Valley) burning nettle was not controlled and the population of burning nettle increased significantly over the 3-year trial period (Canevari et al., 2004; Van Deynze et al., 2004). Tank mixtures with Velpar (hexazinone) or paraquat controlled burning nettle. Van Deynze et al. (2004) recommend that the best way to prevent weed shifts is to avoid using the same herbicide year after year, rotate herbicides and crops, and include non-herbicide strategies to control weeds. Weeds that are difficult to control with glyphosate, such as dodder and cheeseweed, may need to be treated early and may require a second application. Smother crops should be planted before alfalfa to suppress weeds. For example, sorghum-sudangrass hybrid or foxtail millet both suppressed weeds and enhanced subsequent alfalfa establishment (Forney et al., 1985).
- *Glyphosate application*—Puricelli and Tuesca (2005) found that continuous glyphosate application in field studies on three crop rotation sequences and two tillage systems lead to quantitative and qualitative changes in weed communities. They found that glyphosate application was a more important factor than crop sequence to explain weed community changes in summer crops. They also predicted that continual glyphosate application for longer than the 5 years in their study might lead to the development or higher increases in abundance of weeds resistant to glyphosate. Weed species diversity in conventional versus no-tillage plots did not differ significantly.
- *Rotation patterns in a site-dependent manner*—Harker et al. (2005) reported that field studies of spring wheat-canola-spring wheat rotations of various combinations of GT and non-GT varieties under conventional tillage or low soil disturbance direct seeding systems indicate that weed community shifts are dependent on rotation pattern in a site-dependent manner. In the western Canada field locations, within 3 years, crop systems without GT varieties were associated with green foxtail, redroot pigweed, sowthistle spp., wild buckwheat, and wild oat. The specific weeds associated with all GT variety systems included Canada thistle at the Brandon site, henbit at the Lacombe site, and volunteer wheat, volunteer canola, and round-leaved mallow at the Lethbridge site. There was high variability in wild buckwheat

between the systems. Glyphosate is not very effective on wild buckwheat, so the authors proposed that wild buckwheat seed production or viability may be restricted by glyphosate more than the wild buckwheat biomass. Therefore, after glyphosate application the plant may appear visually robust, but its ability to reproduce has been effected, so in following years less wild buckwheat is observed (Harker et al., 2005).

It is plausible that the 18 weed species that are both resistant to glyphosate and traditionally present problems in alfalfa (see chapter 3) likely pose the greatest threat for weed shifts in a GT alfalfa crop system. These 18 species may be the first candidates for weed shifts in GT alfalfa. However, as discussed in the studies summarized above, weed shifts are dependent on the composition of the weed seedbank in the soil, surrounding sources of weeds, glyphosate application and site specific rotation patterns. All 18 of these weed species are able to grow as naturalized populations in the United States (<http://plants.usda.gov/index.html>). For maps of the current naturalized populations for these species refer to the technical report, *Effects of Glyphosate-Resistant Weeds in Non-Agricultural Ecosystems* (appendix H).

Chapter 3 summarized the current distribution for glyphosate-resistant weeds in crops. In areas where these resistant biotypes are already present in the seedbank there is a greater potential for increase of those weeds if glyphosate is used. For weed species where glyphosate-resistant biotypes have not been identified in the United States (e.g., buckhorn plantain, goosegrass, junglerice, sourgrass, and wild poinsettia) there are presumably no glyphosate-resistant biotype seedbanks in U.S. soil. Resistant biotypes of these weeds could spread to the United States either through inadvertent transportation or local evolution of resistance.

No Action Alternative

Under the no action alternative, gene flow due to pollen transfer and pollination would be no different than the current situation. The approximately 200,000 acres of GT alfalfa already planted would continue to be harvested and there would be no increase in the cultivation of GT alfalfa. New plantings of GT alfalfa would be considered “regulated” environmental releases and would require a permit. There would be no change in the natural occurrence of gene flow between alfalfa populations. Once the current GT alfalfa stands are removed, likely after a 3- to 4-year period, the GT trait is not likely to be imparted to secondary seedlings, seed fields, hay fields and feral or other alfalfa populations because regulated environmental releases have permit conditions to minimize

pollen movement from the site of the environmental release. Seed purity would not be affected under the no action alternative.

Also under the no action alternative, the weediness potential of alfalfa would remain the same because GT alfalfa and non-GT alfalfa are similar in terms of growth and reproduction, independent of whether GT alfalfa is granted nonregulated status. Once the GT alfalfa standards are removed, there would not be higher quality hay with lower weed populations and lower crop injuries. In those acres that currently produce GT alfalfa, genetic, biological/ecological and operational factors suggest that the use of glyphosate in GT alfalfa would not select glyphosate-resistant weeds as strongly as in other GT annual crops. However, experimental data does not exist to empirically document that glyphosate used in GT alfalfa does not result in an increase in glyphosate-resistant weeds in GT alfalfa fields. Genetic, biological/ecological and operational factors also suggest that glyphosate use in the GT alfalfa that is currently grown would alter weed shifts differently than in GT annual crops. However, experimental data does not exist to empirically document glyphosate use in GT alfalfa would alter weed shifts differently than in GT annual crops. In non-GT alfalfa fields, glyphosate would continue to be used as a stand takeout herbicide, but is not likely to change the appearance of glyphosate-resistant weeds or alter weed shifts in non-GT alfalfa fields. However, experimental data does not exist to empirically document that glyphosate use in non-GT alfalfa would not likely to change the appearance of glyphosate-resistant weeds or alter weed shifts in non-GT alfalfa fields. The no action alternative is not likely change the potential appearance of glyphosate-resistant weeds and/or weed shifts in GT alfalfa or non-GT alfalfa.

C. Biological Impacts

APHIS assessed the potential impacts, if any, of Threatened and Endangered species (T&E) exposed to the gene product of GT alfalfa, and/or an increase in glyphosate-based herbicide application expected in GT alfalfa systems (technical report, *Potential Impacts to Wildlife, Amphibians, Plants, and Ecosystems from Increased Glyphosate and Other Chemical Usage* (appendix N)).

Preferred Alternative

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|---|---|
| 1. Impacts to T&E Species from GT alfalfa J101 and J163 Gene Product | The full deregulation of GT alfalfa is expected to result in an increase in the prevalence of GT alfalfa events J101 and J163 from the current exposure due to 200,000 acres of GT alfalfa already in production, and an associated increase in the likelihood of exposure of threatened and endangered species to their gene product. APHIS analyzed the potential impacts of GT alfalfa events J101 and J163 on T&E species. Direct effects were evaluated to determine whether an impact was expected on |
|---|---|

any listed or proposed T&E species or any designated critical habitat from directly contacting, consuming, or hybridizing with GT alfalfa events J101 and J163 and/or its progeny

(http://ecos.fws.gov/tess_public/pub/listedAnimals.jsp;

http://ecos.fws.gov/tess_public/pub/listedPlants.jsp;

<http://crithab.fws.gov/>; all accessed January 2009).

- GT alfalfa events J101 and J163 are not expected to become more invasive in natural environments or have any different effect on critical habitat (designated by the Endangered Species Act) than their parental non-GT line in the absence of glyphosate selection. This conclusion is based on results of more than 150 field trials conducted over a 5-year period in 33 different states (Rogan and Fitzpatrick, 2004). The data show GT alfalfa events J101 and J163 are essentially equivalent to non-GT variations in form and shape, such as growth habit, vegetative growth, and flower and pollen morphology (USDA-APHIS, 2009). Several agronomic traits were evaluated and no biological differences between GT and non-GT alfalfa were noted for traits that may influence weediness, including seed dormancy, seed germination, seedling emergence, seedling vigor, winter survival, spring vigor, seed yield, vegetative growth, plant dormancy, survival, and relationship with symbiotic organisms (USDA-APHIS, 2009).
- Analysis of forage samples from several locations demonstrates that it is compositionally and nutritionally equivalent to other alfalfa varieties currently on the market except for the expression of the transgene protein, and therefore is not expected to have nutritional effects on any T&E species that feeds upon it (technical reports, *Presence of Glyphosate-Tolerant Alfalfa in Human Food and Animal Feed* (appendix Q), and *Character and Quality of Glyphosate-Tolerant Alfalfa Traits* (appendix U), (FDA, 2004) [appendix P], (Rogan and Fitzpatrick, 2004).
- The transgene protein does not have toxic or pathogenic effects that would affect T&E species or their critical habitat. The EPSPS protein from plants and from the CP4 *Agrobacterium* strain are not known for pathogenic or toxic effects on human, animal, or plants based on numerous laboratory and field studies with these purified proteins or plants expressing these proteins (technical reports, *Presence of Glyphosate-Tolerant Alfalfa in Human Food and Animal Feed* (appendix Q), and *Character and Quality of Glyphosate-Tolerant Alfalfa Traits* (appendix U), (FDA, 2004) [appendix P], (Rogan and Fitzpatrick, 2004). Nor do the proteins dispose plants to become more susceptible to disease (USDA APHIS, 2009). The same CP4 EPSPS enzyme is expressed in numerous glyphosate-tolerant crops already grown on millions of acres across the United States.
- GT alfalfa events J101 and J163 are not expected to form hybrids with any State or federally listed threatened or endangered species of plants

or plant species proposed for federal listing (technical report, *The Potential for Gene Flow from Glyphosate-Tolerant Alfalfa (Medicago sativa L.) to Related Species* (appendix I)).

After reviewing possible effects of granting nonregulated status in whole to GT alfalfa events J101 and J163, APHIS has not identified any stressor that could affect the reproduction, numbers, or distribution of a listed T&E or species proposed for listing. Consequently, an exposure analysis for individual species is not necessary. APHIS has considered the effect of production of GT alfalfa on designated critical habitat or habitat proposed for designation and could identify no difference from impacts that would occur from the production of other alfalfa varieties (non-GT varieties or organic varieties). APHIS has reached a conclusion that the release of GT alfalfa plants J101 and J163 or their progeny, following a determination of nonregulated status, would have no effect on federally listed threatened or endangered species or species proposed for listing, nor is it expected to adversely modify designated critical habitat or habitat proposed for designation, compared to current agricultural practices. Consequently, a written concurrence or formal consultation with the United States Fish and Wildlife Service or the National Marine Fisheries Service is not required.

No Action Alternative

Under the no action alternative, there would be no change in the likely exposure of T&E plants and animals to GT alfalfa events J101 and J163. Exposure due to the approximately 200,000 acres currently planted to GT alfalfa would remain the same. After the GT alfalfa stands were removed (likely after 3 to 4 years), exposure to GT alfalfa would be limited to those permitted GT alfalfa environmental releases. No change in effects, compared to any current effects due to non-GT alfalfa, would be expected on T&E species or critical habitat under the no action alternative.

Preferred Alternative

2. Impacts to T&E Species from Herbicide Application

Under the preferred alternative, GT alfalfa is expected to result in a potential increase in the use of glyphosate-based herbicide formulations and the reduction/elimination of other, more environmentally toxic herbicides. APHIS received 16 comments from GT alfalfa farmers during the public comment period for the Notice of Intent in January and February 2008 that provided quantitative details on their farming practices. These GT alfalfa farmers account for approximately 24,415 acres of the 200,000 acres currently planted to GT alfalfa (12.2 percent), and apply either 1 or 2 applications of glyphosate on their GT alfalfa crop, instead of using glyphosate during stand take-out. If these applications are ground applications, the total pounds of glyphosate (a.e.) applied to these 24,415 acres of GT alfalfa is between 37,843 (1 application) and

75,687 (2 applications) pounds. According to the growers of GT alfalfa, the amount of glyphosate applied to GT alfalfa is concurrent with the elimination of between 2 and 4 applications of other herbicides used during the production of non-GT alfalfa, including Arrow, Firestorm, diuron, Velpar, Raptor, Pursuit, Poast, Treflan (all with greater environmental impact quotients compared to glyphosate (see table 5.2.1 in technical report, *Potential Impacts to Wildlife, Amphibians, Plants, and Ecosystems, from Increased Glyphosate and Other Chemical Usage* (appendix N)).

Under the preferred alternative, instead of experiencing glyphosate exposure only during stand take-out, T&E animal and plant species within and adjacent to GT alfalfa fields could be exposed to glyphosate up to twice a year via aerial drift and surface water runoff. T&E animal and plant species within and adjacent to GT forage alfalfa fields may be protected by the elimination of up to four exposures to other, more environmentally harmful herbicides, as discussed in chapter 3 and the technical report, *Potential Impacts to Wildlife, Amphibians, Plants, and Ecosystems from Increased Glyphosate and Other Chemical Usage* (appendix N).

APHIS has no authority under the Plant Protection Act to regulate herbicide use associated with GT plants that are granted nonregulated status. The use and application rate of glyphosate is regulated by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) restrictions administered by the EPA, which mandate registration and use of all pesticides. EPA includes instructions and restrictions on how glyphosate herbicides can be applied, and has determined that there is no unreasonable environmental risk if the user adheres to the labeled directions. Directions include application restrictions that minimize impacts on nearby environments. Individuals applying pesticides must do so in a manner not only consistent with federal laws, but also consistent with state laws and regulations which differ from State to State. In general, States have primary authority for compliance monitoring and enforcing against use of pesticides in violation of the labeling requirements. Violators of the regulations are liable for all negative consequences of their actions, therefore, farmers who use glyphosate are very likely to follow its label restrictions, and adverse impacts from the predicted increased glyphosate use can be expected to be minimized. The information in this section is provided to inform the public of the risks associated with glyphosate use. Glyphosate is currently undergoing the reregistration process with EPA.

In 2008, Monsanto Company released a report entitled, “Overview of the Analysis of Possible Risk to Threatened and Endangered Species Associated with Use of Glyphosate-Containing Herbicides in Alfalfa

Production” (Honegger et al., 2008). The report included a risk assessment conducted to analyze the risk of direct effects of glyphosate and Roundup® agricultural herbicides to threatened and endangered animal and plant species. This assessment follows in large measure EPA’s overview document on endangered species effects determinations (EPA, 2004) and EPA’s Environmental Fate and Effects Risk Assessment for the new uses of glyphosate on bentgrass (Termes and Reider, 2006; EPA, 2006), from which the majority of the environmental fate input parameters and toxicity endpoints were taken to determine Risk Quotient (RQ) values. Based on the risk assessment, the report made the following conclusions, which are supported by an independent APHIS review (technical report, *Potential Impacts to Wildlife, Amphibians, Plants and Ecosystems from Increased Glyphosate and Other Chemical Use* [appendix N]):

- Terrestrial and aquatic T&E animals are expected to be at low risk of direct effects from exposure to glyphosate used in agriculture.
- T&E aquatic plants are expected to be at low risk of direct effects from exposure to glyphosate used in agriculture.
- Terrestrial and semi-aquatic T&E plants are expected to be at low risk of direct effects from exposure to glyphosate used in agriculture at ground application rates less than 3.5 lb pounds acid equivalent per acre (a.e./A).
- Terrestrial and semi-aquatic T&E plants may be at risk of direct effects from exposure to glyphosate used in agriculture at ground application rates greater than or equal to 3.5 lb a.e./A and aerial application rates greater than or equal to 0.7 lb a.e./A.

Because T&E plant species may be at risk from certain application rates of glyphosate in alfalfa production, a more detailed evaluation of the locations of T&E plant species relative to areas of alfalfa production was undertaken. Priester et al. (2007, 2008) determined the co-occurrence of T&E plant species and alfalfa production at the county level and assessed the proximity of land areas where alfalfa could be grown (relevant land use) to sub-county locations of T&E plant species that had been identified as “requiring further analysis” in the county-level analysis. The sub-county species location data for the plant species identified in the county-level analysis were obtained from the FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act) Endangered Species Task Force MJD (Multi-Jurisdictional Database) or from state data sources, where necessary. Geographic information system (GIS) tools were used to compare the locations of the relevant land use with the species locations to assess whether the species had overlap with or was within 250 feet of the relevant land use (Priester et al., 2007; Priester et al., 2008).

The analysis determined that there are counties in 31 States where listed plant species may be in proximity to relevant land use—land that has been

used historically, or is suitable for future for alfalfa production. There are 78 plant species that have been observed to be proximate to relevant land use (Honegger et al., 2008).

Under the preferred alternative, there is the possibility that some of these relevant lands will be cultivated with GT alfalfa. If so, individual plants of 78 T&E plant species are at risk for adverse impacts such as the inability to photosynthesize, the inability to complete respiration, the inability to synthesize nucleic acids and amino acids, and plant death if the individuals in these species are exposed to glyphosate, and the rate of application is equal or exceeds 3.5 pounds glyphosate a.e. per acre or aerial application rates are equal to or exceed 0.7 lb a.e./A (rates that are regulated by EPA pursuant to FIFRA). Ground applications of glyphosate on GT alfalfa are lower (1.55 pounds glyphosate a.e. per acre) than the application rate where plant death may occur (3.5 pounds glyphosate a.e. per acre). Thus, negative impacts on T&E plants due to glyphosate use on GT alfalfa are not likely to occur during ground applications, but negative impacts may occur in situation of aerial applications, which may be applied at a rate of 1.55 pounds glyphosate a.e. per acre and have a higher probability of drifting into neighboring fields. However, the risk due to aerial application is relatively low. Only 2 percent of glyphosate is applied aerially to all agricultural crops in the United States (EPA, 2009). Given that aerial application in GT alfalfa is not expected to be any different than other agricultural production systems, approximately 2 percent of glyphosate used in GT alfalfa is expected to be applied aerially. Further modeling analyzed the use of buffer zones between the GT alfalfa field and potential distributions of T&E plant populations and found that 250 foot buffer negates any negative impacts on T&E plant species due to drift of glyphosate from aerial applications. Therefore, the impacts to T&E plants due to glyphosate use on GT alfalfa could be mitigated by following label use restrictions that maintain application rates below critical levels in the counties where listed species would be within 250 feet of GT alfalfa fields. APHIS, however, does not have the regulatory authority to mandate label use restrictions for glyphosate used on GT alfalfa fields.

No Action Alternative

Under the no action alternative, GT alfalfa would continue to be a regulated article and there would not be an increase in the cultivation of GT alfalfa from the approximately 200,000 acres currently planted. The current use of glyphosate on GT alfalfa is not likely to significantly impact T&E animal species. If the current GT alfalfa fields were managed using ground applications of glyphosate, there would likely be no consequential impacts to T&E plant species from the use of glyphosate herbicides associated with GT alfalfa production under the no action alternative. Any

impacts on T&E species associated with the use of glyphosate on conventional alfalfa fields, and the impacts of T&E species associated with the use of any other herbicide used on conventional alfalfa fields would still occur. Moreover, as explained above in reference to the preferred alternative, use of glyphosate on GT alfalfa fields may eliminate up to four exposures to other, more environmentally harmful herbicides, as discussed in chapter 3 and the technical report, *Potential Impacts to Wildlife, Amphibians, Plants, and Ecosystems from Increased Glyphosate and Other Chemical Usage* (appendix N).

3. Glyphosate and Other Herbicide Use and Comparative Toxicity

Several analyses of pesticide use concluded that herbicide use has been reduced due to the adoption of herbicide-tolerant crops (Brimner et al., 2005; Fernandez-Cornejo, 2006; Gianessi and Reigner, 2006; Kleter et al., 2007; Sankula, 2006; Johnson et al., 2008). One analysis of pesticide use concluded that herbicide application has increased due to herbicide-tolerant crops (Benbrook, 2004). Despite disagreement regarding the overall quantity of herbicide application, all the studies agreed that herbicide use has shifted towards glyphosate. Using standardized methods for ranking environmental impact, researchers have concluded that glyphosate is less harmful to the environment than many other herbicides and that the shift of herbicide use away from more toxic herbicides and to the use of glyphosate has resulted in a net lower environmental impact from herbicides (Kleter et al., 2007).

Weeds in conventional alfalfa cannot be managed completely with glyphosate and are instead controlled using a cocktail of other herbicides (based on OMAFRA, 2008; Canevari et al., 2007; Rogan and Fitzpatrick, 2004; Loux et al., 2007). The 20 other herbicides commonly used on alfalfa have varying chemical fates. In general, most were more persistent and were characterized by higher mobility in soils, making them more apt to continually contaminate surrounding water systems. Also, most have been found to exhibit a higher measured environmental impact quotient (EIQ) relative to glyphosate and have a greater general environmental impact (Kovach et al., 2007).

Preferred Alternative

The full deregulation of GT alfalfa would result in a shift in herbicide use towards glyphosate and away from other, more toxic herbicides used to control weeds in non-GT alfalfa systems under this alternative. There is contradictory evidence on the effect GT alfalfa would have on the overall quantity of herbicide application, although, according to certain studies, it is possible that the deregulation of GT alfalfa would lead to a decrease in the overall amount of herbicides applied (see discussion in chapter 3). For examples, as stated above, APHIS received 16 comments from GT alfalfa farmers during the public comment period for the Notice of Intent in

January and February 2008 that provided quantitative details on their farming practices. These GT alfalfa farmers account for approximately 24, 415 acres of the 200,000 acres currently planted to GT alfalfa (12.2 percent), and apply either 1 or 2 applications of glyphosate on their GT alfalfa crop, instead of using glyphosate once every 3 to 8 years during stand take-out. If these applications are ground applications, the total pounds of glyphosate (a.e.) applied to these 24, 415 acres of GT alfalfa is between 37, 843 (1 application) and 75, 687 (2 applications) pounds. According to the growers of GT alfalfa, the amount of glyphosate applied to GT alfalfa is concurrent with the elimination of between two and four applications of other herbicides used during the production of non-GT alfalfa, including Arrow, Firestorm, diuron, Velpar, Raptor, Pursuit, Poast, Treflan (all with greater environmental impact quotients compared to glyphosate (see table 5.2.1 in technical report, *Potential Impacts to Wildlife, Amphibians, Plants, and Ecosystems, from Increased Glyphosate and Other Chemical Usage* (appendix N)).

Based on the analyses that find glyphosate to be generally less harmful to the environment than the herbicides it replaces in GT alfalfa systems, this shift has the potential to result in lower general environmental impacts in areas where GT alfalfa replaces conventional alfalfa fields. Full deregulation of GT alfalfa would increase the use of other herbicides for stand removal of GT alfalfa. In conventional alfalfa fields, glyphosate is often used to remove alfalfa after 3 to 8 years when it has become vulnerable to weeds and thinning. For stand removal, adoption of GT would likely result in a shift from glyphosate to other herbicides due to the inability of glyphosate to remove stands of GT alfalfa.

No Action Alternative

Under the no action alternative, non-GT alfalfa would continue to be cultivated using conventional herbicide regimes, and glyphosate would continue to be used for stand take-out for non-GT alfalfa. There would not be a shift from other toxic herbicides to comparably less-toxic glyphosate to control weeds in alfalfa cultivation. Because of this, there would be more application of the combination of other herbicides, most of which have a higher measured EIQ. General environmental impacts due to herbicide application in alfalfa cultivation would likely be higher under the no action alternative than it would be under the preferred alternative. However, in order for benefits of the preferred alternative to be realized, GT alfalfa fields would have to replace conventional alfalfa fields. If the preferred alternative resulted in an increase in GT alfalfa cultivation without a corresponding decrease in conventional alfalfa cultivation, the no action alternative would not result in an increase in the net amount of harmful herbicides applied to alfalfa and would result in no effect to herbicide use.

4. Impacts on Plants

Most plant species, when exposed to glyphosate, experience high levels of toxicity. Higher plants that use the shikimate pathway to produce aromatic amino acids will experience toxic effects as they metabolize glyphosate (as discussed in the technical report, *Glyphosate-Tolerant Alfalfa Presence in Human Food and Animal Feed* [appendix Q]). These toxic effects could include the inability to photosynthesize, the inability to complete respiration, and the inability to synthesize nucleic acids and amino acids. Although the effects can be slow to progress, all of these toxic effects could result in plant death (USDA-FS, 2003; Giesy et al., 2000).

Preferred Alternative

The deregulation of GT alfalfa is expected to result in an increase in the use and application of glyphosate-based herbicide formulations (see chapter 3.B.2.). This would lead to an increase in the amount of incidental glyphosate exposure to terrestrial and aquatic plants in the vicinity of GT alfalfa fields either by spray drift, or transport in surface water runoff. However, it is also likely to result in a decrease in the amount of other, more toxic herbicides applied to control weeds in alfalfa fields, as they would be replaced by glyphosate. Because of the high toxicity of glyphosate to plants, as is the case for any herbicide used, deregulation of GT alfalfa could potentially result in adverse effect to plant species near GT alfalfa fields, if they are exposed through aerial drift or runoff of surface waters containing glyphosate. If aerial applications are minimized, this risk to non-target terrestrial plants would be reduced. Because glyphosate binds strongly to soil particles, conservation tillage and no tillage practices have the potential to mitigate impacts to aquatic plants through decreasing soil-laden runoff.

No Action Alternative

Under the no action alternative, the rates and volumes of glyphosate applications would remain unchanged in the context of application to alfalfa fields, resulting in a decrease compared to the action alternatives, except for the 200,000 acres currently under GT alfalfa production. In the cases that the no action alternative precluded conventional alfalfa fields from being converted to GT alfalfa, this would result in the continued use of an array of other herbicides which would be applied at greater volumes compared to glyphosate. The herbicides used in conventional alfalfa systems have been shown, in general, to be more environmentally harmful than glyphosate (Kovach et al., 1992). Therefore the no action alternative has the potential to restrict the replacement of these herbicides with a more environmentally benign alternative. However, the impact of this alternative on specific plant species is unknown as the herbicides used in

conventional alfalfa systems have different effects on different plant species. The herbicides currently used in conventional alfalfa production kill particular groups of plants such as annual grasses, perennial grasses, or broadleaf weed species. Glyphosate, on the other hand, is a single broad spectrum herbicide and is toxic to the vast majority of plant species.

Preferred Alternative

5. Impacts on Animals

The deregulation of GT alfalfa is expected to result in a potential increase in the use and application of glyphosate-based herbicide formulations as more GT alfalfa fields are established, conventional alfalfa fields are replaced with GT alfalfa fields, and fewer pounds of more toxic herbicides are applied in alfalfa fields. This would lead to an increase in the amount of glyphosate exposure to animal species within and adjacent to those fields via aerial drift and surface water runoff, as discussed in chapter 3, and a decrease in exposure to other herbicides.

In general, glyphosate has a low toxicity to animals; however, the end use herbicide formulations are more toxic to certain species. Based on the data available on glyphosate usage on GT alfalfa, chemical fate, and toxicity, and after a Tier 1 “high-end use case” scenario screening of hazard quotients, glyphosate application is not expected to pose a risk if GT alfalfa is granted nonregulated status (see the technical report, *Potential Impacts to Wildlife, Amphibians, Plants and Ecosystems from Increased Glyphosate and Other Chemical Use* [appendix N]). Glyphosate itself is slightly toxic to amphibians; however, amphibians exhibited greater sensitivity to Roundup® formulations than to glyphosate tested as an acid or isopropylamine (IPA) salt. This could be due to the surfactant (POEA) used in agricultural formulations, which has been found to be more toxic to amphibians and other aquatic animals than the herbicide itself (Lajmanovich et al., 2003). Some researchers have suggested that, in combination with POEA, Roundup® could cause extremely high rates of mortality to amphibians that could lead to eventual population declines (Relyea, 2005). However, the testing methods of the Relyea (2005) study have been called into question due to the high exposure doses, which exceed application rates of glyphosate (regulated by FIFRA), as well as the fact that this Roundup® product is not approved for use in an aquatic setting. Additionally, the impacts of the preferred alternative on amphibians are unlikely because Roundup® Weed and Grass Killer (the glyphosate formulation hypothesized to affect amphibians) is not approved for use on Roundup® Ready Alfalfa. Amphibians use a wide range of aquatic habitats for their breeding sites and could be exposed to glyphosate in surface water under full deregulation of GT alfalfa. This would most likely occur as a result of heavy rainfall after a recent application and subsequent dissipation into stream sediment (Lajmanovich et al., 2003).

Although this raises the possibility that the full deregulation of GT alfalfa would potentially have adverse impacts on amphibian populations in watersheds where GT alfalfa is cultivated, this conclusion cannot be made with certainty. There are no experimental studies investigating glyphosate application on amphibian populations to examine potential impacts. However, possible adverse impacts to amphibians resulting from the deregulation of GT alfalfa may be offset by the shift away from other herbicides in GT alfalfa systems which are known to have higher environmental impacts in general. Additionally, amphibian habitat in watersheds where GT alfalfa is produced could be improved under the preferred alternative due to the likelihood that GT alfalfa fields would not be tilled, resulting in decreased soil erosion, decreased sedimentation in runoff, and decreased turbidity in ponds, lakes, and rivers fed by surface waters. However, this benefit would only be realized if conservation tillage in GT alfalfa fields replaced fields that were tilled prior to their conversion.

No Action Alternative

Under the no action alternative, approximately 200,000 acres of GT alfalfa would remain in production, and new planting of GT alfalfa would be regulated. There would be no change in the prevalence of the current GT alfalfa fields in production or the associated use of glyphosate herbicides on in GT and non-GT alfalfa systems. Under no action alternative, the impacts to animals, including amphibians, from the exposure to glyphosate due to GT alfalfa or non-GT alfalfa would be the same. Any effects due to glyphosate use in conventional alfalfa settings, as well as other agricultural systems will still occur. No acute or chronic risk to birds, mammals, terrestrial invertebrates, aquatic invertebrates, or fish due to glyphosate use associated with GT alfalfa would be expected under this alternative; any effects due to glyphosate use in conventional alfalfa settings, as well as other agricultural systems, will still occur. It should be noted that in circumstances where GT alfalfa replaces conventional alfalfa, there is a shift away from more environmentally harmful herbicides towards glyphosate in order to control weeds. Glyphosate has a lower EIQ, and is considered more environmentally benign than the herbicides it replaces in alfalfa production (Kovach et al., 2007), so there is the potential for the no action alternative to result in adverse impacts to wildlife compared to the preferred alternative.

D. Socioeconomic Impacts on Domestic Non-GT Alfalfa Markets

Preferred Alternative

The discussion throughout this section is formed in the context of the preferred alternative. The discussions under each heading are not broken down into both a preferred alternative and a no action alternative discussion, but instead, the no action alternative impacts discussion comes at the end of this section. Unless explicitly defined, all of the following considerations can be assumed to be related to the preferred alternative.

1. Conventional Alfalfa Hay Farming

Evidence of farming distinctions between GT alfalfa and conventional alfalfa come mostly from field trials and from those farmers that planted GT alfalfa during the time period in which it was deregulated (between June 2005 and March 2007). During this period over 200,000 acres of GT alfalfa are estimated to have been planted (Putnam, 2007). Much of the latter type of evidence is anecdotal, and based on the observation of one or a few GT alfalfa fields.

Canevari (2007) presents a small (non-random) survey with 24 growers in addition to a few consultants, seed and marketing dealers, and university faculty which investigated the control of weeds with glyphosate in GT alfalfa. Users of GT alfalfa were generally satisfied with weed control in GT alfalfa. According to this paper, GT alfalfa would reduce the costs of herbicides used while improving the quality of alfalfa hay due to lesser weed content. Miller et al. (2006) refer to field trials done at the University of Wyoming and University of Nebraska and suggest the main features of GT alfalfa are its “ease of use, flexibility, and broad spectrum weed control.” Individual farmers that had experimented with GT alfalfa after initial deregulation and that sent comments to APHIS provide additional reports, including that of possible increase in yields (due to lesser stunting caused by use of other herbicides), eliminating the use of other, more toxic herbicides, and a reduction in herbicide costs.

Given the relevance of yield and quality of alfalfa hay for the determination of economic returns to alfalfa farmers, it is particularly important to understand the impact of GT alfalfa deregulation on these two aspects of alfalfa production. Alfalfa hay yield is influenced by a wide range of factors, including seed variety, proper planting and establishment, climate, soil and moisture conditions, and weed and insect control (Dixon et al., 2005). Hundreds of alfalfa varieties have been developed for use in North America, including a large number of GT alfalfa cultivars (cultivated plants selected because of its useful characteristics). These varieties are adapted to the various major alfalfa

production zones, and all contain genes selected for high yield and resistance to diseases, insects, and nematodes (Van Deynze et al., 2004).

There is no conclusive evidence on whether GT alfalfa presents higher or lower yields than non-GT alfalfa. As shown in table 4-4, variety trial results do not indicate any systematic hay yield advantage or disadvantage for GT alfalfa hay cultivars. Dr. Daniel Putnam, a leading alfalfa research agronomist at the University of California-Davis, has been conducting variety trial testing of GT and other alfalfa cultivars throughout California. Putnam (2008) notes that in general, the yield performance of GT alfalfa cultivars (as a group) are no different than what could be expected from similar conventional lines of equal fall dormancy characteristics. Moreover, he notes that there are differences between conventional varieties that are due to fall dormancy, and due to the superiority of individual cultivars within a dormancy group, but the range of variation observed in conventional cultivars is similar to the range of variation observed in GT cultivars (Putnam, 2008).

Table 4-4. Comparative Variety Trial Yield Results.

Variety Trial Location and Date	Average Annual Yield, All GT Alfalfa Varieties (Tons/Acre)	Average Annual Yield, All Varieties (Tons/Acre)
Illinois (Freeport), 2007 ¹	6.10	6.17
Iowa (Ames), 2007 ²	4.61	4.64
Kansas (Thomas Co.), 2007 ³	8.22	8.41
Nebraska (Havelock), 2006 ⁴	5.04	5.12
New York (Cobleskill), 2006 ⁵	2.6	2.9
South Dakota (Brookings Co), 2006 ⁶	3.81	3.86
Wisconsin (Lancaster), 2006 ⁷	4.77	4.07

¹ Source: <http://vt.cropsci.uiuc.edu/forage.html>

² Source: <http://www.croptesting.iastate.edu/alfalfa/results/2007-alfalfa.xls>

³ Source: <http://kscroptests.agron.ksu.edu/07/07alf/7a-thi6.asp?Loc=thi6>

⁴ Source: <http://varietytest.unl.edu/alfalfa/2006/Roundup-Havelock2006table06.xls>

⁵ Source:

<http://plbrgen.cals.cornell.edu/programsandprojects/departamental/foragetest/alfalfa06.htm>

⁶ Source: http://plantsci.sdstate.edu/forages/Alfalfa%20Trials/SD_Alalfa_Trials.html

⁷ Source: <http://www.uwex.edu/CES/crops/RRAlfalfa07.htm>

With respect to quality, conventional alfalfa hay varies in terms of weed content, and so it is difficult to make direct comparisons between GT and conventional alfalfa hay from a weed content standpoint. Putnam (2008) argues that while the relative weed-free nature of GT alfalfa tends to give it an edge in terms of quality over conventional alfalfa, one cannot systematically attribute higher quality to GT alfalfa over conventional alfalfa, since sometimes conventional weed control systems can be quite effective. However, Van Deynze et al. (2004), Dillehay and Curran (2006), and Rankin (undated) all report better weed control in GT alfalfa using the glyphosate weed management system, suggesting there is the potential for higher quality forage from GT alfalfa.

Based on the discussion above, the scenarios below simulate the impact on economic returns to conventional alfalfa hay farmers from adoption of GT alfalfa under various assumptions. The scenarios stem from the same University of Wisconsin Integrated Pest Crop Management Roundup Ready® Alfalfa Calculator used in chapter 3. Assumptions are changed to allow use of GT seeds, glyphosate, and various scenarios of alfalfa hay quality.²¹ No differences in yield are assumed between GT alfalfa and non-GT alfalfa, and no additional differences in management systems are assumed. Results are shown for the seeding year.

Based on the existing literature, the following values (sometimes ranges) are adopted in the scenarios below. This information can also be found in chapter 3.C.1.

- *GT alfalfa seed costs*—Sold at U.S. \$6-7.50/lb during its deregulation period, including its technology fee of \$125 per 50/lb bag east of the Rocky Mountains, and \$150 per 50/lb bag west of the Rocky Mountains (<http://www.purdue.edu/UNS/x/2007a/070323NeesAlfalfa.html>; <http://ipcm.wisc.edu/WCMNews/tabid/53/EntryID/208/Default.aspx>; <http://www.roundupreadyalfalfa.com/home.aspx?page=valuecalculator>)
- *Glyphosate costs*—Prices have ranged from \$56.30 per gallon in 1998 (USDA NASS, 1998) to \$28.90 per gallon in 2007 (USDA–NASS, 2007); 2008 prices of glyphosate (\$40.50 per gallon) seem to have rebounded from a few years of reduced prices (USDA–NAAS, 2008). The number of glyphosate applications used in the scenarios are one or two per year at 22 ounces/acre.
- *Weed content*—No glyphosate resistance is assumed and only glyphosate is used as an herbicide. Improvements in weed content are built into the scenarios as increases in the quality of hay (for example, from good to premium or to supreme) with reflections on prices, according to USDA available alfalfa hay prices for the relevant locality and year.

In all scenarios summarized in table 4-5, there would be an increase in returns over total costs with the use of GT alfalfa already in the seeding year, as long as the cost of the technology fee is distributed throughout the life of the stand, and in two of the four scenarios even if the cost of the technology fee were fully paid for in the seeding year. Profit per acre

²¹ These scenarios should not be interpreted as likely differentials in costs and returns between conventional and non-GT alfalfa in any particular setting, since the differences in management systems between the two varieties are likely to involve other factors not taken into consideration in the scenarios (such as the time spent by farmers with weed control) and the impact of the deregulation of GT alfalfa on the prices paid for alfalfa of various qualities is ignored.

Table 4-5. Cost Scenarios for GT Alfalfa

	Technology fee distributed throughout life of stand				Two Apps ¹ (\$35/Gallon)				One App, Improved Hay Quality (\$110/Ton: a 10% Price Increase ² , \$40/Gallon)			
	Conv ³	GT	GT ⁴	GT	Conv	GT	Conv	GT	Conv	GT	Conv	GT
Seed cost/50 lbs (\$)	\$200	\$250	\$250	\$250	\$200	\$250	\$200	\$250	\$200	\$250	\$200	\$250
Lbs of seed per acre	12	12	12	12	12	12	12	12	12	12	12	12
Tech. fee/bag (\$/bag)	\$0	\$125	\$125	\$125	\$0	\$125	\$0	\$125	\$0	\$125	\$0	\$125
Yld seeding yr (t/a DM) ⁵	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Herbicide cost (\$/acre/app lication)	\$20	\$6	\$6	\$6	\$20	\$6	\$20	\$6	\$20	\$6	\$20	\$6
Herb. app. cost (\$/acre)	\$10	\$10	\$10	\$10	\$10	\$10	\$10	\$10	\$10	\$10	\$10	\$10
Number of herb. apps	1	1	1	1	2	2	2	2	2	2	2	2
Value of ease of roundup use (\$/acre)	\$0	\$0	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Yield depression from pursuit/rapt or (t/a DM)	0.3	0	0	0	0.3	0	0.3	0	0.3	0	0.3	0
Expected stand life (yrs including seeding year)	3	3	3	3	3	3	3	3	3	3	3	3
Value of hay per ton DM)	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$110
Fixed costs/acre/year	\$180	\$180	\$180	\$180	\$180	\$180	\$180	\$180	\$180	\$180	\$180	\$180
Harvesting costs per acre per harvest	\$35	\$35	\$35	\$35	\$35	\$35	\$35	\$35	\$35	\$35	\$35	\$35
Number of harvests	2	2	2	2	2	2	2	2	2	2	2	2

Table 4-5. *continued*

Seeding Year Production Costs/Results							
	Conv	GT	GT ⁴	Conv	GT	Conv	GT
Seed cost (prorated + tech fee) per acre ¹	\$16	\$50	\$30	\$16	\$50	\$16	\$50
Total seed and herb. cost per ton of hay	\$14	\$19	\$13	\$23	\$23	\$23	\$24
Total cost/ton hay-seeding yr	\$86	\$90	\$85	\$95	\$95	\$95	\$95
Profit/ acre - seeding year	\$50	\$34	\$54	\$17	\$18	\$17	\$16
						\$50	\$68

Source: first 2 data columns: Integrated Pest Crop Management, U. of Wisconsin; other columns elaborated from base numbers.

¹Apps = glyphosate applications; 2 applications in these columns contrasts with the single application of the first two columns

² Data from various Midwestern markets suggest \$100/ton was the price paid for good quality hay within the last year, while premium quality hay would go for 15-35% more, so the quality improvement assumed is quite modest.

³ Conventional

⁴ Original numbers - shown in the first two columns - prorate seed cost over life of stand but leave full technology fee in seeding year. This assumption is maintained in this table, except for in the third column where the technology fee is prorated as well.

⁵ t/a DM = Tons per acre Dry Matter

would be higher for GT alfalfa in years following that of the seeding year. The increased returns are the result of lower herbicide costs, improved hay quality, or both.

a. Supply of Conventional Alfalfa for Forage

The discussion above suggests a possible reduction in average costs necessary to produce alfalfa of a given quality or, in other words, an increase in the quality of alfalfa hay at a given production cost. The overall impact would be a shift downwards in the supply curve of alfalfa hay. This is represented in figure 4-1 below and would imply a decrease in prices and increase in quantity of alfalfa sold, as dairy and meat farmers substitute alfalfa for other feeds. The following discussion comes in part from the technical report, *Economic and Social Impacts to Conventional and Organic Farmers of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix S).

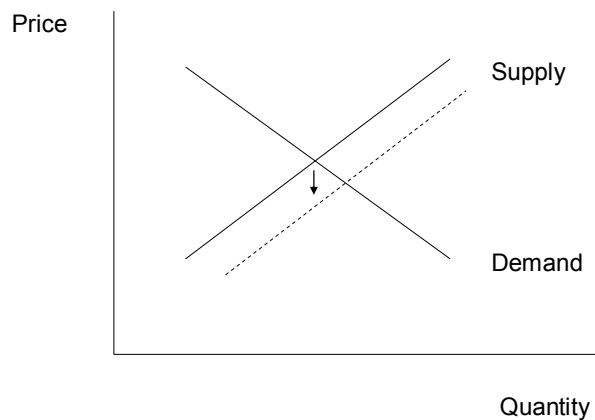


Figure 4-1. Overall impact on supply with introduction of GT alfalfa.

Within the domestic conventional alfalfa market, however, there is demand for higher and lower quality alfalfa. Since GT alfalfa will likely generate alfalfa hay of high quality (low weed content), the above portrayed shift in supply will be stronger in the market segment for high quality alfalfa forage and may actually shift in the opposite direction (upwards) in the low quality alfalfa segment if farmers currently growing low quality alfalfa hay also adopt GT alfalfa.

b. Demand of Conventional Alfalfa for Forage

The reduction in the price of high quality alfalfa hay will likely have an impact on the demand for alfalfa hay of lower quality, as well as on the demand for alfalfa hay of high quality that is only available at higher costs (non-GT alfalfa). To the extent that high quality and low quality (or higher cost) alfalfa hay are substitutes, a reduction in the price of high

quality alfalfa hay would shift the demand for low quality alfalfa hay downwards.

The main possible impact of GT alfalfa deregulation on the domestic demand for conventional alfalfa hay, however, depends on the existence of a GT-sensitive market among domestic consumers of alfalfa hay. If glyphosate tolerance is seen as an undesirable quality in alfalfa hay by some, these consumers will seek to substitute their purchases by: (a) seeking imported non-GT alfalfa hay; (b) seeking some form of GE-free certification; (c) using GE-free hay based on other crops; or (d) shifting to organic alfalfa hay to minimize the intended presence of GT alfalfa.

Deregulation of GT alfalfa will likely have little or no impact on the domestic demand for conventional alfalfa hay. As discussed in chapter 3, there is insufficient evidence on the sensitivity of domestic demand to the presence of GE material, and any existing preference for non-GE foods would possibly not translate to a reduction in demand. Furthermore, other genetically engineered crops (e.g., corn, soybeans, canola) have been deregulated in the United States for a number of years with no substantial drop in demand for conventionally produced dairy products or meat, the main source of demand for alfalfa hay (Fernandez-Cornejo and Caswell, 2006; Putnam, 2005).

c. Conventional Alfalfa Seed Markets

The main possible advantage of GT alfalfa for seed production is in weed control. Canevari (2007) notes that the ability to control post-emergence dodder (a genus of parasitic plants) before seeding and without injury to alfalfa “would be a significant breakthrough.” However, as noted in the cost studies reported in chapter 3, weed control, although fundamental for seed acceptance in the market, is a lesser cost in seed production than other operational costs such as pollination and insect control.

The market for seed will likely follow the tendency of the market for alfalfa hay, since it is a derived demand. As the quantity of alfalfa hay produced and consumed is expected to increase in a scenario of GT alfalfa deregulation, so would the demand for GT alfalfa seeds. The supply of conventional seeds would be partially occupied by GT alfalfa, according to demand. Myer et al. (1998), using panel data from seven states, find that the demand for alfalfa seed is highly inelastic. In other words, an increase in seed prices does not significantly reduce its demand and is absorbed by seed consumers. This is to be expected given the importance of appropriate seed choice for alfalfa hay yields and quality and the relatively low share of total alfalfa hay production costs represented by seeds.

This discussion is taken in part from the technical report, *Economic and Social Impacts to Conventional and Organic Farmers of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix S).

2. Impacts on Domestic Organic Alfalfa Markets

In the Notice of Intent (NOI) published on January 7, 2008, (73 FR 1198-1200), APHIS requested information regarding the economic impacts of GT alfalfa on organic alfalfa production, given that, at the time of NOI publication, GT alfalfa had already been in commercial production for over two years:

“9. What are the potential economic and social impacts of glyphosate-tolerant alfalfa release on organic and conventional alfalfa farmers? What are the potential impacts of the presence of glyphosate-tolerant alfalfa caused by pollen movement or seed admixtures? What are the economic issues associated with using alfalfa seed or hay commingled with glyphosate-tolerant alfalfa? What are the particular economics of growing seed or hay of organic alfalfa, conventional alfalfa, or glyphosate-tolerant alfalfa? What are the potential changes in the economics of growing and marketing organic and conventional alfalfa that may occur with the use of glyphosate-tolerant alfalfa? What are the potential changes in production levels of other crops that may occur with the use of glyphosate-tolerant alfalfa (i.e., will the release of glyphosate-tolerant alfalfa result in more or fewer acres of corn, wheat, other forage crops, etc.)? What are the potential changes in growing practices, management practices, and crop rotational practices in the production of alfalfa hay or seed for planting or sprouting purposes that may occur with the use of glyphosate-tolerant alfalfa? What are the potential changes in the choice of seeds available for organic and conventional alfalfa farmers that may occur with the use of glyphosate-tolerant alfalfa?”

Unfortunately, APHIS did not receive any specific economic data or information related to the economic ramifications for organic producers due to the production of GT alfalfa. APHIS was expecting data to be submitted during the comment period for the NOI that could be used for predicting the coexistence production costs for organic alfalfa and GT alfalfa, including the costs to organic alfalfa growers to avoid gene flow or the costs associated with organic alfalfa rejected from buyers due to unintended presence of excluded methods (pesticides or genetically engineered crops). Although APHIS did not receive any data from organic alfalfa growers confirming that they in fact have some increased costs in order to implement measures to avoid gene flow from the currently planted 200, 000 acres of GT alfalfa; nevertheless, APHIS is assuming that scenarios exist in which some economic impacts may be felt by some organic alfalfa producers, or those producers who grow alfalfa for

GE-sensitive markets (e.g., for export to certain countries), given the current production of GT alfalfa.

The supply of organic alfalfa hay and organic alfalfa seeds would not be directly affected by adoption of GT alfalfa by non-organic producers of alfalfa. Organic alfalfa growers cannot adopt GT alfalfa because genetic engineering is an excluded method, and GE crops may not be certified as organic. USDA organic certification would also not be affected given that organic certification does not require testing for GE content and focuses on the process used to grow the product—the farming operations—rather than on content of the product itself. From the preamble of the final rule for the National Organic Program:

“Certifying agents attest to the ability of organic operations to follow a set of production standards and practices that meet the requirements of the [Organic Foods Protection] Act and the [National Organic Program] regulations. This regulation prohibits the use of excluded methods in organic operations. The presence of a detectable residue of a product of excluded methods alone does not necessarily constitute a violation of this regulation. As long as an organic operation has not used excluded methods and takes reasonable steps to avoid contact with the products of excluded methods [including genetically engineered crops] as detailed in their approved organic system plan, the unintentional presence of the products of excluded methods should not affect the status of an organic product or operation.”

65 *Federal Register* 80556

Two assumptions are required if organic alfalfa producers are to experience negative economic impacts due to the production of GT alfalfa: a) consumers of organic alfalfa demand alfalfa free from any unintended presence of GT traits; and b) current organic practices and GT alfalfa stewardship are insufficient to minimize cross-fertilization. Organic alfalfa farming production costs may increase due to increased avoidance costs and returns may decrease from the loss in alfalfa production due the presence of GT alfalfa (via cross-fertilization or gene flow) under these assumptions because:

- (1) *Avoidance costs*—If organic alfalfa producers want to avoid unintended presence, whether through adopting buffer zones or requiring testing for GT alfalfa traits in alfalfa seeds used for production, there is a cost of avoidance that must be incorporated into production costs.
- (2) *Loss in production*—If organic alfalfa producers cannot avoid unintended presence above those levels found acceptable by the market, any alfalfa seeds or forage previously destined to those

markets that contain unintended presence of GT alfalfa traits will have to be shifted to markets (i.e., non-organic) that may pay a lower price.

The impact on supply is best understood by imagining two separate market segments: a GT sensitive market (a market that will not accept GT alfalfa) and a non-GT sensitive one (a market that will accept GT alfalfa). If there is loss in production destined to the GT-sensitive market or an increase in costs of supplying that market, the supply curve for that market would shift upwards. If non-GT alfalfa that is destined to the non-GT sensitive market contains GT alfalfa (loss in production), or if some farmers are not able to continue supplying the existing market given the increased costs and shift to the non-GT sensitive market (avoidance costs), the supply curve for that market would shift downwards (see figure 4-2 and the technical report, *Economic and Social Impacts to Conventional and Organic Farmers of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix S)).

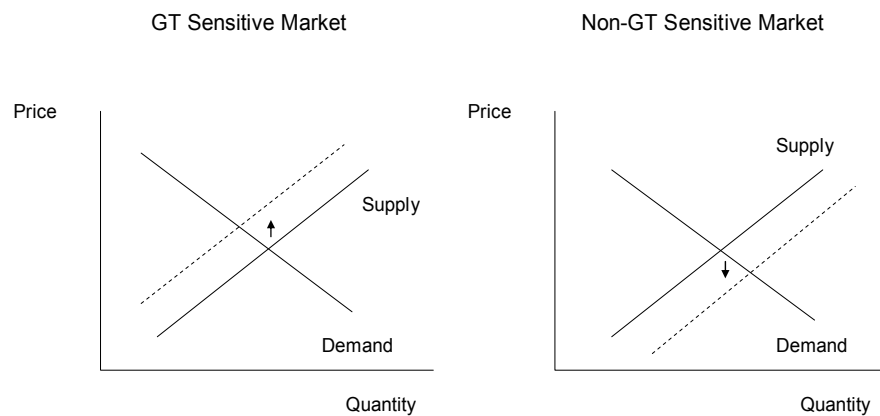


Figure 4-2. Impact of presence of GT alfalfa.

A numerical estimation of the impact GT alfalfa deregulation would have on the supply of organic alfalfa, under these assumptions, is not possible given the lack of available information. It would require quantifying the amount of GT alfalfa in organic alfalfa, what share of the organic market is sensitive to unintended presence of GT traits, and what the sensitivity of the demand curve to changes in prices (the price-elasticity of demand) is, since this will determine how much the price would change with shifts in the supply curve.

There is not enough information to evaluate the likelihood of the above scenario. As previously mentioned, it relies on two assumptions: (1) that consumers of organic alfalfa demand alfalfa free from any unintended presence of GT traits; and (2) that current organic practices and GT alfalfa

stewardship are insufficient to minimize unintended presence. However, the existing evidence does not support these two assumptions.

On the first assumption, the demand for organic alfalfa is a demand derived from the demand for organic dairy and beef. Organic dairy represented nearly 90 percent of the total sales value of the combined U.S. organic dairy and meat market in 2006 (Organic Trade Association, 2007) and is by far the main client for organic alfalfa hay.

There is no evidence of GT sensitivity of the demand for organic dairy in a scenario of GT alfalfa deregulation, particularly considering that: (a) current organic standards do not allow for intentional use of GE feed, so any presence of GT traits in alfalfa used for feed in organic dairy or meat farms would be unintended; (b) there is no evidence that any GE material in animal feed currently in use is actually transmitted to milk or meat; and (c) consumer preferences for organic over GE foods are influenced in part by philosophical factors that are likely unrelated to unintended cross-fertilization of feed crops with GE material. Additionally, no quantitative information related to the GT sensitivity on the demand for organic dairy products was submitted during the NOI public comment period, so APHIS has no data to establish or confirm such GT sensitivity.

Survey evidence presented in Brookes and Barfoot (2004) showed that the vast majority (92 percent) of U.S. organic farmers had not incurred any direct additional costs or incurred losses due to GE crops having been grown near their organically produced crops. According to the report, four percent had experienced lost organic sales or downgrading of produce as a result of GE organism presence and the remaining four percent of farmers had incurred small additional costs only for testing. Brookes and Barfoot (2004) also noted that an examination of trends in the planting of GE and organic crops suggests that the growth of the crop area used for GE plants has not impeded the development of the organic sector in North America.

However, as observed in Apted and Mazur (2007), the Brookes and Barfoot (2004) study was not able to quantify the impact of measures undertaken by organic producers to avoid GE material coming into contact with organic crops. Nonetheless, there is data to indicate that farmers using organic production systems are being compensated for the unidentified costs associated with meeting any contractual obligations and NOP standards for alfalfa produced through organic systems. Cost premiums for organic hay production vary between 10 and 50 percent (Lehnert, 1998).

As presented in chapter 3, successful marketing of the National Organic Program (NOP) certified foods has already had to contend with the risk of

GE material accidentally spreading from deregulated cultivars of soybeans, corn, and canola to organic crops. Despite the potential for unintended cross-fertilization, however, organic food sales in the United States continue to grow at a rapid rate. As noted earlier, one reason may be that most U.S. consumers do not appear to have strong or adverse opinions regarding health or safety impacts from GE foods deregulated for U.S. production. Another is that philosophical factors largely unrelated to unintended cross-fertilization are important drivers of organic demand (Anderson et al., 2006). While there is the potential that organic food sales would have grown even more rapidly in the absence of this risk, no published studies have been found that document or estimate this effect.

If there is a segment of the *conventional* market that is sensitive to GT alfalfa, there is actually a possibility for an increase in the demand for organic products, given that much of the information that U.S. consumers currently have regarding purposeful GE content in the foods they eat comes from the presence or absence of organic labels (Ganiere et al., 2006). Consumers of conventional alfalfa that are disinclined to consume GE products could presumably shift their demand to organic products.

The second assumption is that current organic practices and/or GT alfalfa stewardship measures are insufficient to minimize cross-fertilization. However, APHIS is not aware of nor has been provided any data to establish or confirm this assumption. Organic certification under the NOP place the responsibility of managing the potential contact of organic products with other substances not approved for use in organic production systems, whether from the non-organic portion of a split operation or from neighboring farms, on the organic producer. The organic system plan, developed individually by a grower, must outline the steps taken to avoid contact or mixing, and it is the organic producers who are ultimately obligated to manage their operations so as to avoid unintentional contact with non-organic material. This was explicitly affirmed in the response to public comment on the establishment of the NOP (65 FR 80556). The NOP writes specifically about buffer zones and defines them as areas located between a certified organic production operation and an adjacent land area that is not maintained under organic management. A buffer zone must be sufficient in size or other features (e.g., windbreaks or a diversion ditch) to prevent the possibility of unintended contact with prohibited substances applied to adjacent land areas.

The NOP has recognized the practicality of protecting organically-produced crops, and the investment farmers put into their production practices, by requiring that organic production plans include methods to protect organically produced crops.

“Organic crops must be protected from contamination by prohibited substances used on adjoining lands (for example, drifting pesticides, fertilizer-laden runoff water, and pollen drift from genetically engineered...)”(NCAT, 2003).

Typically, more than one method is used under organic practices to prevent unwanted material from entering their fields including; isolation of the farm, physical barriers or buffer zones between organic production and non-organic production, as well as formal communications between neighboring farms (NCAT, 2003). Farmers using organic methods are requested to let neighboring farmers know that they are using organic production practices and request that the neighbors also help the organic farmer reduce contamination events (NCAT, 2003; Krueger, 2007). The organic plan used as the basis for organic certification should also include a description of practices used to prevent or reduce the likelihood of unwanted substances, like GE pollen or seed, at each step in the farming operation, such as planting, harvesting, storing and transporting the crop (Riddle, 2004; Krueger, 2007; Kuepper et al., 2007). Organic plans should also include of how the risk of GE pollen or seed co-mingling will be monitored (Kuepper et al., 2007). Practices that help organic farmers minimize the risk of unintended GE presence in their field include: (1) Use seed that is from a known, non-GE stock (lists of organic seed suppliers can be found at www.attra.org); (2) Use temporal buffers such that alfalfa being produced using organic methods is receptive to pollen at a different time of year than when the neighboring alfalfa flowers; (3) Harvest alfalfa at 10 percent bloom to reduce the number of flowers available for pollination (however, harvesting alfalfa prior to formation of seed (approximately 4 weeks after bloom) will also minimize the potential of gene flow into an organic alfalfa forage field; see table 4-3); (4) remove bee hives surrounding alfalfa fields prior to alfalfa blooming period (5) Maintain physical isolation from GT alfalfa (either through distance or natural barrier (e.g., tree rows)); (6) Plant alfalfa at the edge field to act as a trap for GE pollen and harvest these buffer rows separately.

Thus, commonly used production practices for alfalfa, and the practical methods typically used by alfalfa farmers using organic methods to protect their crop and maximize their profits and price premiums granted to alfalfa under organic production, currently provide many effective measures that greatly reduce the likelihood of accidental gene flow between GT and non-GT alfalfa. APHIS assumes that organic farmers are already using, or have the ability to use, these common, reasonable practices to minimize gene flow between GT and non-GT alfalfa, because organic alfalfa growers have not informed APHIS to the contrary, and because USDA organic certification requires measures to minimize unintended presence to GT alfalfa. Recommended organic production practices for alfalfa are also readily available (Guerena and Sullivan, 2003). It is important to note

that organic production systems have been coexisting with GT alfalfa since 2005 and there is currently 200, 000 planted acres of GT alfalfa.

Additionally, the contractual obligations for GT alfalfa growers also include required measures to minimize the gene flow of GT alfalfa. These measures are mandatory for the GT alfalfa seed growers and include isolation distances for alfalfa seed production fields: when leafcutter bees are used for pollination, the distance between GT and non-GT alfalfa seed production fields must be greater than or equal to 900 feet; when using Alkali bees, the isolation distance must be greater than or equal to 1 mile; and when honey bees are used as a pollinator, the isolation distance must be greater than or equal to 3 miles. FGI has validated their Best Practices for seed production and believes they can produce non-GT alfalfa seed reliably with >99.5 percent purity (FGI, 2007).

Thus, APHIS is not aware of any specific evidence to support the assumption that current practices in either organic production systems or GT alfalfa production are insufficient to minimize the unintended presence of GT alfalfa. The assumptions that support the scenario of increased production costs and reduced demands for organic alfalfa farmers have not been established or documented and APHIS is aware of no data that confirms these assumptions.

On the demand side, in addition to the possible segmentation of the organic alfalfa markets in GT sensitive and non-GT sensitive segments, demand for organic alfalfa hay could shift downwards under two possible scenarios—

- (1) If organic dairy and meat farmers consider shifting to conventional farming due to the decreased costs of high quality conventional alfalfa (and presumably increased returns).
- (2) If the decreased costs of high quality conventional alfalfa are transmitted to conventional dairy and meat costs, increasing the price differential between conventional and organic dairy and meat, stimulating organic dairy and meat consumers to purchase conventional products.

There is no evidence that the first scenario would occur. To the extent that organic farmers have chosen organic production out of philosophical values and/or to supply the organic alfalfa market, the economic incentive to switch to conventional farming should not have an impact.

The likelihood of the second scenario is also not clear. A report by the U.S. General Accounting Office (2001) studied the factors influencing farm and retail dairy prices. The report notes that changes in milk production costs do not necessarily reflect in changes in retail prices of

dairy. Farmer milk prices represent roughly 40 percent of retail milk prices and are affected by Federal and State programs establishing minimum prices. The process of transmission of dairy farms costs to prices is not a simple one to determine. In the case of meat, alfalfa is likely a lower share of feed costs in cow-calf production than it is in dairy production since the main source of feed is grazing (Short, 2001). As cattle move on to feedlots (sometime through stocker operators) feed becomes mostly grain based ration. Short (2001) argues that prices paid for cattle tend to be similar across the country, despite differences in cow-calf production costs because cattle are routinely transported. This suggests that any transfer of cost changes to prices down the chain would be unlikely. Under the unlikely scenario that the supply curve was shifted by presence of GT alfalfa as previously shown, and that the demand curve was shifted downwards by loss of competitiveness of organic products when compared to conventional products, the impact on the organic market would be as shown in figure 4-3.

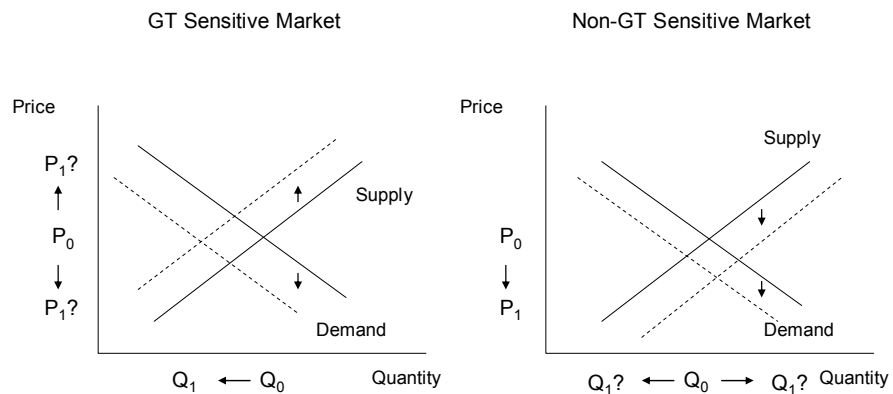


Figure 4-3. Impact of GT alfalfa deregulation on organic alfalfa for forage with GT-sensitive domestic markets.

The result of GT alfalfa deregulation under this scenario would depend on the extent of the GT-sensitive market within the organic market. The larger the GT-sensitive market is, the more likely quantities sold would decrease, although with an unclear effect on prices. The larger the non-GT sensitive market is, the more likely prices would decrease, but with unclear effect on quantities.

Once again, there is not enough information to estimate numerically the impact for organic farmers under this scenario, even though APHIS in its NOI specifically requested information on the economic impacts of GT alfalfa on organic beef and dairy markets (73 FR 1198-1200). In addition to changes in supply and demand, we also requested data (but did not receive any) on the share of the organic market that is GT-sensitive and the magnitude of the decrease in prices expected of conventional alfalfa. An expansion of this discussion can be found in the technical report,

3. Impacts on Dairy and Beef Markets

Based on the above analyses, we have concluded that the deregulation of GT alfalfa would likely have no impact or minor impact on the domestic demand for conventional or organic dairy and beef products. As discussed in chapter 3 and in the technical report, *Downstream Effects to Organic Production and Marketing of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix T), there is insufficient evidence on the sensitivity of domestic demand to the presence of GE products, and any existing preference for non-GE foods would likely not translate to a reduction in demand. Furthermore, other genetically engineered crops (e.g., corn, soybeans, canola) have been deregulated in the United States for a number of years with no substantial drop in demand for conventionally produced dairy products or meat (Fernandez-Cornejo and Caswell, 2006; Putnam, 2005).

On the supply side, alfalfa is likely a considerable share of dairy feed costs. Short (2004) reports hay and straw (presumably mostly alfalfa) represents roughly a third of feed costs. Alfalfa may additionally be used in cubes or pellets. In some regions (Wisconsin, Minnesota), haylage is also a significant share of feed. As adoption of GT alfalfa would likely increase the quality of alfalfa for forage without an increase in costs, this should increase productivity of non-GT sensitive dairy farms and allow for an increase in production without an increase in costs. The impact on dairy farms would be to increase the feasibility of operations. MacDonald et al. (2007) report that currently many small dairy farms are operating with incomes above operational costs but below total costs (they are not covering overhead and capital recovery costs). The impact on reduced costs would, however, impact farms of all sizes, since feed seems to be of similar importance to all farms. If GT alfalfa requires less labor, this may be to the advantage of smaller farms where labor is a greater share of costs. Whether decreased dairy farm production costs and a potential increase in production would translate into reduced prices for dairy is not clear, as previously mentioned, given governmental regulation of farmer milk prices. As stated above, the effect of GT alfalfa deregulation on the supply of organically produced alfalfa would depend on the extent of the GT-sensitive market within the organic market.

In the case of meat, alfalfa is likely a lower share of feed costs in organic or conventional cow-calf production than it is in dairy production since the main source of feed is grazing (Short, 2001). The impact of potentially reduced alfalfa costs on meat production may be important for cow-calf production, particularly in areas where supplementary feeding is more important in winter, such as the North Central region—Iowa, Illinois, Missouri (Short, 2001). If the alfalfa used is often of lower quality (Klonsky et al., 2007) the impact would depend on the extent to which

reduction in prices of high quality alfalfa also decreases the prices of lower quality alfalfa. It is unlikely; however, that GT alfalfa deregulation would have significant impact on organic or conventional meat farming costs or meat prices, given the relatively low share of alfalfa in production costs.

4. Impacts on Trade

The following discussion is taken in part from the technical report, *Impacts to United States Trade of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix R).

There is considerable dissimilarity among countries on regulation pertaining to GE food and feed (Gruère, 2006). While most countries lack any regulations at all, Japan, Saudi Arabia and South Korea, main alfalfa export markets, all have approval processes for GE products and labeling requirements.

Japan has zero tolerance for non-approved GE foods and conducts inspection and testing of cargoes arriving in Japan, inspecting up to 50 percent of all cargoes (Gruère, 2006). A 1-percent threshold for unintended, or unplanned, presence of GE content in feed is allowed as long as the GE product has been approved by the exporting country and the exporting country is considered to have safety assessments equivalent to Japan's (Gruère, 2006). Labeling is mandatory for all GE foods as long as GE material can be detected, the GE ingredient is one of the first three ingredients of a product, and the GE material accounts for more than five percent of the total weight (Gruère, 2006). Labeling requirements are based only on product content and not process (Gruère and Rao, 2007).

Because alfalfa hay is predominantly used as feed, the impacts of deregulation associated with the export market in Japan may be similar to those of soybeans and corn. Japanese regulations do not seem to have had a significant impact on these crops and labeling is not required for products from GE fed animals—at least not for meat—and corn used for feed is typically GE corn (Gruère, 2006).

However, there is evidence in several countries other than the United States that businesses have often chosen to protect themselves against market risks associated with commercializing GE products, in the face of consumer negative perceptions. A USDA (2005) document notes how business associations have sometimes adopted lower required levels of unintended presence for acceptance of products than those required by legislation (United Kingdom). The same document notes that some insurance companies have added exclusions to insurance contracts to protect themselves from potential losses triggered by the presence of GE material. There is some indication that Japanese alfalfa importers are concerned with importing GE alfalfa. Putnam (2005) states that foreign

importers have asked for GE-free alfalfa and that this has led U.S. exporters to require signed contracts from producers asserting the GE-free status of alfalfa sold to them. Similar anecdotal evidence is provided by Woodward (2004) and recognized by the National Alfalfa and Forage Alliance (2008b).

The United States appeared to have already been steadily losing market share in its exports of alfalfa hay and cubes to Japan before the 2005 deregulation of GT alfalfa. In the 10 years in which Japan's total forage imports increased by 18.5 percent, exports of U.S. forage only increased by 7.5 percent. Although Canada's share of this market has remained stable, Australia's share grew 800 percent from 1995 to 2004 (Woodward, 2006).

Sales in the United States of alfalfa for forage to Japan may decrease with GT alfalfa deregulation. There is evidence of precautionary resistance from Japanese importers for GT alfalfa and the United States has already been losing market share to competitors (Australia). Exporters may have to show that any unintended presence of GT traits would fall well below Japan's 1-percent threshold level for unintended presence of GE feed.

South Korea has similar approval processes and labeling requirements as Japan. Labeling in South Korea is mandatory for unprocessed GE food and for unprocessed non-GE food containing more than three percent unintended presence of GE content. In the case of processed foods, labeling is required if the GE ingredient is among the top five and is detectable in the final product. GE animal feed must also be labeled (USDA-FAS, 2008a). Processed food with non-detectable levels of GE material, such as dairy, meat and vegetable oils do not require labeling.

Non-government Organizations (NGOs) in South Korea have increasingly advocated for expansion of labeling requirements to products using GE ingredients, independently of whether these can or cannot be detected in the final product (USDA-FAS, 2008a). USDA-FAS (2008a) notes that labeling of feed does not seem to have an impact in the market because most feed is GE, but that an expansion of food labeling requirements to include use of GE ingredients even when not detectable could turn South Korea into a non-GE market. As in the case of Japan, there is evidence of consumer negative views of GE products (Cho, Undated; USDA-FAS, 2008a). South Korean businesses, however, have been opposing expansion of GE labeling given the potential increase in their costs from buying non-GE products.

For alfalfa seed, the most important export market is Saudi Arabia. Although the country allows imports of labeled GE variety grains and plant/vegetable processed foodstuffs, imports of GE variety seeds have

been banned since 2004 (USDA-FAS, 2007a). Saudi Arabia would currently not purchase GT alfalfa seeds. Whether Saudi Arabia would continue purchasing non-GT alfalfa seeds from the United States would likely depend on the extent to which non-GT alfalfa seed producers are able to avoid unintended presence of GT alfalfa traits.

Mexico, the main downstream export market for dairy, seems to have no significant trade barriers to foods derived from biotechnology. GT alfalfa has been approved for food and feed in Mexico, and Mexico regularly imports and consumes GE corn, soybeans and cotton from the United States (USDA-FAS, 2008b). Mexico's existing labeling requirements for GE products have not been implemented, according to Gruère (2006). In the case of Canada, another important market for alfalfa downstream products from the United States, GT alfalfa has also been approved and there is no mandatory labeling for GE products (Gruère, 2006).

On the import side, U.S. imports of alfalfa hay and seed come mostly from Canada. To the extent that GT alfalfa deregulation would reduce foreign demand for U.S. exports, alfalfa hay and seed production previously destined to foreign markets would possibly be channeled to the domestic market. As the domestic market for non-GT alfalfa hay and seed would be expected to decrease with GT alfalfa deregulation, U.S. production would possibly substitute imports.

5. Social Impacts

GT alfalfa adoption by farmers, cross-fertilization of non-GT alfalfa fields, and the demand response to GT alfalfa deregulation could have several social impacts, which are further discussed in the technical report, *Economic and Social Impacts to Conventional and Organic Farmers of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix S).

Businesses Lost and Gained

Farmers adopting GT alfalfa would possibly face decreased costs or improved markets for the possibly less expensive GT alfalfa while GT-sensitive farmers would possibly face a reduction in demand for the more expensive organic alfalfa. Early GT alfalfa adopters may gain markets while conventional non-GT alfalfa farmers producing high quality alfalfa may lose, due to potentially higher costs and lower quality when compared to GT alfalfa. If there is GT-sensitivity in the market for organic alfalfa, those organic farmers that are most affected by the unintended presence of GT alfalfa may lose markets, while organic farmers less affected may gain.

Market Structure

Increased land costs that could affect non-GT alfalfa farmers attempting to avoid the presence of GT alfalfa could benefit larger alfalfa farmers. Land costs generating economies of scale in alfalfa grown for forage are also a major cost factor in alfalfa seed production.

The impact of increased land costs on seed production would likely be mitigated, however, by the highly inelastic demand for seeds. In other words, as seed quality is important for alfalfa forage producers and seed costs are a small cost of their total production costs, increases in seeds costs should not significantly affect sales of seeds. Moreover, land costs for GT-sensitive alfalfa forage growers may be reduced as there are other mechanisms available to minimize the presence of GT alfalfa in GT-sensitive alfalfa fields.

If adoption rates of GT alfalfa were high, alfalfa seed farmers would face increased demand for GT alfalfa seeds and would shift production to this variety. There would likely be an increased market concentration in the supply of alfalfa seed technology.

To the extent that organic farming is more suitable for small farms than conventional farming (less economies of scale related to greater dependency of labor), a reduction in the demand for organic products could favor larger farmers. Therefore, overall, alfalfa production may shift to larger farms.

Distribution of Costs of Loss of Production and Avoidance

Based on the assumption that there is a level of presence of GT alfalfa that the organic market will not bear, and to the assumption that current alfalfa production practices are not already in place to protect against unintended presence of GT alfalfa in GT-sensitive alfalfa fields, organic producers could bear a cost in either loss of production or measures to reduce the likelihood of unintended presence. However, APHIS is not aware of nor has been provided with any reliable evidence that currently establishes or supports either of these assumptions.

Social Aspects of Organic Farming

The absence of a GT-sensitive domestic demand for organic products does not mean GE products are necessarily welcome by organic consumers, but rather that any sensitivity to GE content may not translate into a decrease in sales of organic alfalfa. Organic producers (and consumers) would possibly still be unhappy with the outcome. To the extent that organic farming involves broader life choices related to philosophical attitudes,

this discontent would be a negative impact. This situation may conceal a market for GE free products in need of development.

No Action Alternative Socioeconomic Impacts

Under the no action alternative, the opportunity for improved quality and/or reduced costs of alfalfa hay would be lost, except for the 200,000 acres of GT alfalfa currently in production. This would mostly have a negative financial impact on alfalfa hay and dairy farmers. Marketing and business efforts conducted around the over 200,000 acres of GT alfalfa planted during the time in which GT alfalfa was deregulated would also be lost. Organic farmers would neither be negatively affected by potential (although unlikely) increased production costs or decreased demand, nor would it have the opportunity to gain GT-sensitive conventional consumers. Exporters would possibly continue to lose alfalfa hay markets to competitors.

E. Human Health and Safety Impacts

The use of glyphosate herbicide does not appear to result in adverse effects on development, reproduction, or endocrine systems in humans and other mammals, as discussed further in the technical reports, *Potential Impacts to Wildlife, Amphibians, Plants, and Ecosystems from Increased Glyphosate and Other Chemical Use* (appendix N), and *Health and Safety Risks from Increased Glyphosate and Other Chemical Usage on Humans (Exclusive of Field Workers)* (appendix L). Under present and expected conditions of use, glyphosate herbicide does not pose a health risk to humans.

Current weight-of-evidence from similar GE crops such as GT wheat (Peterson, 2005), GT soybean, GT corn, GT cotton, and GT sugarbeet suggests that the transgenic CP4 EPSPS protein present in GT alfalfa poses negligible risk to humans, livestock, and wildlife. Most studies available in scientific literature support the view that food from GT crops is substantially equivalent to non-transgenic crops.

1. Introduction of Gene Product into Foods

As mentioned in chapter 3, it was concluded that the CP4 EPSPS protein produced by GT alfalfa events J101 and J163 was biochemically and functionally equivalent to CP4 EPSPSs produced by other Roundup Ready® crops, and to the family of EPSPS proteins that naturally occur in crops and microbiologically based processing agents that have a long history of safe consumption by humans and animals (U.S. FDA, 2004). Human food uses of alfalfa are minor, with the majority of alfalfa consumed by humans as freshly sprouted seedlings (sprouts) or as compressed leaf material in dietary supplements or herbal teas. Since alfalfa is not a reported allergenic food and may be a relatively minor

contributor to some respiratory allergic diseases, the risk to human health is minimal (Metcalf et al., 1996). Monsanto, the developer of GT alfalfa, pursuant to its mandatory MTA measures for growing its GT alfalfa lines, does not allow GT alfalfa to be planted for sprouts (Hubbard, 2008); therefore, human exposure to GT alfalfa appears to be minimal.

Preferred Alternative

If GT alfalfa is deregulated, there is an increased possibility that the gene product would be incorporated into foods, beyond the currently incorporation into food due to the 200,000 acres of GT alfalfa currently in production. With the deregulation of GT alfalfa, it will be more widespread in the environment, and that will increase the chance that nearby, non-GT alfalfa crops contain GT alfalfa content. This is only a possibility, however, as Monsanto will still not allow GT alfalfa to be planted for sprouts, and Monsanto and FGI will encourage Best Management Practices. The GT alfalfa lines J101 and J163 have both successfully completed the voluntary consultation process with FDA, which evaluated food and feed safety of GT alfalfa (FDA, 2004; appendix P).

No Action Alternative

2. Impact of Introduction of Gene Product into Animal Feed

Humans are already currently exposed to gene product from GT alfalfa events J101 and J163, as this gene product is found in other crops (e.g., soybean). Approximately 200,000 acres of GT alfalfa are currently being grown. For the areas using GT alfalfa, and for those areas that request permits to plant GT alfalfa for research under the no action alternative, the risks to human health and safety from the gene product introduction into food would not change from current conditions.

After reviewing the Monsanto and FGI submission to FDA and other information, APHIS agrees with the FDA assessment and concludes that no concerns exist for the food and feed safety of GT alfalfa compared to conventional alfalfa. Studies on the persistence of plant-derived recombinant DNA in livestock have indicated that feed ingested DNA fragments do survive in the terminal gastrointestinal (GI) tract and that uptake into the GI tissue does occur. There is no evidence thus far to indicate that the recombinant DNA would be digested and metabolized in a manner any different from the genetic material of conventional feed products. Additionally, no negative effects of the CP4 EPSPS protein or gene consumption on the nutritional characteristics of dairy cattle, livestock, or poultry have been reported (Combs and Hartnell, 2007). Field observations of GT alfalfa events J101 and J163 have revealed no negative effects of the transgene on non-target organisms such as bees and earthworms. No effects have been observed on pollen harvest behavior of

workers bees, or on survival and development of honey bee egg, larvae or pupa post exposure to the CP4 EPSPS protein.

Combs and Hartnell (2007) showed that milk production, milk composition, feed intake and feed efficiency were not different for dairy cows fed GT versus control alfalfa hay ($P>0.05$). The nutritional safety of a similar GT crop - maize line GA21, was evaluated by Sidhu et al. (2000) in a poultry feeding study. Results from this study showed that there were no significant differences in growth, feed efficiency, adjusted feed efficiency, and fat pad weights between chickens fed with GA21 grain or with parental control grain. These studies further confirm the feed safety of glyphosate and the CP4 EPSPS protein.

Preferred Alternative

If GT alfalfa is deregulated, in whole, then there is an increased possibility that the gene product would become present in animal feed. With the deregulation of GT alfalfa, it will be more widespread in the environment, and as discussed in Gene Flow (chapter 4.B) that will increase the chance that GT alfalfa may be present in nearby, non-GT alfalfa. Also, as most alfalfa is grown for forage, and the amount of crops grown using GT technology increases, the amount of feed that contains the gene product will increase. As stated, this will likely have no adverse effects on livestock or humans.

No Action Alternative

For the 200,000 acres of GT alfalfa currently in production, it is likely that the gene product in GT alfalfa would have no adverse effects on livestock or humans. If further plantings of GT alfalfa were to require a permit, risks to human health and safety from the gene product fertilization of livestock feed would not change from current conditions. The gene product in GT alfalfa is already present in animal feed. The potential of unintended presence itself would remain low if GT alfalfa remained regulated.

3. Glyphosate Exposure

The use of currently registered pesticide products containing glyphosate in accordance with the labeling will not pose unreasonable risks or adverse effects to humans or the environment (according to EPA). However, there is a concern that glyphosate use in general could increase with the adoption of GT crops, leading to a potential increase in glyphosate exposure. However, glyphosate is of relatively low oral and dermal (via the skin) acute toxicity. For this reason, glyphosate has been assigned to Toxicity Categories III and IV for these effects (Toxicity Category I indicates the highest degree of acute toxicity, and Category IV the lowest). See the technical report, *Health and Safety Risks from Increased*

Glyphosate and Other Chemical Usage on Humans (Exclusive of Field Workers) (appendix L) for this and further discussion.

Where pesticides may be used on food or feed crops, EPA also sets tolerances (maximum pesticide residue levels) for the amount of the pesticide that can legally remain in or on foods. EPA undertakes this analysis under the authority of the Federal Food, Drug, and Cosmetic Act (FFDCA). Under the FFDCA, EPA must find that such tolerances will be safe, meaning that there is a reasonable certainty that no harm will result from aggregate exposure to the pesticide chemical residue. This finding must be made and the appropriate tolerance established before a pesticide can be registered for use on the particular food or feed crop in question. Several factors must be addressed before a tolerance can be established, including:

- the aggregate, non-occupational exposure from the pesticide (exposure through diet, from using pesticides in and around the home, and from drinking water);
- the cumulative effects from exposure to different pesticides that produce similar effects in the human body;
- whether there is increased susceptibility to infants and children, or other sensitive subpopulations, from exposure to the pesticide; and
- whether the pesticide produces an effect in humans similar to an effect produced by a naturally-occurring estrogen or produces other endocrine-disruption effects.

a. Hazard Identification and Exposure Assessment for Field Workers

To determine if workers are at risk of adverse effects associated with glyphosate, estimated exposures are compared with a health benchmark specific to glyphosate. USDA (2003) used a dermal reference dose (RfD) for acute (i.e., accidental) and chronic (i.e., general) exposure scenarios for glyphosate of 2 mg/kg of body weight per day. This means that individuals with dermal exposure doses equal to or less than 2 mg/kg of body weight per day are not at risk of adverse effects associated with exposure to glyphosate. The risk metric used to determine if individuals are at risk of adverse effects is called the hazard quotient (HQ). The hazard quotient is the ratio of the estimated exposure dose to the chemical-specific health benchmark (e.g., RfD) (See Equation below). If the HQ is estimated to be less than 1, no adverse effects are expected as a result of exposure to the chemical of concern. If the HQ is greater than 1, adverse health effects are possible. However, an HQ exceeding 1 does not indicate that adverse effects are certain to occur.

$$HQ = \frac{Exposure}{RfD}$$

Where:

HQ	=	Hazard quotient (<i>no units</i>)
Exposure	=	Estimated exposure dose (mg/kg body weight per day)
RfD	=	Reference dose (mg/kg body weight per day)

See tables 4-6 and 4-7 for HQs calculated for both chronic (general) and acute exposures, which are based on the amounts of chemicals handled per day, the application rates, the acres treated per day, and the dermal absorption rate, among other factors. These calculations are described in further detail in the technical report, *Health and Safety Risks from Increased Glyphosate and Other Chemical Usage on Humans (Exclusive of Field Workers)* (appendix L) and *Health and Safety Risk for Field Workers* (appendix M). Conservative values were used for all of these calculations, in order to get an idea of the worst-case scenario.

Table 4-6. Chronic Dermal HQs for General Worker Exposure Scenarios.

Scenario	Central Estimate	Lower Estimate	Upper Estimate	RfD (in mg/kg BW per day)
Directed Foliar	0.0131	0.0005	0.0800	2
Broadcast Foliar	0.0224	0.0007	0.1512	
Aerial	0.0147	0.0002	0.0800	

Table 4-7. Acute Dermal HQs for General Worker Exposure Scenarios.

Scenario	Central Estimate	Lower Estimate	Upper Estimate	RfD (in mg/kg BW per day)
Spill on hands	0.007	0.002	0.025	2
Spill on legs	0.017	0.005	0.062	

Preferred Alternative

If GT alfalfa is deregulated in whole, then there is no change in impact on exposure risk to individual workers. As discussed, the evaluation of exposure risk is based on factors that do not change based on the amount

of GT alfalfa grown or the number of workers exposed. Exposure risk remains the same for both general, chronic exposure and accidental, acute exposure risks to workers.

No Action Alternative

Continuation of GT alfalfa as a regulated article will result in very little change to exposure risk assessments for workers and the general public, even for the 200,000 acres of GT alfalfa currently in production. Risk assessments were evaluated based on current conditions and measurements. While these assessment values remain the same, the actual chance of exposure to glyphosate residue would remain low if GT alfalfa remained regulated. Exposure to herbicides presently used in alfalfa production, which includes glyphosate during stand takeout, would not change.

b. Risk Assessment

The general public is not at a high risk of exposure to substantial levels of glyphosate under typical use conditions (EPA, 1993; USDA, 2003). Dermal and inhalation routes of exposure are not considered in this analysis because it is assumed that GT alfalfa will not be grown by members of the general public or in close proximity to non-farm populations. Thus, it is assumed that the general public will not directly come in contact with or inhale herbicides recommended for use on GT alfalfa. It is, however, assumed that members of the general public may be exposed orally to these herbicides via consumption of foods that have been treated by herbicides containing glyphosate. Because consumers are likely to be exposed to residues of glyphosate on many food items, exposure scenarios evaluated acute effects from consumption of fruit and vegetables contaminated with residues of glyphosate by adults, the elderly, and infants under 1 year of age. Please see the technical report, *Health and Safety Risks from Increased Glyphosate and Other Chemical Usage on Humans (Exclusive of Field Workers)* (appendix L) for further details and discussion.

In the 1993 U.S. EPA RED (Reregistration Eligibility Decision) for glyphosate, the EPA conducted a dietary risk assessment and determined that non-nursing infants under 1 year of age are at highest risk of adverse effects associated with glyphosate exposure (EPA, 1993). The EPA completed an additional risk assessment for glyphosate in 2006 to address its specific use on Indian mulberry and dried peas (EPA, 2006). In this later assessment, the EPA also found that infants under 1 year of age are at greatest risk. APHIS conducted its own risk assessment, based on factors such as amount of fruit and vegetable consumption, glyphosate application rate, and residue rates on a crop.

The analysis, which used the same RfD as that for the worker exposure scenarios, showed that central and lower hazard quotient (HQ) estimates were all under 1, suggesting that the majority of the population is not at risk of adverse health effects associated with acute exposure to glyphosate (see technical report, *Health and Safety Risks from Increased Glyphosate and Other Chemical Usage on Humans (Exclusive of Field Worker)* (appendix L)). Based on upper estimates of exposure, however, infants consuming fruit and all age groups consuming vegetables may be at risk of adverse effects associated with acute exposure to glyphosate. The age group at highest risk is infants under 1 year of age, which is consistent with EPA's findings (EPA, 2006; EPA, 1993). The upper estimate HQ for infants with acute exposure to fruit was approximately 3. The upper estimate HQs for all age groups with acute exposure to vegetables ranged from approximately 2 to 6. These results are all over 1, suggesting the potential for adverse health effects associated with glyphosate (see tables 4-8 and 4-9). It should be noted, though, that the upper estimates of risk are based on highly conservative fruit and vegetable intake rates and a high estimate of glyphosate residue concentrations; thus it is anticipated that only a very small number of individuals, if any, will have this magnitude of exposure and, therefore, be at this level of risk.

Table 4-8. Acute HQs by Age Group and Scenario.

Scenario	Age Group	Central Estimate	Lower Estimate	Upper Estimate	RfD (in mg/kg BW per day)
Fruit	Adults	0.01	0.00	0.62	2
Fruit	Elderly	0.02	0.01	0.23	2
Fruit	Infants	0.10	0.09	3.16	2
Vegetable	Adults	0.16	0.09	2.30	2
Vegetable	Elderly	0.18	0.11	2.55	2
Vegetable	Infants	0.31	0.00	6.07	2

Table 4-9. Chronic HQs by Age Group and Scenario.

Scenario	Age Group	Central Estimate	Lower Estimate	Upper Estimate	RfD
Fruit	Adults	0.01	0.00	0.34	2
Fruit	Elderly	0.01	0.00	0.12	2
Fruit	Infants	0.06	0.00	1.73	2
Vegetable	Adults	0.09	0.05	1.26	2
Vegetable	Elderly	0.10	0.06	1.40	2
Vegetable	Infants	0.17	0.00	3.32	2

Preferred Alternative

If GT alfalfa is deregulated, then there is an increased possibility that the general public will have more sources of exposure to glyphosate through residues in and on food crops and other foods. With the deregulation of GT alfalfa, GT alfalfa will likely be grown in many areas of the country.

The addition of another GT crop to agricultural production may lead to a greater chance that a GT crop, including GT alfalfa may be grown near food crops. This could lead to higher hazard quotients with respect for glyphosate for the general public because there would be more chance for glyphosate residue to affect food crops. Nonetheless, such increase risk of exposure to glyphosate residue will not result in increased risks to the general population because the current upper estimates of risk are based on highly conservative fruit and vegetable intake rates with an assumed high estimated amount of glyphosate residue; thus it is anticipated that only a very small number of individuals, if any, will have this magnitude of exposure and therefore be at this level of risk. Moreover, the potential exists for decreases in the applications and subsequent residues of more toxic herbicides if GT alfalfa is deregulated.

No Action Alternative

If GT alfalfa is not deregulated, there will be an increased possibility that the general public will have an increased exposure to glyphosate residue due to the approximately 200,000 acres of GT alfalfa currently grown. There will also be decreases in applications and subsequent residues of more toxic herbicides in the areas surrounding the 200,000 acres of GT alfalfa currently in production. In the remaining alfalfa acreage that is not planted to GT alfalfa, there will be no change in the current exposure risk to glyphosate residues or to the current exposure risk to the other, more toxic herbicides currently used in alfalfa.

c. Risk Characterization

Risk characterization integrates the information from the hazard identification, dose-response, and exposure assessments, using a combination of qualitative information, quantitative information, and information regarding uncertainties. In general, the way in which glyphosate acts on plants to injure or kill them (through its metabolic pathway) will not occur in humans or other animals, and, thus, the way in which glyphosate affects plants is not directly relevant to the human health risk assessment. EPA considers glyphosate to be of low acute and chronic toxicity by the dermal route of exposure. Glyphosate is considered a Category IV dermal toxicant and is expected to cause only slight skin irritation. This is corroborated by the low HQs determined from the worker assessments, where there is the greatest likelihood of dermal exposure. Workers using the methods of application analyzed above to apply herbicides, and workers who accidentally spill herbicides, are not at risk of adverse effects associated with chronic or acute dermal exposure to glyphosate.

The analysis concerning exposure to the general public considers the possibility that any type of fruit or vegetable could contain residues of glyphosate (see technical report, *Health and Safety Risks from Increased Glyphosate and Other Chemical Usage on Humans (Exclusive of Field Worker)*[appendix L)). Central, upper, and lower estimates of consumption rates were used to estimate exposure and risk for adults, infants, and the elderly. It is anticipated that the results of this analysis are highly conservative for several reasons. First, the upper bound exposure and risk estimates are based on fruit and vegetable consumption rates characteristic of the 100th percentile of the population (the maximum consumption rate). In addition, in assuming a spray drift of one for all scenarios, this analysis assumes that fruits and vegetables will have the same residue of glyphosate as the GT alfalfa will. Application rates are specific to herbicides used to treat GT alfalfa forage fields, which is not meant for human consumption, as opposed to rates specific to fruits and vegetables. Acute and chronic scenarios assume that fruits and vegetables growing in nearby fields will have residues of glyphosate at the same level; however this is a highly unlikely scenario, but used for the purpose of an initial risk assessment before determining whether there is a need for refined consumption, use or residue data.

In terms of chronic toxicity from oral exposure, one of the more consistent effects of exposure to glyphosate is loss of body weight. Other general and non-specific signs of toxicity from chronic exposure to glyphosate include changes in liver weight, blood chemistry (may suggests mild liver toxicity), liver pathology, and in pituitary weight (USDA-FS, 2003). Glyphosate is not a carcinogen, however, and has been classified by the EPA as a Group E carcinogen (evidence of non-carcinogenicity for humans) (EPA, 2006; EPA, 1993).

Preferred Alternative

If GT alfalfa is deregulated in whole, then there is expected to be an overall increase in exposure to glyphosate as discussed earlier because more glyphosate will be use in areas where it may not be used, or used as much as it is now. However, as described above, the overall risk to the general population and workers is not expected to be different than under the current labeled uses of glyphosate. The above data, calculated by the EPA and USDA, show an overall low risk to human health and safety from glyphosate and GT alfalfa. These analyses were designed as worst-case scenarios, and assumptions most likely resulted in an extremely protective estimate of exposure and risk. The use of currently registered pesticide products containing glyphosate in accordance with the labeling will not pose unreasonable risks or adverse effects to humans or the environment. The general population and workers are not at risk from the deregulation of GT alfalfa.

No Action Alternative

If GT alfalfa is not deregulated, glyphosate, along with other herbicides will still be used in the production of conventional alfalfa, GT soybean, GT cotton, GT corn, GT sugarbeet, other conventional crops, and will be used for the 200,000 acres of GT alfalfa currently under production. The use of currently registered pesticide products containing glyphosate in accordance with the label will not pose unreasonable risks or adverse effects to humans or the environment. There will be no change in the current exposure risk to glyphosate residues, as well as no change in the current exposure risk to residues from herbicides currently being used in alfalfa production.

4. Consumption of GT Alfalfa Events J101 and J163

The CP4 EPSPS protein produced by GT alfalfa events J101 and J163 was isolated from forage and characterized using analytical methods capable of assessing the chemical and functional characteristics of the protein (FDA, 2004). As a result of the characterization, it was concluded that the CP4 EPSPS protein produced by GT alfalfa events J101 and J163 was biochemically and functionally equivalent to CP4 EPSPSs produced by other Roundup Ready® crops and to the family of EPSPS proteins that naturally occur in crops and microbiologically based processing agents that have a long history of safe consumption by humans and animals. All of these data and information taken together demonstrate a history of safe experience with respect to GT crops which have been consumed in significant amounts, either directly or as processed products, by humans and animals since their initial commercialization in 1996.

Preferred Alternative

If GT alfalfa is deregulated in whole, then there is no change in risk from consumption of GT alfalfa. As discussed, the evaluation of risk from GT alfalfa consumption is based on factors that do not change based on the amount of GT alfalfa grown. The gene product is safe for consumption, regardless of regulation status.

No Action Alternative

As with the full deregulation alternative, the no action alternative would not change current levels of risk from GT alfalfa consumption. The gene product has been found to be safe for consumption, and other GT products, as well as products from the 200,000 acres of GT alfalfa under production, are currently on the market.

5. Impacts from Changes in Production Practices to Human Health and Safety

As GT alfalfa is adopted, it is expected that glyphosate herbicide will replace other forms of weed control currently used in alfalfa. Heimlich et al. (2000) noted that using glyphosate in the context of GT crops has resulted in the replacement of herbicides that are at least three times as toxic and persist almost twice as long as glyphosate. For example, in cotton and soybeans fields, for the most part, several herbicides were replaced by glyphosate (million pounds reduction): bentazon (-4.4), disodium methanearsenate (DSMA; -0.8), fluometuron (-4.5), imazethapyr (-1.0), metribuzin (-1.5), methylarsonic acid sodium salt (MSMA) (-1.7), paraquat (-2.9), pendimethalin (-14.0), sethoxydim (-1.1), and trifluralin (-13.0).

Preferred Alternative

If GT alfalfa is deregulated, in whole, then there is no change from the above expected impacts. GT alfalfa will most likely become widely adopted, and glyphosate use will increase (as has been shown, in general, with other GT crops). This will likely result in an overall decrease in the amount and number of other herbicides used. If glyphosate replaces more toxic herbicides, as has been shown for cotton and soybeans and currently for the 200,000 acres of GT alfalfa under production, then this will result in less danger of human exposure to toxic chemicals.

No Action Alternative

The assumed risks from increased glyphosate use during production of GT alfalfa occurring as a result of deregulation would not be of concern. The approximately 200,000 acres of GT alfalfa will remain in production, and for these areas, glyphosate use will increase, and the use of the other herbicides will decrease. However, in areas that remain free of GT alfalfa, any concerns with respect to the current herbicides used in alfalfa production will remain.

F. Land Use and Production Practices

1. Implications for Cultivation Practices

Based on the adoption of other GT crops, it is expected that GT alfalfa will replace conventional alfalfa production, especially where alfalfa is highly managed (e.g., west and southwestern States). It is not expected to be adopted in areas where alfalfa is minimally managed and where inputs are low. These areas include pastures, hay fields, and road sides with mixed stands of perennial grasses and other perennial forage legumes and in these same areas in which herbicides are generally not used to control weeds. As discussed in chapter 4.C.1 and 4.E.5, it is expected that glyphosate herbicide will replace other forms of weed control currently used in alfalfa with the adoption of GT alfalfa. However, disagreement

exists over whether overall herbicide usage has increased in the past as a result of herbicide-resistant crops (see chapter 3.D.2).

There has been some speculation that weed-free alfalfa stands may result in longer stand life, which may subsequently cause a change in land use. Extended stand life provides positive economic and environmental benefits because a significant amount of the total production costs over the life of the stand are associated with the establishment year. These costs include those associated with seed bed preparation, seed, fertilizer, herbicides and pesticides (Ward, 2007). After the stand is successfully established, costs diminish, and extending a healthy stand will increase profitability. In addition, increased stand life would result in less tillage of agricultural lands and growth of additional alfalfa harvests. Since alfalfa is a plant that provides nitrogen to the soil due to a *Rhizobium*-legume symbiotic relationship resulting in high fixation rates of nitrogen that is usable by the following crop (Vance et al., 1988), growing alfalfa could possibly reduce the need for nitrogen fertilizers obtained through the utilization of fossil fuels. Thus, removal of weeds in the final years of the stand without crop injury provides the opportunity to maintain a healthy and weed-free stand (USDA-APHIS, 2009).

Crop rotation options may be different between conventional and GT farming systems. Many of the non-glyphosate herbicides have follow-up planting restrictions that limit crop rotation choices in conventional farming. Farmers using GT cropping systems are advised to include some years of non-GT crops in rotation, so there may be limitations in the use of other GT crops if GT alfalfa is used in a rotation plan.

Herbicides that can be used to remove GT alfalfa have rotation restrictions. For example, following clopyralid (Curtail® or Stinger®), pea, lentil, potato, and dry bean cannot be planted for 18 months. Picloram (Tordon®) can only be followed by grasses for the year after application. Sunflower, dry bean, and potato should not be planted for several years following picloram (Miller et al., 2006). Dicamba (Banvel®) should not be used prior to soybean and is also limited seasonally in California (Dillehay and Curran, 2006). Because of these restrictions, alfalfa stand removal and rotation schedules should be closely coordinated. Non-glyphosate herbicides are available to manage alfalfa volunteers in wheat, oats, barley, sugar beet, and corn. Therefore, rotations from GT alfalfa to those crops should be similar to rotations with non-GT alfalfa (Rogan and Fitzpatrick, 2004).

No-till GT corn can be planted directly into alfalfa. In a study comparing no-till GT corn planted into cut or uncut alfalfa and various herbicide applications to control the alfalfa, corn yield was 13 percent higher following herbicide applications to uncut alfalfa. Application of

glyphosate and dicamba at planting resulted in the greatest corn yield. Given that alfalfa is also a valuable crop, whether the corn yield gain is worth the loss of an alfalfa harvest should be weighed (Glenn and Meyers, 2006).

Preferred Alternative

If GT alfalfa is deregulated, the impact of GT alfalfa on the overall amount of land devoted to alfalfa cultivation is expected to be minimal. The decision for use of agricultural or other lands for alfalfa production is largely a market-driven decision, and the availability of a new weed control option where other options already exist is not expected to impact land use decisions to any great extent. However, due to the broad range of weeds controlled by glyphosate, farmers may choose to plant GT alfalfa on fields with greater weed pressure, and if the life of a stand of alfalfa can be extended longer, this might impact land-use decisions and crop-rotation practices. In general, overall land devoted to alfalfa cultivation will be impacted largely by the price of alfalfa hay and not by the availability of GT technology. It is likely, as seen with other GT crops, that glyphosate use will increase. In general, however, glyphosate is more environmentally and toxicologically benign than many of the herbicides that it replaces (Brookes and Barfoot, 2006).

No Action Alternative

The no action scenario would result in no change to current cultivation practices or land use decisions.

G. Physical Environment

Preferred Alternative

1. Impacts on Soils

The deregulation of GT alfalfa is not expected to have an adverse effect on soils. Although the use of GT alfalfa will result in an increase in the use of glyphosate herbicide formulations, glyphosate adsorbs strongly to soil and does not generally move vertically below 6 inches through the soil. Also, glyphosate is rapidly degraded by soil microbes in the environment into AMPA, but observed concentrations of AMPA are many times lower than where toxic effects might occur (Gimsing et al., 2004).

Deregulating GT alfalfa could indirectly benefit the environment through the soil conservation practices of conservation tillage and no tillage, which would increase in popularity (Wiebe and Gollehon, 2006) because of the reduced cost of these practices and the effectiveness of glyphosate in controlling weeds alone, without the need for tillage. Conservation tillage and no tillage practices would improve soil quality by increasing the soil

organic matter that helps soil bind nutrients and prevents the loss to runoff, erosion, and leaching (Leep et al., 2003). Conservation tillage and no tillage practices likely to be implemented with GT alfalfa also have the potential benefit of mitigating potential minor effects on soil biological/chemical properties because it leads to enhanced organic carbon and plant residues in surface soils.

Mowing would be employed to prevent alfalfa flowering in GT alfalfa systems, resulting in compaction of the soil. However, conventional alfalfa is also commonly mowed to prevent flowering, and is also mowed as a weed control technique. The preferred alternative would require less mowing for weed control and could result in less frequent mowing of alfalfa fields and less soil compaction.

Because soil is the habitat for a wide variety of microorganisms, impacts on soil often correspond to impacts on microorganisms. Although many microorganisms produce aromatic amino acids through the same pathway that glyphosate inhibits in plants, there is little empirical evidence to support the conclusion that glyphosate application results in a negative impact on soil microbes and in some cases, field studies have shown an increase in microbial activity (USDA-FS, 2003). In the cases where GT alfalfa is cultivated using no-till or conservation till systems, there may be positive impacts on soil microbes (Giesy et al., 2000). It is noted that GT alfalfa does not alter the symbiotic association with the nitrogen-fixing bacterium *Sinorhizobium meliloti* and does not negatively affect the availability of nitrogen in the soil (USDA-FS, 2003).

No Action Alternative

Under the no action alternative, the 200,000 acres of GT alfalfa currently under production would remain in the field, and at these sites there would be no impact on soils. New plantings of GT alfalfa would require a permit. Under No Action, there would be no potential for the conversion of conventional agricultural systems (alfalfa or other crops) to commercial GT alfalfa fields. This could preclude an increase in the amount of acres managed using conservation tillage and no tillage systems and may result in adverse impacts to soils compared to the action alternatives. Possible impacts under No Action for those areas that do not contain GT alfalfa may include increased soil erosions, decreased organic matter in soils, and disturbances to soil microorganisms.

Preferred Alternative

2. Impacts on Climate and Air Quality

The deregulation of GT alfalfa and the increase in acres of GT alfalfa cultivation is expected to result in greater amounts of glyphosate herbicide application and a decrease in the mechanical tillage of alfalfa fields.

Because glyphosate is not volatile (evaporating readily) at normal temperatures and is not considered an atmospheric contaminant, the deregulation of GT alfalfa is not expected to result in adverse impacts to air quality. If glyphosate is applied aerially, the risk of drift through the air increases, but this can be minimized by limiting aerial application on GT alfalfa. Approximately 2 percent of glyphosate is applied aerially in the United States (EPA, 2009).

Because the use of glyphosate as a post emergence herbicide is expected to result in an increase in no till farming, a corresponding decrease in the use of mechanical tilling by tractors and other equipment would result under if GT alfalfa were deregulated. Emissions related to global warming, ozone depletion, summer smog and carcinogenicity, among others, were found to be lower in GT crop systems than conventional systems (Bennett et al., 2004). Therefore, full deregulation would lead to a small, positive impact on air and climate.

No Action Alternative

Under the no action alternative, for those 200,000 acres currently planted with GT alfalfa, there would be an increase in the amount of glyphosate applied, as well as a decrease in mechanical tillage of GT alfalfa fields. For new, regulated plantings of GT alfalfa, there would be little increase in the amount of glyphosate applied for the cultivation of alfalfa because new plantings of GT alfalfa would be limited for research and require a permit. This would result in no changes from current conditions to air quality, and no changes in air pollution and greenhouse gases made possible by shifting from tillage to no till practices. There is also no change in the type of herbicides applied, either by ground or aerial application. Therefore, there is a possibility that the no action alternative would result in slightly higher adverse impacts to air pollution and greenhouse gas emissions.

3. Impacts on Water and Water Use

a. Surface Water

Preferred Alternative

Deregulation of GT alfalfa would lead to the increased application of glyphosate herbicides, and a decrease in the application of other, more toxic herbicides, in alfalfa cultivation. Herbicides that adsorb strongly, such as glyphosate, will be protected from degradation and volatilization, and will not readily leach to groundwater. Glyphosate will be found in surface water runoff when erosion conditions lead to the loss of surface particles. However, deregulation of GT alfalfa would likely lead to an increase in conservation tillage and no tillage systems, which would result in less mechanical disturbance of the soil during alfalfa cultivation and

thereby decrease the loss of surface soil. Because of this and the fact that glyphosate binds strongly to soil particles, no tillage and conservation tillage could mitigate the increased application of glyphosate by decreasing glyphosate-laden soil particle in surface water runoff (Wiebe and Gollehon, 2006).

GT alfalfa could provide additional benefit to the water bodies fed by surface waters by encouraging the adoption of conservation tillage and no tillage practices in alfalfa cultivation, thereby reducing erosions and decreasing the amount of sediments in rivers and streams. Sedimentation increases the turbidity (cloudiness of the water due to suspended particles) of water bodies, reducing light penetration, impairing photosynthesis and altering oxygen levels, which can cause a reduction food sources for some aquatic organisms. Sedimentation can also cover spawning beds and impact fish population levels. Phosphorous (a major component of fertilizer) bound to soil particles can be transferred to lakes and rivers via soil erosion, giving rise to high levels of phosphorous in surface waters, which may lead to algal blooms that can impact desirable fish populations.

Additionally, the conversion of conventional alfalfa to GT alfalfa would lead to a shift away from other herbicides toward glyphosate for weed control. As described in chapter 4.E.5., the other herbicides used on alfalfa have varying chemical fates, but, in general, most were more persistent and were characterized by higher mobility in soils, making them more apt to continually contaminate surrounding water systems.

No Action Alternative

Under the no action alternative, no impacts to surface waters are expected to result from the increased application of glyphosate and the resulting contamination of surface waters from glyphosate runoff. Other herbicides will still cause impacts to surface waters. However, the no action alternative would not change the amount of agricultural land managed by conservation tillage and no tillage systems and would result in any of the potential benefits to surface waters associated with this practice, except areas near to the 200,000 acres currently planted to GT alfalfa. In this respect, the no action alternative may lead to increased impacts to surface waters due to increased sedimentation and turbidity.

b. Groundwater

Preferred Alternative

Because glyphosate binds strongly to soil, and its low potential to leach into groundwater, deregulating GT alfalfa is not likely to have an adverse impact on groundwater. It is possible that the reduction in number and

type of other herbicides resulting from a transition from conventional to GT alfalfa, could potentially reduce negative impacts on groundwater from those herbicides; however, no studies have been produced to substantiate such a conclusion.

No Action Alternative

Under the no action alternative there would be no change to the impacts on groundwater associated with the cultivation of alfalfa. However, the possibility exists that the no action alternative would inhibit the shift away from herbicides used on conventional alfalfa towards the more environmentally benign glyphosate on those lands not currently under production of GT alfalfa. The continuing use of more toxic herbicides, instead of glyphosate, could result in a more environmentally harmful contingent of herbicides in groundwater; however, no studies have been produced to substantiate this conclusion and more analyses are needed before this relationship can be analyzed in detail.

H. Mitigation Measures

1. Introduction to Mitigation Measures

As defined in the CEQ regulations implementing NEPA (sec. 1508.20) mitigation includes:

- avoiding the impact altogether by not taking a certain action or parts of an action;
- minimizing impacts by limiting the degree or magnitude of the action and its implementation;
- rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
- reducing or eliminating the impact over time by preservation and maintenance operations
- during the life of the action; and
- compensating for the impact by replacing or providing substitute resources or environments.

This analysis has determined that the proposed action of granting nonregulated status to GT alfalfa would not result in significant adverse impacts to the human or natural environment. The measures listed below, if employed, would lessen adverse impacts associated with the proposed action. However, not employing the methods would not result in significant impacts to the human or natural environment. Furthermore, because GT alfalfa is unlikely to pose a plant pest risk and thus, APHIS has no authority to continue to regulate it, APHIS likewise does not have the regulatory authority to require any mitigation measures be imposed on the deregulated GT alfalfa lines. See chapter 4.B through 4.G for a

discussion of specific impacts resulting from the action alternatives. A summary of mitigation measures are presented by resource area below.

2. Mitigation Measures by Resource Area

a. Measures to Minimize Gene Flow

- If the glyphosate tolerance trait moves from GT alfalfa events J101 and J163 to other alfalfa populations in the United States, these individuals, should they arise and where they require control, could be controlled using other available chemical and/or mechanical means.
- Seed growers undergo training and must be licensed to grow GT alfalfa seed.
- Any farmer who purchases GT alfalfa seed for producing hay is required to sign and comply with a mandatory MTA, and although this requirement is not verified by APHIS, APHIS assumes that growers will fulfill their contractual obligations associated with growing GT alfalfa and that Monsanto and FGI will effectively monitor and enforce compliance with their mandatory MTA and Best Practices. The FGI Best Practices for seed growers is the primary mechanism for limiting gene flow. Features of the MTA and FGI Best Practices are as follows:
 - GT alfalfa seed producers may not sell seed to any party other than FGI and growers may not save seed for any purpose.
 - Bee hives cannot be moved out of GT alfalfa until pollination is finished for the year. This prevents pollen being carried via hive between GT and non-GT alfalfa. Grower must indicate main pollinator species on the FGI Seed Grower Contract.
 - Isolation through distance from other alfalfa fields is required. For pollination with leafcutter bees the distance must be greater than or equal to 900 feet, for Alkali bees greater than or equal to 1 mile, for honey bees greater than or equal to 3 miles.
 - FGI reports seed field location and planting date to local seed certifying organizations, which GT-sensitive farmers can refer to in order to certify isolation distances.
 - Stand removal and volunteer management must be sufficient to allow seed certification inspectors to validate stand removal. Stand removal date and method must be reported to FGI and verified.
 - Cleaning requirements for equipment are included in the FGI Best Practices.
 - The Monsanto MTA requires hay growers to harvest at or before 10 percent bloom.
 - The establishment of barriers between fields can mitigate gene flow. Types of barriers can include bodies of water, or other, more attractive plants for bee foraging in between fields. A border of plants at field edges has the benefit of being a buffer

zone, as pollen would be deposited in the border population before leaving a GT alfalfa field.

b. Measures to Reduce Volunteer Alfalfa and Glyphosate Resistance in Weeds

- Less than 100 percent alfalfa stand termination can result in volunteer alfalfa plants in the following crop. Therefore, good stand termination procedures would be an appropriate method of eliminating volunteer GT alfalfa plants.
- The best way to prevent weed shifts is to avoid using the same herbicide year after year, rotate herbicides and crops, and include non-herbicide strategies to control weeds.

c. Measures to Minimize Impacts to the Biological Environment

- Impacts to threatened and endangered (T&E) plants could be mitigated by maintaining application rates below 3.5 lb a.e./A for ground-based application and 0.7 lb a.e./A for aerial application in the counties where listed species would be within 250 feet of GT alfalfa fields. The maximum single use application rate for ground and aerial applications of glyphosate on GT alfalfa is 1.55 lb a.e./A.
- Aerial applications of glyphosate to GT fields can be minimized to mitigate the risk of herbicide drift to non-target plant species. It is estimated that only 2 percent of glyphosate use would be conducted aerially in GT alfalfa.
- Conservation tillage and no tillage practices have the potential to mitigate impacts to aquatic plants through decreasing runoff loaded with glyphosate.
- Conservation tillage and no tillage practices can mitigate the impacts to amphibian habitat by resulting in decreased soil erosion, decreased sedimentation and herbicide residue in runoff, and decreased turbidity in ponds, lakes, and rivers fed by surface waters.

d. Measures to Minimize Impacts to the Physical Environment

- Conservation tillage and no tillage practices likely to be implemented with GT alfalfa also have the potential benefit of mitigating potential minor effects on soil biological/chemical properties because it leads to enhanced organic carbon and plant residues in surface soils.
- No tillage and conservation tillage could mitigate adverse impacts to surface water associated with increased application of glyphosate by decreasing glyphosate-laden soil particles and general sedimentation and nutrient loading in surface water runoff.

I. Other Impacts

1. Unavoidable Impacts

The preferred alternative is the deregulation of GT alfalfa events J101 and J163 under the regulations at 7 CFR part 340 and once deregulated, these GT alfalfa lines can be grown anywhere in the United States. Under the no action alternative, APHIS would not deregulate GT alfalfa events J101 and J163, and they would continue to be a regulated article and permits issued by APHIS would be required for new introductions of J101 and J163 plants. The preferred alternative of granting nonregulated status to GT alfalfa would result in an increase in the amount of GT alfalfa produced in the United States and a corresponding increase in the prevalence of the gene product in the environment. This would also result in a change in alfalfa cultivation and management practices such as tillage practices and herbicide use, which have implications for the human environment. However, if APHIS determines that GT alfalfa does not pose a plant pest risk, then APHIS has no regulatory authority to deny the deregulation of GT alfalfa events J101 and J163; likewise, APHIS would have no regulatory authority or basis to deny the deregulation of the GT alfalfa based on those potential environmental effects of any increase in the amount of GT alfalfa produced in the United States, a corresponding increase in the prevalence of the gene product in the environment, and a potential increase in glyphosate use. See chapter 4.B through 4.G for a discussion of specific impacts resulting from the action alternatives. As described in chapter 4.C, 4.E, and 4.G, the preferred alternative may diminish certain agricultural impacts due to a shift to more environmentally benign herbicide regimes and conservation tillage practices, but only in the instances that GT alfalfa farming directly replaces non herbicide-tolerant crops and that conservation tillage is adopted in GT alfalfa cultivation. GT alfalfa events J101 and J163 are unlikely to pose plant pest risks (USDA, APHIS, 2009). Therefore, APHIS would no longer be able to regulate GT alfalfa events J101 and J163.

2. Short-term Versus Long-term Productivity

The National Environmental Policy Act (NEPA) states in section 102 (42 U.S.C. 4332) that all agencies of the Federal government shall:

(C) include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on --

(iv) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity,...

This portion of the NEPA regulations recognizes that short-term uses and long-term productivity of the environment are linked, and that opportunities that are acted upon have corollary opportunity costs in terms of foregone options and productivity that could have continuing effects

well into the future. The preferred alternative and the no action alternative are not likely to adversely affect the relationship between short-term uses and long-term productivity on the resource categories discussed in this EIS, chiefly due to the low likelihood of short-term impacts on these resources resulting from deregulating GT alfalfa. In fact, it is likely that the preferred alternative would result in an increase in the long-term productivity of alfalfa cultivation and would have no significant adverse impact or may even have a small positive impact on the short-term uses of the environment.

3. Irreversible Commitment of Resources

Irreversible resource commitments represent a loss of future options. It applies primarily to the use of nonrenewable resources and to factors that are renewable only over long time spans. An irretrievable commitment of resources represents opportunities that are foregone for the period of the proposed action. It relates to the use of renewable resources, such as timber or human effort, as well as other utilization opportunities that are foregone in favor of the proposed action. NEPA section 102 (42 U.S.C. 4332) and Council on Environmental Quality (CEQ) regulations (40 CFR 1502.16) require that all agencies of the Federal government shall:

(C) include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on --

(v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

Implementation of the preferred alternative would result in the commitment of natural and man-made resources as the amount of GT alfalfa cultivated in the U.S. would increase. However, this would not represent a significant change over the level of present commitment of resources, nor would it be irreversible. For example, while an increase in the amount of GT alfalfa planted would require more acres of land for agricultural cultivation, data does not indicate that this would result in an irretrievable loss of undisturbed area. It is expected that much of the land that would be used for GT alfalfa cultivation under the deregulation alternative is presently used for agricultural production. Additionally, the overall land devoted to alfalfa is more closely linked to the price of alfalfa hay than it is to the availability of GT technology.

The adoption of the preferred alternative will lead to the increase in the use of glyphosate. The manufacture of glyphosate herbicides would require material and energy inputs, which can be considered irreversible commitments. However, the net impact on these resources is likely to be small, because the use of glyphosate would result in a shift away from other herbicides which also require similar inputs in their manufacture.

There is scientific disagreement over how the overall amounts of herbicide applications change in GT crop systems.

4. Cumulative Impacts

This section describes potential cumulative impacts in connection with deregulating GT alfalfa events J101 and J163. APHIS considered potential impacts of the preferred alternative reported above in chapter 4 of this EIS in combination with the potential impacts of other relevant past, present, and reasonably foreseeable future actions that may have an impact on the same resources. These combined impacts are called cumulative impacts.

Council on Environmental Quality (CEQ) regulations (40 CFR 1500 to 1508) that implement the procedural requirements of the National Environmental Policy Act (42 U.S.C. 4321 et seq.) (NEPA) require a cumulative impacts analysis of the action as part of the environmental impact statement (EIS) process. CFR 1508.7 defines cumulative impacts as:

[T]he impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

In this section, actions that could have effects that coincided in time and space with the effects from the proposed deregulation and associated activities are identified and considered in combination with the impacts of other federal, non-federal, and private actions.

a. Structure of the Cumulative Impacts Analysis

For this EIS, the analysis of cumulative impacts follows the analysis steps described in *Considering Cumulative Effects Under the National Environmental Policy Act* (CEQ, 1997):

- Specify the class of actions for which effects are to be analyzed.
- Designate the appropriate time and space domain in which the relevant actions occur.
- Identify and characterize the set of receptors to be assessed.
- Determine the magnitude of effects on the receptors and whether those effects are accumulating.

b. Class of Actions to be Analyzed

This analysis addresses large, regional and national-scale trends and issues that have impacts that may accumulate with those of the preferred alternative. This analysis does not evaluate site-specific cumulative impacts, primarily due to the speculative nature of when, where, and for what duration GT alfalfa may be cultivated if deregulated under the preferred alternative.

c. Geographical and Temporal Boundaries for the Analysis

As discussed in chapter 2 (preferred alternative), APHIS is proposing the deregulation of GT alfalfa without geographic restrictions other than those mandated at the municipal and state level. GT alfalfa has been cultivated in 1,552 counties in 48 States after it was deregulated in 2005. Therefore, the spatial domain for past, present, and reasonably foreseeable future actions considers the entire nation and in some cases, has international implications. This analysis focuses more on geographic interaction of projects than timing of interactions because the actual timeframes for many of the reasonably foreseeable future actions are uncertain.

APHIS considers reasonably foreseeable actions as those future actions for which there is a reasonable expectation that the action could occur, such as the preferred alternative under analysis, a project that has already started, or a future action that has obligated funding. APHIS has identified activities relevant to the cumulative impacts analysis from reviews of information available from government agencies, such as environmental impact statements, land-use and natural resource management plans, and from private organizations. Not all actions identified in this analysis would have cumulative impacts on all resource areas.

d. Resources Analyzed

Resources evaluated in this cumulative impacts analysis include the resource areas discussed in chapters 3 and 4: Biological; Socioeconomic; Human Health and Safety; Land Use and Production Practices; and Physical Environment. However, as discussed in chapters 4.B through 4.G, the preferred alternative is not expected to result in adverse impacts on all resource areas. Resources that would experience impacts from the deregulation of GT alfalfa in combination with other actions are described, and an analysis of the cumulative effects to the resource is presented below.

e. Magnitude of Effects on Resources

The potential extent of the impacts of the preferred alternative combined with other actions, and the duration of those impacts are considered in determining the magnitude of cumulative effects that impact each resource area. When possible, the assessment of the effects on a resource is based on quantitative analysis, however, many effects are difficult to quantify. In these cases, a qualitative assessment of cumulative impacts is made. The approach taken for this cumulative impact analysis is consistent with the intent of CEQ regulations at 40 CFR 1502.22—incomplete or unavailable information. This regulation directs agencies how to proceed when evaluating effects on the human environment in an environmental impact statement when there is incomplete or unavailable information. While information describing the characteristics and potential effects of other projects and activities within the time and space domain is primarily qualitative and in some cases is incomplete or unavailable, there is enough information to consider the cumulative effects of the deregulation of GT alfalfa. This qualitative approach is used when necessary throughout this section and for each resource area. It can be assumed that if a topic is not discussed or is discussed qualitatively, further details about the topic are either incomplete or unavailable.

As suggested by the CEQ (1997) handbook, *Considering Cumulative Effects Under the National Environmental Policy Act*, this EIS considered the following basic types of cumulative effects that might occur due to the preferred alternative:

- *Additive*—loss of a resource from more than one incident.
- *Countervailing*—adverse effects are compensated by beneficial effects.
- *Synergistic*—total effect is greater than the sum of effects when considered independently.

In the following analysis, cumulative impacts should be considered additive unless designated as otherwise. In the case of most resources that may experience cumulative impacts, the preferred alternative is only responsible for a contribution of an incremental portion the total impact on the resource. The past, present, and reasonably foreseeable connected actions typically contribute to the majority of impacts experienced by the resource, and would continue to have impacts on the resource even if the no action alternative were implemented.

5. Analysis of Cumulative Impacts by Resource Area

a. Biological Impacts

As discussed in chapter 4.C, the preferred alternative has the potential to result in impacts to biological resources; either directly from the GT alfalfa events J101 and J163, or indirectly from the associated application of glyphosate herbicide formulations and its accumulation in the environment. Although no significant adverse impacts are expected as a result of GT alfalfa events J101 and J163, the preferred alternative is expected to lead to the increased use of glyphosate herbicide formulations.

Previous GT crops that have been granted nonregulated status include GT sugarbeet, GT corn, GT cotton, and GT soybean. In 2009, approximately 115,000,000 acres of herbicide-tolerant crops were planted, mostly glyphosate- or glufosinate-tolerant corn, cotton or soybean. There are approximately 200,000 acres of GT alfalfa currently planted. Herbicide-tolerant corn and cotton constitute up 48 percent of the total acres devoted to those respective crops, and herbicide-tolerant soybean comprises 91 percent of the soybean acres planted in 2009. Approximately 59 percent of the sugarbeet crop in the United States is tolerant to glyphosate (roughly 650,000 acres), and adoption in 2009 has been estimated to be 95 percent

(<http://www.ers.usda.gov/Briefing/sugar/background.htm>). Almost 21,000,000 acres of alfalfa were grown in the United States in 2009 (USDA-NASS 2009). In the future, if GT alfalfa were grown on half of all alfalfa acres in the United States, GT alfalfa would constitute approximately 10,500,000 million acres. If the acreage currently planted to herbicide-tolerant crops were to remain the same, approximately 8 percent of the herbicide-tolerant acreage grown in the United States would be GT alfalfa. However, there is no data available to suggest the GT alfalfa would reach 50 percent market share, or be more than 50 percent market share.

In 2005, the amount of glyphosate used on GT soybean during the year was 63 million pounds (a.e.) (Kleter et al., 2007). A study conducted by Purdue University found that approximately 42 percent of 1,200 GT corn growers surveyed used 2 post-emergence applications of glyphosate on GT corn, and up to 76 percent may use a preplant or burndown application of glyphosate (Givens et al., 2009). Using 3 application of glyphosate as an estimate for the United States, in 2005 GT corn received 47 million pounds of glyphosate (a.e.). In GT cotton, approximately 40 percent of growers surveyed in 2005 used 3 post-emergence applications of glyphosate (Givens et al., 2005). If three post-emergence and one preplant or burndown application of glyphosate was used in 2005 in GT cotton, approximately 17 million pounds of glyphosate (a.e.) was used in 2005. Thus, perhaps as much as 127 million pounds of glyphosate (a.e.) were applied in 2005 to GT corn, cotton, and soybean. (This estimate is not an

estimate for the pounds of glyphosate used in the environment; only an estimate for glyphosate use on highly-adopted GT crops in 2005. Glyphosate is used extensively in other agricultural, non-GT crops, lawns, nurseries, forestry, and for restoration of habitat.) Estimating for GT alfalfa, if two applications of glyphosate were applied to GT alfalfa, and GT alfalfa comprised 50 percent of all alfalfa acreage (with no increase in alfalfa acreage over the years), the pounds of glyphosate used on GT alfalfa would be approximately 15.6 million pounds of glyphosate (a.e.), or approximately 12 percent of the glyphosate used in GT crops. In comparison, if glyphosate is used extensively in non-GT alfalfa as a burndown application, a single year use of glyphosate in non-GT alfalfa in 2005 could be as high as 37 million pounds (a.e.). However, that calculation assumes that all non-GT alfalfa would be rotated to a different crop in the same year.

APHIS does not have the authority under the Plant Protection Act to regulate herbicide use associated with GT plants that are granted nonregulated status. The use of glyphosate is regulated by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) restrictions administered by the EPA, which mandate registration and use of all pesticides. EPA includes instructions and restrictions on how glyphosate herbicides can be applied, and has determined that there is no unreasonable environmental risk when used according to the label directions. Violators of the regulations are liable for all negative consequences of their actions, therefore, farmers who use glyphosate are very likely to follow its label restrictions, and adverse impacts from the predicted increased glyphosate use will be minimized. The discussion throughout this cumulative impacts section is based on the assumption that even in the context of FIFRA regulations and label restrictions, there is a chance that glyphosate use would nonetheless result in environmental impacts. This biological impacts section discusses the adverse impacts on plants—threatened and endangered as well as non-target plants—and potentially, amphibians.

The past actions that relate to the cumulative impact of the deregulation of GT alfalfa on biological resources include the deregulation of other GT crops and the shift in herbicide regimes to glyphosate formulations. Glyphosate was first introduced as an herbicide under the trade name of Roundup® by Monsanto in 1974. No calculations or speculation on GT alfalfa's specific impact on herbicide usage have been published, however data are available on the amount of glyphosate applications to GT crop systems in general. Glyphosate use increased more than six-fold between 1992 and 2002, to become the most used herbicide in the United States, mostly due to approval of several GT crops (Gianessi and Reigner, 2006). The transgene responsible for glyphosate tolerance was first introduced in soybeans in 1996, and has been commercialized in several other crops

including cotton, sugarbeet, rapeseed, and corn (http://www.aphis.usda.gov/brs/not_reg.html). Glyphosate usage on GT crops would be dependent on the weather conditions, weed profile, and various other stochastic factors.

As GT alfalfa is adopted, it is expected that glyphosate herbicide will replace other forms of weed control currently used in alfalfa, based on historical information. Using soybeans as an example, the high percentage of adoption of plants engineered for herbicide tolerance (>91 percent of soybeans in the United States in 2009 were herbicide-tolerant) illustrates the shift in herbicide use away from other herbicides and towards glyphosate herbicide formulations (Kleiter et al., 2007). However, as discussed in chapters 3.D.2 and 4.E.5, the actual impact of glyphosate-tolerant crops on herbicide use has not been unanimously concluded. A few studies have claimed that the volume of herbicide use is greater due to GT crops (Benbrook, 2004), while other studies demonstrate a decrease on overall herbicide usage related to the increased use of herbicide resistant crops (Fernandez-Cornejo, 2006; Gianessi and Reigner, 2006; Sakula, 2006; Johnson et al., 2008; Hiemlich et al., 2000).

Benbrook (2004) determined that genetically engineered corn, soybeans, and cotton have led to a 138 million pound increase in herbicide use since 1996, which is a 5 percent increase. According to his calculations, across all crops, genetically engineered crops reduced pesticide use from 1996 to 1998, but from 1999 to 2004, pesticide use increased.

Others have noted that using glyphosate has resulted in the replacement of herbicides that are at least three times as toxic and persist in the environment almost twice as long as glyphosate, (Gianessi and Carpenter, 2000). Trewavas and Leaver (2001) conducted an analysis which revealed that 3.27 million kg of other herbicides have been replaced with 2.45 million kg of glyphosate in soybean fields in the United States. Gianessi and Reigner (2006) noted that an increase in glyphosate usage coincided with a decrease in aggregate amount of herbicide usage by 61 million pounds (of active ingredient) between 1997 and 2002. Much of this reduction occurred in cotton and soybeans, where several herbicides were replaced by glyphosate.

Figure 4-4 (Kleiter et al., 2007) presents the change in herbicide active ingredient per hectare for U.S. GT soybean production.

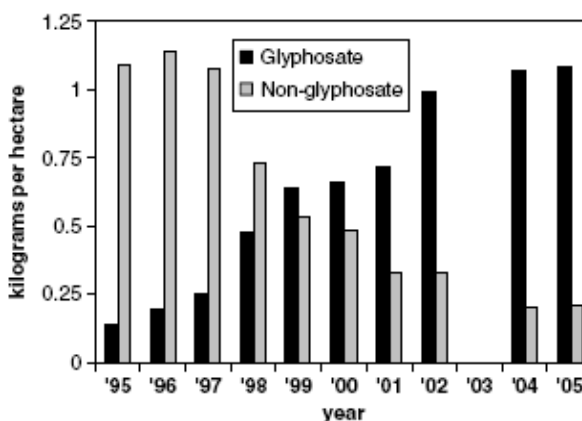


Figure 4-4. Herbicide use in soybeans, percent of total acres, 1995-2005.

As described in chapter 3.B.2, when exposed to glyphosate, or other herbicides, plant species experience high levels of toxicity. When sprayed with glyphosate, plants that use the shikimate pathway to produce aromatic amino acids will experience toxic effects as they metabolize glyphosate. These toxic effects could include the inability to: (a) photosynthesize; (b) complete respiration; and (c) synthesize nucleic acids and amino acids. Although the effects can be slow to progress, all of these toxic effects could result in plant death.

Under the preferred alternative, plant species—including threatened and endangered species—found in the vicinity of GT alfalfa crops may be at risk for increased exposure to glyphosate and a potential for decreased exposure to other herbicides, even though the exposure would be limited if the label use restrictions are followed. Also, human actions such as changes to transportation and energy infrastructure, urban and suburban development, conversion of land for agricultural use, and resource extraction, have the potential to negatively impact plant species, as the actions result in the decrease of available habitat for the plants. The ongoing impacts of widespread human activities resulting in habitat loss, along with the incremental effect of increased exposure to glyphosate resulting from the preferred alternative, could result in cumulative impacts to plant species. These same effects are possible with other future actions resulting in habitat degradation and could result in adverse cumulative impacts on plant populations when combined with the incremental impacts resulting from the preferred alternative. Future actions that could result in habitat degradation include increased pollutant accumulation in the soil over time due to various point and non-point sources, topsoil erosion and runoff from future development (housing or other) and/or pressure from the introduction of invasive species.

The deregulation of other GT crops could also result in cumulative effects to plants. Petitions for Nonregulated Status are pending for GT corn and

creeping bentgrass (http://www.aphis.usda.gov/brs/not_reg.html). If deregulated, the production of these GT crops would lead to increased glyphosate application, and in the instances that it is cultivated in or near the same geographic areas where GT alfalfa is produced, this could lead to a cumulative impact on plants affected by the preferred alternative. In addition, in 2009, GT sugarbeet was commercial grown for the first time. The impact of GT sugarbeet on the cumulative use of glyphosate is minimal, however, because of the relatively small acreage devoted to sugarbeet (less than 1 million acres). For comparison, there are 20 million acres of available alfalfa production which could be converted to GT alfalfa. Additionally, current soybean acreage is 74 million acres, of which over 90 percent (66.6 million acres) are grown using GT soybean (USDA–NASS, 2009).

Legally mandated label use restrictions should decrease the likelihood of these cumulative impacts of increased glyphosate use. Predicting potential cumulative impacts is difficult due to the dynamics of other factors that come into play. For example, cumulative impacts are not likely to occur unless aerial drift or surface water runoff from GT alfalfa and other GT fields reach the same plant species. Even under these circumstances it is unlikely that cumulative impacts to any given plant populations would result unless fields of GT alfalfa and other GT crops were located adjacent to each other, label restrictions were not observed, the decreased use of other, less toxic herbicides did not result in the protection of some plant species, and no other herbicides were used in agricultural production.

The likely adoption of conservation tillage practices in GT alfalfa production (described in chapter 4.C.2.) has the potential to decrease glyphosate-laden sedimentation in surface water runoff, and would lessen some of the impacts of the preferred alternative on plants. Also, practices in application of glyphosate (observing the legally-mandated maximum aerial and ground-based application rates that are governed by FIFRA regulations) would likely decrease the amount of drift and lessen the impacts of the preferred alternative on T&E and nontarget plant species. Either of these could result in a decrease in the incremental impacts on plants due to the preferred alternative, and could, therefore, lower the net cumulative effect of the other actions described above.

Glyphosate is only slightly toxic to amphibians and is not expected to be a risk to amphibian populations. However, amphibians exhibited greater sensitivity to Roundup® formulations than to glyphosate tested as an acid or IPA salt. This could be due to the surfactant (POEA) used in agricultural formulations, which has been found to be potentially more toxic to amphibians and other aquatic animals than the herbicide itself (Lajmanovich et al., 2003). Some researchers have suggested that Roundup® (in combination with POEA, specifically Roundup® Weed and

Grass Killer used in this study) could cause high rates of mortality to amphibians that could lead to eventual population declines (Relyea, 2005). However, the testing methods of this study have been called into question due to the high exposure doses, which exceed application rates of glyphosate, as well as the fact that this Roundup® product is not approved for use in an aquatic setting. Additionally, the impacts of the preferred alternative on amphibians are unlikely because Roundup® Weed and Grass Killer (the glyphosate formulation hypothesized to affect amphibians) is not approved for use on Roundup® Ready Alfalfa. Therefore, the preferred alternative should not result in an increase in the use of this particular product. However, there is a remote possibility that these products may be used on GT alfalfa fields, so their impact cannot be ruled out entirely.

Correspondingly, glyphosate itself is slightly toxic to fishes and aquatic invertebrates, but toxicity data suggest certain surfactants in glyphosate formulations result in a higher toxicity. For GT alfalfa use, glyphosate exposure does not result in risk exceeding levels of concern for fishes or aquatic invertebrates; however, the end use herbicide concentration (Roundup ®) could not be estimated to enable a quantitative risk assessment. Therefore, impacts to fishes and aquatic invertebrates resulting from the preferred alternative cannot be determined. As is the case with amphibians, this does not preclude the possibility that the surfactants found in the end-use herbicide could result in adverse impacts on fishes and aquatic invertebrates.

Habitat loss and degradation are by far the greatest threat to amphibians, fishes, and aquatic invertebrates at present. Habitat loss and degradation can result from several broad classes of actions. These include:

- grazing, logging, mining, and other extractive industries;
- pollution and pesticide use (including pH and metals toxicity);
- dams, other water diversions, and water extraction;
- transportation and energy infrastructure development; and
- urban and suburban development.

In the case of impacts to amphibians, fishes, and aquatic invertebrates, the above activities have the potential to contribute cumulatively to adverse impacts. Glyphosate-laden agricultural water runoff (a minimal effect if label use restrictions are followed) would place an additional stress on populations that could be affected by, ongoing habitat loss leading to smaller populations in the watershed (area of land where all the water that is under it or drains off of it goes into the same place) where the preferred alternative could occur

(<http://www.epa.gov/owow/watershed/whatis.html>). However, the shift to glyphosate from more toxic herbicides may lessen any effects that are due

to agricultural water runoff. Widespread habitat degradation from human activities such as housing construction, transportation infrastructure development, and water pollution could also potentially compound the incremental impacts resulting from the preferred alternative's effects on water quality.

Many species of fishes are being affected by over-fishing, which can negatively impact fish populations. The demand for certain species, such as salmon, has continued to increase while population levels have decreased. A possible overall decrease in fish populations due to incremental mortality from exposure to glyphosate and/or other herbicide formulations, combined with ongoing present and future over-fishing impacts, could result in cumulative adverse impacts to commercially and recreationally valuable species. The stress of the preferred alternative on fish populations is minimal when compared to the stress of over-fishing.

It is important to note that the impact to amphibians, fishes, and aquatic invertebrates resulting from the preferred alternative is uncertain. In addition, tillage practices likely to be adopted under the preferred alternative would lessen potential adverse impacts to aquatic amphibian habitat due to the decrease in erosion and sedimentation (see chapter 4.G.3), and decreases in the use of other, more environmentally harmful herbicides. Additionally, adherence to the label restrictions for glyphosate herbicides has been determined not to lead to unreasonable environmental impacts by the EPA. This minimizes, but does not eliminate the environmental risks of the preferred alternatives.

Plants at risk due to the use of glyphosate are at risk due to the use of any herbicide, as herbicides are made to kill plants. Plants and animals that are in alfalfa fields and surrounding alfalfa fields are currently exposed to herbicides that are currently used in conventional alfalfa production, including glyphosate. Glyphosate is likely being substituted for other more toxic herbicides in GT alfalfa production, compared to non-GT alfalfa production. Cumulatively in alfalfa production, glyphosate is a more environmentally preferred herbicide compared to other herbicides currently used in alfalfa production, i.e., generally less toxic and generally metabolizes more rapidly, and may even decrease the potential of negative consequences to plants and animals that may be exposed to other herbicides in alfalfa production. The commercial planting of GT alfalfa is likely to result in the cumulative increased use of glyphosate. EPA has the regulatory authority to register herbicides and has determined that there is no unreasonable harm to the environment when label restrictions for glyphosate are followed. Additionally, APHIS is not aware of any data indicating that such a cumulative increase in the use of glyphosate will amount to a significant impact on the environment.

b. Socioeconomic Impacts

Glyphosate-Resistant Weeds

GT alfalfa deregulation would likely lead to increased use of glyphosate, in addition to the increased use already fostered by past deregulation of other GT crops, and the decrease of other herbicides used in alfalfa production. If the increased use of glyphosate leads to an increase in the presence of glyphosate-resistant weeds in GT alfalfa—as well as in crops with which GT alfalfa is rotated—then glyphosate would have to be substituted or complemented in farming by other herbicides.

Furthermore, if GT alfalfa is widely adopted in areas where it is a major crop, the potential that alfalfa acreage would overlap with glyphosate-resistant weed locations varies across states, depending on the current occurrence of glyphosate-resistant weeds and the acreage devoted to alfalfa. The current use of glyphosate on other deregulated GT crops such as soybean, cotton, sugar beet, rapeseed, and corn in addition to GT alfalfa, represents the use of glyphosate beyond GT alfalfa and would increase the potential of glyphosate-resistant weed development which may occur in GT alfalfa fields as they become more widespread. Also, possible deregulation of other GT crops would mean increased use of glyphosate, may consequently increase the development of glyphosate-resistant weeds. These actions would have an adverse cumulative effect on the ability to use GT alfalfa for weed management, and would also incrementally increase the potential for glyphosate-resistant weed development.

Although the potential for glyphosate-resistant weeds exists in GT alfalfa, it is important to note that there are no studies or data that equivocally demonstrate if GT alfalfa would directly cause the development of glyphosate-resistant weeds, or where glyphosate-resistant weeds would occur in the environment if GT alfalfa was deregulated, or how widespread glyphosate-resistant weeds would be if GT alfalfa would be deregulated. As stated previously, although GT alfalfa is likely to result in an increased use of glyphosate; that increased glyphosate use does not immediately or directly result in glyphosate-resistant weeds. Because GT alfalfa is a perennial, and the production of GT alfalfa includes mowing, these biological and production characteristics may result in delayed or non-existent glyphosate-resistant weed development and/or delayed or non-existent weed shifts if GT alfalfa is deregulated.

If there are glyphosate-resistant weeds in GT alfalfa fields that require the use of other herbicides for control of such weeds, this would most likely result in an increase in production costs for GT alfalfa. However, the production costs would still most likely be lower than the present

conventional system. In a worst-case scenario, GT alfalfa would be treated as in a conventional system and result in alfalfa hay of quality similar to that of a conventional system. The price of GT alfalfa seed would likely be reduced for the survival of the variety in the market. Another unknown is the availability and environmental profile of new herbicides that may enter the market, and may provide an additional alternative for glyphosate-resistant weeds.

There is some literature on the costs of herbicide use in GT crops that have been previously deregulated. An increase in herbicide costs over time would likely reflect cost effects of increased presence of glyphosate-resistant weeds. However, the existing literature does not indicate that such an increase in costs has occurred to date. Brookes and Barfoot (2005) report that after nine years of GT soybean cultivation, estimates of cost savings actually increased, with savings mostly attributed to reduced herbicide costs. They also report continued cost savings with herbicides in the United States after 8 years of herbicide-tolerant cotton (mostly GT) cultivation and after 6 years of GT canola cultivation.

The continued savings in herbicide costs in GT crops to date does not mean absence of an increase in herbicide resistance, since costs depend not only on the volume of herbicide used but also on prices. It also does not mean increased costs would not still occur in the future. It only means that, to date, there is little evidence of a reversal in the herbicide cost reductions generally identified in GT crops in the United States. It must also be noted that reduced costs with herbicides do not necessarily mean increased economic returns. Fernandez-Cornejo and McBride (2002) noted that the literature on the economic impact of GT soybeans in the United States is mixed, and some farmer surveys show reduced herbicide costs being offset by higher technology fees.

Seed Market Concentration

If acceptance among alfalfa farmers of GT alfalfa is high, there will likely be an increased concentration in the market for alfalfa seed technology. Increased market concentration is often associated with monopoly rents and decreased welfare. Fernandez-Cornejo and Schimmelpenninck (2004) note that the commercial seed market has already gone through a process of consolidation since the early 1990s. The importance of this consolidation is enhanced by the fact that research and development in crop varieties has become mostly a private sector activity in the United States since the late 1980s. Fernandez-Cornejo and Schimmelpenninck (2004) suggest there is some evidence that this market consolidation—in an activity increasingly undertaken by the private sector—has been accompanied by a decrease in the intensity of public

research in crop variety development, suggesting a possible negative impact of market concentration on future research and development.

Feed Costs

A recent USDA document (USDA-ERS, 2008b) suggests feed costs will increase in the coming years due to increased production of corn for ethanol. To the extent that dairy farms are affected by this increase in feed costs, GT alfalfa deregulation may help mitigate these effects by improving the quality of available alfalfa without an increase in costs.

Growth of Organic Markets

Chapter 4.D notes that there is not enough information to predict the impact of GT alfalfa deregulation on organic markets. Any impact, however, will likely be magnified or diminished by the current growth trend in organic markets. As shown in chapter 3, organic alfalfa acreage has grown since 2000. If this growth is associated with a growth in demand for non-GE foods, GT alfalfa deregulation may give additional impulse to the demand for organically certified products. If deregulation increases organic production costs associated with isolation, buffer zones, or relocation, this growth may be slowed.

Export Markets

Deregulation of GT alfalfa could imply losses in exports of alfalfa seed and hay to the main U.S. clients (Saudi Arabia and Japan, for each product respectively). Any losses are unlikely to be regained in the future, since the trust established by lasting commercial relationships is often valued in international trade. The extent of these losses will depend on evolving regulations for trade in genetically engineered crops.

Regulations and markets for GE products are still being largely developed in most countries. In the case of Japan, for example, there is not enough information on whether genetically engineered content in animal feed will become increasingly rejected or accepted by consumers. In the case of an increased rejection, much of this market could be lost, depending on the level of market tolerance (beyond standards) for adventitious presence. In the case of an increased acceptance, the United States may actually benefit from the increased competitiveness of GT alfalfa in a market where competitors (e.g., Australia) are currently gaining ground.

Global Climate Change

Global climate change refers to long-term fluctuations in global surface temperatures, precipitation, ice cover, sea levels, cloud cover, ocean

temperatures and currents, and other climatic conditions. Scientific research has shown that in the past century, Earth's surface temperature has risen by an average of about 1.3 degrees Fahrenheit (°F) (0.74 °C); sea levels have risen 6.7 inches (0.17 meter); Arctic sea ice has shrunk by 2.7 percent per decade, with larger decreases of 7.4 percent in summer, and mountain glaciers and snow cover have decreased (IPCC 2007). Most scientists now agree that this climate change is largely a result of greenhouse gas emissions from human activities. The Intergovernmental Panel on Climate Change (IPCC) recently asserted that, "Most of the observed increase in global average temperatures since the mid-20th Century is *very likely* due to the observed increase in anthropogenic [human-caused] greenhouse gas concentrations" (IPCC, 2007).

A recent U.S. Climate Change Science Program (Backlund et al., 2008) report suggests forage production may benefit from increased temperatures through the lengthening of the growing seasons, but may also be negatively affected by reduced water availability. Precipitation was the main factor determining different predictions of global climate change impacts on alfalfa yields when various studies were compared, with yields more likely to increase in the Pacific Northwest and to decrease in the central regions. The same report suggests both positive and negative effects of global climate change on forage quality are possible and that productivity of dairy cows may decrease with higher temperatures. The quality improvements of GT alfalfa hay may help mitigate some of the potential negative consequences of global climate change on alfalfa and dairy production.

On the other hand, the same report suggests there is some evidence that the effectiveness of glyphosate could be reduced under higher CO₂ levels, and the type of photosynthetic pathway used by weeds (either C₃ or C₄) could play a role.²² Recent research on the impacts of current and increasing CO₂ concentrations in the atmosphere suggest that rising CO₂ concentrations could increase glyphosate tolerance in a C₃ weedy species (Ziska et al., 1999). This finding was supported by another study where a reduction in glyphosate efficacy at higher CO₂ levels was observed concurrently with the stimulation of C₃ weeds in field grown Roundup Ready® soybean (Ziska and Goins, 2006). While in general, relative impacts of increasing CO₂ concentrations have been observed to be greater for C₃ weeds, there have been species –specific responses which demonstrate a range to impacts within C₃ and C₄ weeds. The Ziska and Goins 2006 study on Roundup Ready® soybean concluded that depending on weed species (C₃ vs. C₄), elevated CO₂ can increase weed biomass, decrease yields, and reduce glyphosate efficacy for Roundup Ready® soybean. It is possible that C₃ weeds such as lambquarters and Canada

²² Ziska and Goins (2006) did not investigate the effectiveness of glyphosate under higher CO₂ levels for a third photosynthetic pathway in plants, the CAM pathway).

thistle which are found in GT alfalfa would be affected similarly as CO₂ concentrations increase. This impact of increasing CO₂ concentrations may add to the adverse cumulative effects of development of glyphosate-resistant weeds in GT alfalfa.

Global climate change alone could also result in a cumulative effect to plant species. Global climate change can lead to changes in local and regional temperature and precipitation patterns. When weather has changed to the extent that plant populations are no longer suited to tolerate that area, this can result in population decline, extirpation, or local extinction. Studies have noted the response of biological and chemical characteristics of ecosystems to climate conditions, especially temperature change. Substantial research has examined the effects of climate change on vegetation and wildlife, leading to the conclusion that the changing climate is already having a real and demonstrable effect on a variety of ecosystem types (CCSP, 2008a). As noted in the IPCC report, plants and animals can reproduce, grow, and survive only within specific ranges of climate and environmental conditions (Fischlin et al., 2008). Changes in climate can affect terrestrial ecosystems by shifting range boundaries or densities of individuals within their ranges or causing extirpation or extinction (Rosenzweig et al., 2007).

The potential incremental effect of increased mortality due to glyphosate exposure, combined with larger competition pressures from ongoing species migrating as temperature and precipitation patterns change (Parmesan and Yohe, 2003), could result in substantial population declines or even local extinction of some plant species. However, it is worth noting that the effect of glyphosate use on plant population structure and distribution is small when compared to the impacts of global warming, and the effect of glyphosate use would likely be the same or less than the use of other herbicides. In this respect, global climate change is not to likely magnify the impacts of the preferred alternative, and global climate change, in combination with herbicides more toxic than glyphosate, could still lead to cumulative adverse impacts to plant populations. Historical data for many parts of the United States indicate an increase in the frequency of high-precipitation events (e.g., >5 cm in 48 hours) correlated to global climate change, and this trend is projected to continue for many regions (CCSP, 2008b). This can lead to field flooding, increased sedimentation, and leaching of nutrients and agricultural chemical into surface water. These effects, compounded with the incremental effect of glyphosate runoff expected as a result of the preferred alternative, could also constitute an adverse cumulative effect on aquatic plant species if the comparison was glyphosate use compared to no herbicide use. Again, however, glyphosate is currently used in alfalfa, and is likely to replace other herbicides currently used in alfalfa production if GT alfalfa is deregulated. Thus, the overall cumulative impact of increasing glyphosate

and decreasing other herbicides is likely negligible given the context of conventional agricultural production.

Global climate change may also be affecting amphibian, fish, and aquatic invertebrate populations. While more analysis is needed, the potential impacts of global climate change are clear. Extreme weather events or other factors that would affect the timing of breeding and amphibian life cycles are unlikely to be the primary cause for the observed decline in amphibian populations in many regions. However, global climate change may play an enabling role, or magnify other, more direct causes of mortality for amphibians as well as fishes and aquatic invertebrates (CCSP, 2008b). Although no data are presently available that can be analyzed to determine the combined impact of global climate change and herbicide application on amphibian species, it is possible that the poleward migration of disease agents known to result in increased frog mortality, such as the Chytrid fungus (NSTC, 2008), enabled by a warming climate would have a greater impact on amphibian populations whose vitality has been compromised by exposure to herbicides. Given that glyphosate is less toxic than other herbicides, and would be used instead of more environmentally harmful herbicides in GT alfalfa, it is likely that the increased use of glyphosate in GT alfalfa would have little cumulative effect on amphibians.

A warming climate is expected to increase water temperatures and modify regional patterns of precipitation, and these changes can have effects on water quality. As temperature increases, the ability of water to hold dissolved oxygen declines, and as water becomes anoxic, aquatic species begin to experience suboptimal conditions (NSTC, 2008). This could act in concert with the toxic effects of herbicide exposure to result in adverse cumulative impacts to amphibian, fish, and aquatic invertebrate populations. Given that glyphosate use likely to increase in GT alfalfa, but the use of other more toxic herbicides would likely decrease under the preferred alternative, the cumulative effect of glyphosate use likely be minimal.

Global climate change is also likely to result in increased high-precipitation events throughout the United States (Backlund et al., 2008). An increase of intense rainfall events leading to field flooding would impact amphibians, fishes, and aquatic invertebrates through higher levels of sedimentation and nutrient and chemical leaching in agricultural systems. This has the potential to magnify effects of herbicide use by further increasing the amount of glyphosate accumulation in surface water over what would be expected due to the preferred alternative alone.

Moreover, many fish species depend on spring snowmelt for the water to fill the streams and rivers in which they live and breed. Global climate

change resulting in increase temperatures decreases the amount of winter snowpack (CCSP, 2008b). This can impact the water levels in fish habitat, and may result in an adverse impact to certain fish populations. The potential for cumulative impacts exists if snow-fed streams and rivers are also fed by runoff from GT alfalfa fields. In these cases, the addition of potentially toxic impacts of the herbicide formulations would further impact fish populations already under stress from decreased snowmelt and available habitat. However, the label restrictions for glyphosate should preclude impacts to aquatic habitats.

Previous GT Alfalfa Deregulation Time Period

GT alfalfa was deregulated between June 2005 and March 2007. During this period an estimated 200,000 total acres were planted (Putnam, 2007). This corresponds to 1 to 2 percent of total alfalfa hay acreage. There are no foreseeable cumulative impacts of this deregulation period in the case of alfalfa deregulation. Presumably, the 2005–07 deregulation time period may affect the speed of acceptance of GT alfalfa in the market place, given that some farmers are now familiar with the variety.

Colony Collapse Disorder (CCD)

Incidence of CCD in honey bees emerged in 2007 and the total honey bee population in the United States decreased by 30 percent. Sustained decreases in the honey bee population may affect the cost of pollination, an important cost in alfalfa seed production. Eventual increases in pollination costs will likely be transmitted to seed prices, given that demand for alfalfa seed is highly inelastic (Myer et al., 1998). However, the impact on alfalfa hay farming will likely be minor, given the small participation of seeds on total hay farming costs, and would likely be outweighed by reduced costs from GT alfalfa in the case of deregulation. Sustained incidence of CCD in honey bees could presumably lead to a greater concentration of alfalfa seed production in areas where other bee species, such as alkali bees and leafcutter bees, are more commonly used for pollination. (For more information, see “*Technical White Paper on Colony Collapse Disorder and Glyphosate-Tolerant Alfalfa*” (appendix O)).

Spread of Subspecies “falcata”

Future spreading of the *Medicago sativa* subspecies *falcata*, which is naturalized in the northern and western United States, and is being promoted as a rangeland enhancer for grazing, could result in increased hybridization of *falcata* with GT alfalfa. As discussed in chapter 4.B.4, hybrids with mostly *sativa* parentage are predicted to be hardier than the original GT alfalfa but have less rangeland hardiness than the *falcata*

parent. The *falcata* hybrid possessing the GT trait may potentially become established in rangeland habitats and serve as a reservoir for the GT trait. As the future use of *falcata* increases in rangelands, GT alfalfa seed farmers may have to protect their seed crop from cross contamination with neighboring rangelands. Also, the risk of gene flow from GT fields to organic beef and dairy farmland may increase with the spread of *falcata*. Future spreading of *falcata* may also affect the feral alfalfa populations.

c. Human Health and Safety Impacts

The direct and indirect effects of the deregulation of GT alfalfa to human health and safety are described in chapter 4.E, which concludes that under present and expected conditions of use, glyphosate herbicide does not pose a health risk to humans. Impacts from past actions that add to cumulative impacts related to human health and safety include the past deregulation of other GT crops and the resulting change in herbicide use. As more GT crops were deregulated, glyphosate use increased along with a related decrease in the use of other, more toxic and persistent herbicides (see chapters 4.E.5 and 3.D.2). This impact of other GT crop deregulation, along with the deregulation of GT alfalfa, would result in an increase in exposure to glyphosate for the general public. With more GT crops, there is a greater chance that crops grown for human consumption will be found planted near GT crops, which could result in a greater chance for unintentional glyphosate applications on food crops and a subsequently greater chance for the general public to be exposed. This chance would increase with the deregulation of GT alfalfa. However, glyphosate has been shown to replace more toxic herbicides, so the overall risk to human health, cumulatively, would likely decrease with the deregulation and adoption of GT alfalfa. Thus, the net cumulative result is a likely reduction in the overall exposure to more toxic herbicides for the general public.

There is a risk that the incremental effect of the deregulation of GT alfalfa, when combined with the effect of past deregulation of other GT crops may cumulatively lead to the development of glyphosate-resistant weeds due to the selection pressure of the predominant use of glyphosate. If this happens, farmers would likely adopt herbicide use practices that include different, more toxic herbicides. The risk to human health would then potentially revert to that of current risk assessments based on cultivation of conventional alfalfa.

The Roundup® herbicide (glyphosate) label states that the product can be used for numerous non-crop uses such as airports, apartment complexes, Christmas tree farms, ditches, driveways, dry canals, fencerows, golf courses, greenhouses, industrial sites, landscape areas, municipal sites, natural areas, office complexes, parks, parking areas, pastures, public

areas, railroads, recreation areas, roadsides, schools, sports complexes, storage areas, and wildlife management sites (http://www.monsanto.com/monsanto/ag_products/pdf/labels_msds/roundup_orig_max_label.pdf). The U.S. Forest Service uses glyphosate primarily in conifer release (58.2 percent), noxious weed control (15.5 percent), and site preparation (16.4 percent). Other minor uses (10.3 percent) include hardwood release, facilities maintenance, recreation improvement, right-of-way maintenance, seed orchard protection, wildlife habitat improvement, and other weed control (agricultural, aquatic, or nursery). In 2001, the total annual use of glyphosate by the U.S. Forest Service was approximately 44,700 pounds applied to approximately 19,000 acres, which corresponds to about 0.275 percent of the agricultural use (USDA-FS, 2003). All of these data combines to show that glyphosate is currently a widely-used herbicide, and in numerous applications other than agricultural. The additional incremental increased use of glyphosate that would occur with the deregulation of GT alfalfa, along with the current use as described here, could minimally increase exposure to the general public.

It is not likely that this gene product would be permitted in alfalfa crops grown for human consumption (sprouts) in the near future, but because glyphosate is due for reregistration in 2009, there is a chance that glyphosate regulations may change. However, the exact changes are not known at this time and therefore cannot be incorporated into this analysis. If the regulations do change substantially, then they would have the potential to affect the cumulative impacts of deregulation of GT alfalfa. Global climate change is very likely to have adverse impacts on human health. It is predicted that with global climate change, precipitation levels will increase (Gamble et al., 2008), which could increase runoff and, therefore, increase the chance of contaminating a nearby food crop with glyphosate or with any other pesticide that may have been used.

d. Land Use and Production Practices

The direct and indirect effects of the deregulation of GT alfalfa to land use and production practices are described in chapter 4.F. These include: the expected displacement of other alfalfa varieties where alfalfa is highly managed; the replacement of other forms of weed control with glyphosate; less tillage of soils due to longer stand life; a possible reduction in the amount of nitrogen fertilizers applied; and changes in crop rotation. Factors such as herbicide use, weed resistance, crop rotations, isolation zones and GT alfalfa-free zones all interact cumulatively to impact land use and production practices. However, there are other actions, that when added to the deregulation of GT alfalfa, may cause cumulative impacts to land use and production practices.

The previous deregulation of other GT crops will influence both herbicide use and crop rotations for GT alfalfa. Data and studies have shown that with the introduction of GT crops, glyphosate use has increased and other herbicide use has decreased (see chapters 4.E.5 and 3.D.2). This change in herbicide use that has occurred with other GT crops will most likely continue with the adoption of GT alfalfa. It will encourage the use of glyphosate, as that will be the most cost-effective way of achieving weed-free alfalfa stands. This increased use of glyphosate will replace the use of other herbicides, most of which are more toxic than glyphosate and/or have more negative impacts on the environment than glyphosate. Increased glyphosate use from the preferred alternative would result in an incremental increase in the chance of evolving glyphosate-resistant weeds. If glyphosate-resistant weeds become established in alfalfa, then production practices will revert to those used to manage conventional alfalfa, and growing the crop will once again have those inherent costs. Future deregulation of other GT crops, such as creeping bentgrass or other varieties of corn and cotton, whose proposals for deregulation are pending, would impact land use and production practices in a similar fashion.

The crop rotations necessary for GT alfalfa would be influenced by already deregulated GT crops. Farmers using GT crops are advised to include non-GT crops in rotation, so there may be limitations in the use of other GT crops along with GT alfalfa. The opposite situation is true as well, where the use of GT crops, such as GT corn or GT soybeans, would limit the adoption of GT alfalfa in crop rotations. Farmers must consider these issues when deciding on crop rotations for their fields. Other factors, such as nutrient content and location, would impact crop rotation choices.

Global climate change also has the potential to impact future land use and production practices, as alfalfa cultivation is heavily based on climate. Research has shown that as CO₂ levels increase, as is possible with global climate change, glyphosate loses its efficacy on weeds (Ziska et al., 1999). If this were to happen, then farmers would need to adapt herbicide use and change production practices of GT alfalfa. Thus, climate change may necessitate an increase in the use of glyphosate and could amplify the impacts of the preferred alternative.

e. Physical Environment

As described in chapter 4.G.3, the preferred alternative has the potential to lead to adverse impacts on surface water. This is chiefly due to the chemical fate of glyphosate and its metabolite, which adsorb to soil particles that become suspended in runoff water and can potentially contaminate surface waters as a result of erosion of this soil. Glyphosate will be found in surface water runoff when erosion conditions lead to the

loss of surface soil particles. However, deregulation of glyphosate-tolerant alfalfa would likely lead to an increase in conservation tillage and no tillage systems, which could mitigate the increase application of glyphosate by decreasing sedimentation of glyphosate-laden soil particle in surfac water runoff (Wiebe and Gollehon, 2006). The quality of surface water may also be improved by conservation tillage, as it reduces erosions and decreases the amount of sediments in rivers and streams (see chapters 3.E.5 and 4.G.1 for further discussion on this topic). Additionally, EPA label restrictions result in application rates and practices that have no unreasonable environmental risk.

Past actions contributing to impacts on surface water pollution include agriculture, industry, resource extraction, urban, suburban, and rural development, and other human activities. GT crop systems have led to an increase in the amount of glyphosate herbicide formulations applied in recent years and a decrease in the amount of other herbicides applied.

There are several other actions that have the potential to contribute to cumulative impacts on surface water.

- *Global climate change*—This would lead to high-intensity rainfall events increasing field flooding, sedimentation, nutrient loading, and accumulation of agricultural chemicals in surface waters. The impact of the deregulation of GT alfalfa on surface water would be magnified by high-intensity rainfall events, which could lead to a greater quantity of glyphosate in surface water runoff.
- *Livestock grazing*—Widespread grazing has led to desertification in the western United States, resulting in impacts to surface water via increased sedimentation in runoff. If grazing impacts watersheds that are home to GT alfalfa fields, there is a potential cumulative impact on surface waters due to the sedimentation from grazing, combined with the glyphosate runoff from GT alfalfa.
- *Human activities resulting in non-point source pollution*—These include construction activities, land development, agricultural practices, lawn chemical application, soil erosion, and stormwater runoff. These activities have the potential to cumulatively impact the surface water through sedimentation and pollutants in runoff. If future activities contributing to these impacts occur in watersheds where GT alfalfa is cultivated, there may be potential for adverse cumulative impacts on surface water. Because the impacts would not be a simple incremental increase in the amount of glyphosate in surface water, but would be an interaction of increased glyphosate combined with other pollutants and/or increased sedimentation, the nature of the cumulative impact would be more complex than some of the additive impacts described above.

- *Increase in impervious surfaces*—This has occurred due to the construction of roads, buildings, parking lots, and other impervious structures. This leads to increased quantity and decreased quality of stormwater runoff into watersheds. These actions often have the added effect of removing soil stabilizing vegetation, which increases erosion and sedimentation in water runoff. If future activities contributing to these impacts occur in watersheds where GT alfalfa is cultivated, there may be the potential for adverse cumulative impacts on surface water.
- *Deregulation of other GT crops*—Petitions for Nonregulated Status are pending for GT corn, and creeping bentgrass (http://www.aphis.usda.gov/brs/not_reg.html). If deregulated, the production of these GT crops may lead to increased glyphosate use, and in instances where it is cultivated in the same watersheds where GT alfalfa is produced, this may lead to a cumulative impact on surface water in these areas from glyphosate runoff. GT crops that have been deregulated in the past, such as GT cotton and soybeans, have also led to an increase in the incidence of glyphosate-resistant weeds (USDA, 2008b). As these weeds become more widespread and a problem for GT alfalfa, weed management techniques would adapt in response. Farmers would likely increase their use of mechanical weed control techniques to replace glyphosate use, such as tillage, which could lead to cumulative impacts on surface water from soil erosion and surface water runoff (Fawcett and Towery, 2002).

6. Summary

In conclusion, APHIS examined the cumulative impacts of GT alfalfa and glyphosate use on the biological environment; socioeconomic environment; human health and safety; land use and production practices; and the physical environment. If APHIS were to grant nonregulated status to GT alfalfa lines J101 and J163, any cumulative impact on the human environment attributable to the use of glyphosate would not likely be a significant change to the environment due to the adoption and presence of GT alfalfa plants in alfalfa production. However, in many cases, only a qualitative assessment was conducted due to a lack of available quantitative information.

The past actions that relate to the cumulative impact of the deregulation of GT alfalfa on biological resources include the deregulation of other GT crops and the shift in herbicide regimes to glyphosate. EPA has determined that there is no unreasonable environmental risk when using glyphosate when the user adheres to the label restrictions, as they are legally required to do.

Predicting potential cumulative impacts is difficult due to the dynamics of other factors that come into play. For example, cumulative impacts are not likely to occur unless aerial drift or surface water runoff from both GT

alfalfa fields and other GT fields reach the same plant species, animal species, or sector of the environment. Even under these speculative and hypothetical circumstances, it is unlikely that cumulative impacts to any given populations would result unless fields of GT alfalfa and other GT crops were located adjacent to each other, label restrictions were not observed, the decreased use of other, less toxic herbicides did not result in the protection of some species or environmental attribute, and no other herbicides were used in any agricultural production. Additionally, end use herbicide formulations, including the use of surfactants could not be estimated to enable a quantitative risk assessment. Moreover, the impacts of cumulative use of glyphosate are incrementally small in comparison to the many other much more significant threats to plant and animal species in the environment (such as over-fishing, habitat loss degradation due to grazing, logging, urban and suburban development, transportation and energy infrastructure development, pollution, dams, global climate change, etc.).

If the increased use of glyphosate leads to an increase in the presence of glyphosate-resistant weeds in GT alfalfa—as well as in crops with which GT alfalfa is rotated—then glyphosate would have to be substituted or complemented in farming by other herbicides. Although the potential for glyphosate-resistant weeds exists in GT alfalfa, it is important to note that there are no studies or data that equivocally demonstrate if GT alfalfa would directly cause the development of glyphosate-resistant weeds, or where glyphosate-resistant weeds would occur in the environment if GT alfalfa were deregulated, or how widespread glyphosate-resistant weeds would be if GT alfalfa were deregulated. As stated previously, although GT alfalfa is likely to result in an increased use of glyphosate, that increased glyphosate use does not immediately or directly result in glyphosate-resistant weeds. Because GT alfalfa is a perennial and the production of GT alfalfa includes mowing, these biological and production characteristics may result in delayed or non-existent glyphosate-resistant weed development and/or delayed or non-existent weed shifts if GT alfalfa is deregulated. Thus, we conclude that the increased use of glyphosate does not guarantee an increase in glyphosate-resistant weeds and even with some potential for an increase in glyphosate-resistance weeds, there is no data to confirm such a potential increase in glyphosate-resistant weeds would amount to a significant effect on the environment.

Currently, APHIS is unable to locate enough quantitative information to predict the impact of GT alfalfa deregulation on organic markets. Any impact, however, will likely be magnified or diminished by the current growth trend in organic markets. If this growth is associated with a growth in demand for non-GE foods, GT alfalfa deregulation may give additional impulse to the demand for organically certified products. If

deregulation increases organic production costs associated with isolation, buffer zones, or relocation, this growth may be slowed.

Deregulation of GT alfalfa could imply losses in exports of conventional alfalfa seed and hay to the main U.S. clients (Saudi Arabia and Japan, for each product respectively). If GE content in animal feed becomes increasingly rejected by international markets, much of this market could be lost. If GE content becomes increasingly accepted, the United States may benefit from the increased competitiveness of GT alfalfa in a market where international competitors are currently gaining ground.

The analysis of the direct and indirect effects of the deregulation of GT alfalfa to human health and safety concludes that under present and expected conditions of glyphosate use, GT alfalfa or the glyphosate herbicide are unlikely to pose a health risk to humans. In terms of herbicide use in conjunction with deregulating GT alfalfa, the cumulative impacts related to the past deregulation of other GT crops increases glyphosate use, and decreases in the use of other, more toxic and persistent herbicides. With more GT crops, there is a greater chance that crops grown for human consumption will be found planted near GT crops, which could result in a greater chance for unintentional glyphosate applications on food crops and a subsequently greater chance for the general public to be exposed. This chance would increase with the deregulation of GT alfalfa. However, glyphosate has been shown to replace more toxic herbicides, so the overall risk to human health, cumulatively, would likely decrease with the deregulation of GT alfalfa. Additionally, glyphosate is currently a widely-used herbicide, and in numerous applications other than agricultural. The additional incremental increased use of glyphosate that would occur with the deregulation of GT alfalfa, along with the current use as described here, would minimally increase exposure to the general public.

Past actions contributing to impacts on surface water pollution include agriculture, industry, resource extraction, urban, suburban, and rural development, and other human activities. Glyphosate will be found in surface water runoff when erosion conditions lead to the loss of surface soil particles. However, deregulation of glyphosate-tolerant alfalfa would likely lead to an increase in conservation tillage and no tillage systems, which could mitigate the increased application of glyphosate by decreasing sedimentation of glyphosate-laden soil particle in surface water runoff (Wiebe and Gollehon, 2006). The quality of surface water may also be improved by conservation tillage, as it reduces erosions and decreases the amount of sediments in rivers and streams.

7. Compliance with Statutes, Executive Orders and Regulations

Executive Order (EO) 12898 (US-NARA, 2008), “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,” requires Federal agencies to conduct their programs, policies, and activities that substantially affect human health or the environment in a manner so as not to exclude persons and populations from participation in or benefiting from such programs. It also enforces existing statutes to prevent minority or low-income communities from being subjected to disproportionately high and adverse human health or environmental effects. EO 13045 (US-NARA, 2008), “Protection of Children from Environmental Health Risks and Safety Risks,” acknowledges that children may suffer disproportionately from environmental health and safety risks because of their developmental stage, greater metabolic activity levels, and behavior patterns, as compared to adults. The EO (to the extent permitted by law and consistent with the agency’s mission) required each Federal agency to identify, assess, and address environmental health risks and safety risks that may disproportionately affect children. Each alternative was analyzed with respect to EO 12898 and 13045. Based on the information submitted by the applicant and assessed by APHIS, GT alfalfa lines J101 and J163 are not different than conventional alfalfa and has successfully completed FDA consultation for food and feed use. Therefore, GT alfalfa lines J101 and J163 are not expected to have a disproportionate adverse effect on minorities, low-income populations, or children.

EO 13112 (US-NARA, 2008), “Invasive Species,” states that Federal agencies take action to prevent the introduction of invasive species, to provide for their control, and to minimize the economic, ecological, and human health impacts that invasive species cause. GT alfalfa lines J101 and J163 are very similar in fitness characteristics to other alfalfa varieties currently grown and are not expected to become weedy or invasive (see USDA-APHIS, 2009 for the plant pest risk assessment of GT alfalfa lines J101 and J163).

EO 13186 (US-NARA, 2008), “Responsibilities of Federal Agencies to Protect Migratory Birds,” states that Federal agencies taking actions that have, or are likely to have, a measurable negative effect on migratory bird populations are directed to develop and implement, within 2 years, a Memorandum of Understanding (MOU) with the Fish and Wildlife Service that shall promote the conservation of migratory bird populations. Data submitted by the applicant has shown no difference in compositional and nutritional quality of GT alfalfa lines J101 and J163 compared to conventional alfalfa, apart from the presence of EPSPS. Based on APHIS’ assessment of GT alfalfa lines J101 and J163, it is unlikely that granting nonregulated status to these alfalfa varieties will have a negative effect on migratory bird populations.

a. International Implications

EO 12114 (US-NARA, 2008), “Environmental Effects Abroad of Major Federal Actions,” requires Federal officials to take into consideration any potential environmental effects outside the U.S., its territories, and possessions that result from actions being taken. APHIS has given this due consideration and does not expect a significant environmental impact outside the United States should nonregulated status be granted to GT alfalfa lines J101 and J163. It should be noted that all the considerable, existing national and international regulatory authorities and phytosanitary regimes that currently apply to introductions of new alfalfa cultivars internationally, apply equally to those covered by an APHIS determination of nonregulated status under 7 CFR part 340. Any international traffic of GT alfalfa lines J101 and J163 subsequent to a determination of nonregulated status for the product would be fully subject to national phytosanitary requirements and be in accordance with phytosanitary standards developed under the International Plant Protection Convention (IPPC).

The purpose of the IPPC “is to secure a common and effective action to prevent the spread and introduction of pests of plants and plant products and to promote appropriate measures for their control” (IPPC, 2008); the protection it affords extends to natural flora and plant products and includes both direct and indirect damage by pests, including weeds. The IPPC set a standard for the reciprocal acceptance of phytosanitary certification among the nations that have signed or acceded to the Convention (173 countries as of September 2009). In April 2004, a standard for pest risk analysis (PRA) of living modified organisms (LMOs) was adopted at a meeting of the governing body of the IPPC as a supplement to an existing standard, International Standard for Phytosanitary Measure No. 11 (ISPM-11, Pest Risk Analysis for Quarantine Pests). The standard acknowledges that all LMOs will not present a pest risk and that a determination needs to be made early in the PRA for importation as to whether the LMO poses a potential pest risk resulting from the genetic modification. APHIS’ plant pest risk assessment procedures for genetically engineered organisms are consistent with the guidance developed under the IPPC. In addition, issues that may relate to commercialization and transboundary movement of particular agricultural commodities produced through biotechnology are being addressed in other international forums and through national regulations.

The Cartagena Protocol on Biosafety is a treaty under the United Nations Convention on Biological Diversity (CBD) that established a framework for the safe transboundary movement, with respect to the environment and biodiversity, of LMOs, which includes those modified through biotechnology. The Protocol came into force on September 11, 2003, and

156 countries are Parties to it as of September 30, 2009 (CBD, 2009) . Although the U.S. is not a party to the CBD, and thus not a party to the Cartagena Protocol on Biosafety, U.S. exporters will still need to comply with domestic regulations that importing countries that are Parties to the Protocol have put in place to comply with their obligations. The first intentional transboundary movement of LMOs intended for environmental release (field trials or commercial planting) will require consent from the importing country under an advanced informed agreement (AIA) provision, which includes a requirement for a risk assessment consistent with Annex III of the Protocol, and the required documentation.

LMOs imported for food, feed, or processing (FFP) are exempt from the AIA procedure, and are covered under Article 11 and Annex II of the Protocol. Under Article 11 Parties must post decisions to the Biosafety Clearinghouse database on domestic use of LMOs for FFP that may be subject to transboundary movement. To facilitate compliance with obligations to this protocol, the U.S. Government has developed a Web site that provides the status of all regulatory reviews completed for different uses of bioengineered products (NBII, 2008). These data will be available to the Biosafety Clearinghouse. APHIS continues to work toward harmonization of biosafety and biotechnology consensus documents, guidelines, and regulations, including within the North American Plant Protection Organization (NAPPO), which includes Mexico, Canada, and the U.S., and within the Organization for Economic Cooperation and Development. NAPPO has completed three modules of a standard for the Importation and Release into the Environment of Transgenic Plants in NAPPO Member Countries (NAPPO, 2008). APHIS also participates in the North American Biotechnology Initiative (NABI), a forum for information exchange and cooperation on agricultural biotechnology issues for the U.S., Mexico, and Canada. In addition, bilateral discussions on biotechnology regulatory issues are held regularly with other countries including: Argentina, Brazil, Japan, China, and Korea.

b. Compliance with Clean Water Act and Clean Air Act

This draft environmental impact statement evaluated the changes in alfalfa production due to the unrestricted use of GT alfalfa lines J101 and J163. GT alfalfa is unlikely to lead to the increased production of alfalfa in U.S. agriculture, that is, an increased in the total number of acres planted with alfalfa in the United States. There is no expected change in water use due to the production of GT alfalfa, nor is it expected that air quality will change to do the production of GT alfalfa. If APHIS grants nonregulated status to GT alfalfa, APHIS will be fully compliant with the Clean Water Act and the Clean Air Act.

Appendix A. List of Preparers

List of Preparers

Name, Project Function	Qualifications
APHIS	
Andrea Huberty Project Manager <i>Lead Author for Chapters 1 and 2</i>	<ul style="list-style-type: none"> Ph.D. Entomology, University of Maryland M.S. Entomology, University of Maryland B.S. Ecology and Evolutionary Biology, University of Rochester (NY) 3 years of professional experience evaluating environmental impacts. 15 years of professional experience in insect ecology and population dynamics.
Virgil Meier Senior Biotechnologist <i>Reviewer and Technical Editor</i>	<ul style="list-style-type: none"> Ph.D. Agronomy- Plant Breeding and Genetics, Purdue University M.S. Agronomy- Plant Breeding and Genetics, Purdue University B.S. Agriculture, University of Illinois 5 years professional experience evaluating environmental impacts. 36 years professional experience crop management and development.
ICF International	
<i>Project Management</i>	
Michael Smith Project Manager	<ul style="list-style-type: none"> Ph.D. Sociology, Utah State University M.A. Geography, University of Wyoming B.A. Environmental Studies, University of California, Santa Cruz 16 years of experience in environmental impact assessment.
Nikki Maples-Reynolds Deputy Project Manager, <i>Lead Author for Potential impacts to wildlife, amphibians, plants and ecosystems from increased glyphosate and other chemical usage</i>	<ul style="list-style-type: none"> M.S. Pathobiology, emphasis in Environmental Toxicology, University of Texas at El Paso B.S. Chemistry and Biology, Converse College. Over 7 years of experience in human and ecological risk assessments.
Melissa DuMond, AICP Deputy Project Manager, <i>Preparation of Draft EIS</i>	<ul style="list-style-type: none"> M.N.R. Natural Resource Policy, M.P.A. Environmental Policy and Management, North Carolina State University B.S. Environmental Studies, University of North Carolina at Wilmington. 10 years of experience assessing environmental impacts and the preparation of NEPA documents.

Name, Project Function	Qualifications
Technical / Other Expertise	
Mary Clark Librarian Services	<ul style="list-style-type: none"> ▪ M.L.S. Library Services ▪ 25 years of experience in library services
Elizabeth Dederick Technical Report Lead Author, <i>Health and safety risks to field workers</i>	<ul style="list-style-type: none"> ▪ Ph.D., Environmental Health Policy, Johns Hopkins Bloomberg School of Public Health ▪ Master of Health Sciences, Environmental Health Sciences, Johns Hopkins Bloomberg School of Public Health ▪ M.A., Ethics, Union Theological Seminary ▪ B.A., Renaissance Studies, Davidson College, ▪ 5 years of exposure analysis and risk assessment
Dhyanes Doshi Technical Report Lead Author, <i>Glyphosate-tolerant alfalfa presence in human food and animal feed</i>	<ul style="list-style-type: none"> ▪ M.E.M. Environmental Health and Security, Duke University, North Carolina ▪ B.Pharm. University of Mumbai, India ▪ 4 years of experience in human health and environmental risk assessment.
Steven Hackett Technical Report Contributor, <i>Socioeconomic, Economic, and Trade Impacts</i>	<ul style="list-style-type: none"> ▪ Ph.D., Economics (1989), Texas A&M University, College Station, Texas ▪ Master of Science, Economics (1986), Texas A&M University, College Station, Texas ▪ Bachelor of Science, Agricultural Business/Economics (1983), Montana State University, Bozeman, Montana. ▪ 19 years of professional experience as a tenure-track professor and researcher. ▪ 7 years of experience on various planning-related economic analyses, including economic development strategic plans and EIS's and EIR's.
Kelly Hammerle Technical Contributor, <i>Effects of Glyphosate-Tolerant Weeds in Agricultural Systems</i>	<ul style="list-style-type: none"> ▪ M.P.A. Environmental Policy Emphasis, B.S. Fisheries and Wildlife Sciences. ▪ (East Carolina University, North Carolina State University) ▪ 4 years of experience in environmental analysis. ▪ 1 year of other science-related professional experience
John Hansel Senior Environmental Specialist <i>Preparation of Draft EIS</i>	<ul style="list-style-type: none"> ▪ J.D. Washington College of Law, American University ▪ B.A. Economics, University of Wisconsin ▪ 30 years of experience assessing environmental impacts and the preparation of NEPA documents.
Audrey Ichida, Technical Document Lead Author, <i>Weediness (in crops and in ecosystems), Gene Flow, and Cultivation</i>	<ul style="list-style-type: none"> ▪ Ph.D., University of California San Diego ▪ B.A., Cornell College, Mount Vernon ▪ Graduate and post doctoral work in plant molecular biology and 13 years of experience in risk assessment

Name, Project Function	Qualifications
Penny Kellar, ICF <i>Preparation of Draft EIS</i>	<ul style="list-style-type: none"> ▪ M.S. Ecology, University of California, Davis ▪ B.S. Conservation of Natural Resources, University of California, Berkeley ▪ 23 years of experience working with federal and state agencies, universities, and the private sector in communications about environmental issues and 2 years of experience in NEPA documents
Tanvi Lal <i>Preparation of Draft EIS</i>	<ul style="list-style-type: none"> ▪ M.S.E.S., Specialized – Environmental Conservation and Management, School of Public and Environmental Affairs, Indiana University, Bloomington ▪ M.P.A., Specialized - Environmental Policy, School of Public and Environmental Affairs ▪ B.S., Life Sciences - Biotechnology, St. Xavier's College ▪ 4 years of experience in experience in environmental science, natural resource conservation and management and environmental economics.
Amalia Marenberg <i>Preparation of Draft EIS</i>	<ul style="list-style-type: none"> ▪ B.S., Environmental Science (concentration in Biology), University of Maine at Farmington. ▪ 1 year experience conducting air quality analyses for environmental impact statements and preparing NEPA Documents.
Miguel Matamoros Technical Report Contributor, <i>Socioeconomics, Economic, and Trade impacts</i>	<ul style="list-style-type: none"> ▪ B.A., Economics and History, College of William and Mary ▪ 2 years of experience in economic research, cost-benefit analysis, database management and analysis, and regulatory analysis.
Ami Parekh Technical Report Lead Author, <i>Health and safety risks from increased glyphosate and other chemical usage on humans (exclusive of field workers)</i>	<ul style="list-style-type: none"> ▪ M.P.H., Environmental and Occupational Health, Emory University ▪ B.A., Geology, Colgate University ▪ Over 6 years of experience in human and ecological risk assessments
Julie Reber Technical Report Contributor, <i>Socioeconomics and Ecological Risk</i>	<ul style="list-style-type: none"> ▪ B.S., Biology, Duke University ▪ 4 years of experience in technical analysis, regulatory support, environmental impact assessment support, and risk assessment.
Alex Uriarte Technical Report Lead Author, <i>Socioeconomic, Economic, and Trade Impacts, and Preparation of Draft EIS</i>	<ul style="list-style-type: none"> ▪ Ph.D., Development Studies, University of Wisconsin-Madison ▪ M.S., Economics, University of Wisconsin-Madison ▪ M.S., Business Economics, Getúlio Vargas Foundation, São Paulo, ▪ B.A., Economics, University of São Paulo ▪ 11 years of experience in socioeconomic assessments and studies, and management and monitoring of economic development projects.

Name, Project Function	Qualifications
Jessica Wignall Technical Report Contributor, <i>Gene Flow, Cultivation, and Ecological Risk</i> , and <i>Preparation of Draft EIS</i>	<ul style="list-style-type: none"> ▪ B.S., Biology, University of Virginia ▪ 1 year of experience with environmental impact analyses, regulatory analyses, and human health risk assessments; 5 years of experience with scientific and technical research.
Chris Moelter <i>Preparation of Draft EIS</i>	<ul style="list-style-type: none"> ▪ M.E.M. Environmental Tourism, University of Queensland; B.S. Zoology, University of Wisconsin-Madison ▪ 4 years of experience in environmental impact analysis.
Nate Wagoner <i>Preparation of Draft EIS</i>	<ul style="list-style-type: none"> ▪ M.S. Human Dimensions of Ecosystem Science and Management, Utah State University. B.S. Natural Resources Integrated Policy and Planning, the Ohio State University. ▪ 5 years of experience in environmental impact analysis and public lands planning.

Appendix B. Public Scoping Comments

Public Scoping Comments

Members of the public were invited to participate in the scoping process for this draft EIS through an announcement of a notice of intent (NOI) to prepare an environmental impact statement (EIS) in connection with making a determination on the status of the Monsanto Company and Forage Genetics International (FGI) alfalfa lines J101 and J163 (Docket Number 2007-0044, 73 FR 1198-1200). In this NOI, APHIS asked for comments, data, and information regarding 18 broad, overlapping issues. APHIS also requested the public to provide suggestions for other issues to be discussed or alternatives to be analyzed in the draft EIS. The comment period for the NOI opened on January 7, 2008. During this comment period, which closed on February 6, 2008, APHIS received 242 comments. Comments were made by interest groups, industry representatives, industry trade organizations, farmers, private individuals, State agency representatives, scientists, agricultural producers, and marketing groups. Full text of the comments received during the open comment period is available online at www.regulations.gov.

APHIS received a number of similar comments from glyphosate-tolerant (GT) alfalfa farmers that identified general issues with growing GT alfalfa, and provided information regarding their specific farming operation. Each of these comments addressed the benefits of using glyphosate instead of other, more toxic herbicides on alfalfa, and that these benefits extended not to just the environment, but also to worker safety. These comments also spoke to the high quality of GT alfalfa, and how this improved quality improves farm revenue. The growers included specific information on the crops grown on their farm, acres of GT alfalfa planted, how many applications and types of other herbicides used prior to GT alfalfa, and documented the number of applications of glyphosate these growers used on their GT alfalfa. These comments concluded with a statement that these growers have neighbors that farm using organic farming practices and/or export their product overseas. According to the comment, these GT alfalfa growers have spoken to their neighbors and these non-GT alfalfa growers do not feel that the use of GT alfalfa is jeopardizing their farming operations, and they strongly support the right to choose which products are used by each farmer on their farm.

Other comments received from the public typically were not in direct response to any of the 18 questions specifically identified in the NOI. Therefore, we grouped the comments into 19 main themes. Below is a summary of the comments received for each theme.

1. Potential of Gene Flow between GT and Non-GT Alfalfa

Association of Official Seed Certifying Agencies (AOSCA) submitted a comment describing the seed certification process for alfalfa. AOSCA further describes this certifying process as a long-standing, voluntary, industry-driven approach to certify seed, including GT alfalfa seed. Seed certifying agencies have developed, and AOSCA has approved, the Alfalfa Seed Production Stewardship Program that uses seed certification standards as its foundations, then augments them with additional considerations intended to promote the stewardship of GE traits. Seed producers, whether intending to contain GE traits in their own seed or acting defensively to keep GE traits out, may contact seed certifying agencies to learn more about the Stewardship Program. AOSCA agencies will work with the producer to identify specific needs they may have and assist in tailoring the program to meet producer or market requirements. Seed certifying agencies will

provide third-party oversight and we are confident that this approach will protect the integrity of the alfalfa seed market.

The California Crop Improvement Association (CCIA), a third party certifier of conventional, GE, and organic seed crops, included comments on their:

- work with the alfalfa seed industry to assure the continued integrity and purity of all crops;
- stewardship plans that include voluntarily set isolation distances that are well in excess of the AOSCA/Federal and State Seed Act minimal requirements;
- pinning map program, which documents the presence, location, and size of fields producing GE seed crops;
- certifying several thousand acres of organic alfalfa hay production;
- reading of National Organic Program (NOP) in that the law does not set a zero tolerance for the unintended low level presence of foreign DNA in an organically produced crop;
- belief that producers of a crop need assurance of the genetic purity of their planting stock, and recommends organic seed producers to use organic seed produced under AOSCA certification; and
- record that CCIA has never had an application from a certified organic producer to produce alfalfa seed under an AOSCA seed certification program.

Several GT alfalfa farmers, conventional farmers, scientists, researchers, and those representing farming interests acknowledge that gene flow is not unique to transgenic plants but a natural process. Commenters acknowledge that gene flow from GT alfalfa can occur; however, it is highly unlikely or is minimized due to:

- the current agronomic practice of harvesting alfalfa prior to flowering, and, therefore, no pollen is produced for gene flow to occur;
- production of hay primarily for the dairy market is typically cut a bug stage, economically the best stage;
- use of boundaries;
- alfalfa that is in production for hay or silage is not allowed to fully mature and set seed—alfalfa is typically harvested months before seed could possibly be set;
- seed-seed and hay-seed are the minority (<2 percent) of potential gene flow situations;
- hay-to-hay is the most common situation; scientific evidence shows this situation is manageable and provides the least opportunity for gene flow;
- best management practices in the cleaning and management of seed harvesting and processing equipment are effective in managing admixtures between GE and conventional alfalfa seed;
- coupled with cultural and rotational practices to manage volunteer seedlings, it is likely that seed-mediated gene flow will be very low;
- feral plants have a large disadvantage over commercial fields as they are not managed; there is a reduced chance of synchronous flowering and a high chance they are destroyed by insect, and thus they seldom produce viable seed. The low relative abundance of pollen and pollinators and the high degree of environmental stress on feral plants relative to those within commercial seed production fields will help reduce the likelihood and commercial importance of seed-to-feral and subsequent feral-to-seed or feral-to-hay gene flow risks to near zero;

- better alfalfa growers who have planted GT Alfalfa and their aggressive cutting schedule do not allow the alfalfa plants or weeds to flower and produce seed; and
- some geographical separation for different marketing strategies would minimize pollen flow.

Some commenters were concerned that non-GT alfalfa will contain GT traits, and thus alfalfa seed growers would not be able to sell non-GT alfalfa seed, or GT traits will always be found in non-GT alfalfa. Other commenters were concerned that this issue was not well studied.

Conventional and organic alfalfa growers commented on specific alfalfa management processes that result in alfalfa seed set in hay fields, which would thus encourage gene flow from GT alfalfa into their fields. Some conventional or organic alfalfa growers, members of the public, and interest groups believe that gene flow between GT and non-GT is a hazard and likely to occur. The reasons below were provided by the commenters:

- Alfalfa is a perennial species that flowers over an extended period and requires pollination by bees.
- A small number of alfalfa seed growers that are concentrated in comparatively small geographic areas.
- GT alfalfa has dormant seed and plants will come up year after year even when there is no new seed source.
- Inclement weather prevents farmers from harvesting, thus allowing additional time for the alfalfa to reach sexual maturity and produce pollen.
- Impacts of flooding on gene flow.
- Research contradicts the assertion that transgene flow produces offspring of lower fitness.
- Weed seeds get by in seed cleaning and virtually all of the serious Midwestern weeds have been introduced through hay or hay seed.
- GE pollen will be released to the natural environment and transported via animals, birds, and insects.
- Equipment such as swathers, balers, hopper boxes, harrow-beds, truck, barns, compressors, and containers will provide a pathway for gene flow.
- There are no feasible measures to protect crops from GT alfalfa gene flow.
- Seed movement is through manure spread on fields.
- Honey bees are present in every seed production area yet are ignored for isolation distances when contracting GT alfalfa seed production except California.
- Alfalfa plants can be very long lived and easily become feral and spread pollen.
- alfalfa hay production with non-tenant landowners and inattentive growers allows alfalfa hay fields to go to excessive bloom.

Interest groups, organic farming interests and members of the public were concerned that organic farmers are considered responsible for protecting organic alfalfa from GT alfalfa gene flow. These commenters wanted to focus the responsibility back to the developer of GT alfalfa, or other farmers who grow GT alfalfa. One commenter believed that regulations protecting non-GE alfalfa seed producers should be enacted before allowing widespread dissemination of GT alfalfa.

Concerning gene flow, interest groups, organic and conventional non-GT alfalfa farmers, and organic farming interests wanted the following assessments conducted or questions answered in the EIS:

- Document the genetic diversity decrease from widespread GT alfalfa seed contamination.
- Effects of GE pollen on conventional alfalfa and alfalfa grass hay fields that are also used to produce alfalfa seed.
- Isolation distance requirements to prevent contamination of non-GT alfalfa fields.
- To what extent can organic or conventional alfalfa farmers prevent their crops from being commingled with unwanted, unintended, or unexpected GT alfalfa.
- How will seed be kept separate so that farmers can be assured they are not getting GT alfalfa seed.
- An assessment of gene transfer and the extent to which deregulation of GT alfalfa will affect hybridization between cultivated and feral alfalfa.
- At what gene flow level does APHIS consider the use of mitigation measures such as stewardship practices as a failure due to increasing levels of GT genetic contamination.
- An interest group wanted APHIS to avoid relying on external gene flow scientists who have been paid by Monsanto and FGI to avoid the appearance of bias and unethical research motives.
- Independent research analyzing how long it takes for hard seed to break down in the soil.
- Could a 'marker' be included in GT alfalfa that would have permitted GT alfalfa to have been cleaned out of the conventional seed by special seed cleaning equipment.
- Transfer of GT seed residues from seed cleaning facilities into conventional seed that is subsequently cleaned at the same facility.
- The feasibility of thoroughly removing GT alfalfa seed residues from farm equipment and seed cleaning facilities, given the size of alfalfa seed.
- Assess establishment of volunteer GT alfalfa in fields rotated from GT alfalfa seed or forage production to conventional alfalfa seed or forage production.
- Assess the quantity of alfalfa seed left on the ground after harvest, and the viability of such seed in various rotation scenarios.
- If the GT alfalfa stand is plowed under, what is the viability of unharvested and hard seed after plowing.
- Further study of the soil or other environmental factors fostering increased hard seed prevalence in GT alfalfa.
- APHIS should commission testing of a representative range of conventional alfalfa seed varieties in various alfalfa-producing regions to determine the extent of GT trait presence, and determine the route and cause of contamination wherever possible.
- An assessment of the route and cause of unwanted GE traits in other crops.
- Examine other bees that have not yet been addressed in gene flow studies.
- How long is alfalfa pollen proven viable to zero viability.

2. Difference in Weediness Traits between GT and non-GT Alfalfa

Several commenters felt strongly that the presence of GT alfalfa in agriculture is not likely to increase the weediness traits of sexually compatible and/or feral populations of alfalfa since common agricultural practice for alfalfa is to harvest prior to flowering, and, therefore, the chance of gene flow occurring and creating glyphosate-resistant alfalfa weeds is unlikely.

One commenter was concerned that genetically-engineered (GE) plants will become invasive species, and because the GE versions of non-GE plants look similar, it will be difficult to determine which version is invasive. This commenter advocated the precautionary approach. An interest group believes that gene flow from GT alfalfa to feral alfalfa may increase its weediness potential. Interest groups also called for the following issues related to weediness to be analyzed in the EIS:

- weediness traits evolving in organic alfalfa versus GT alfalfa.
- differences in weediness traits between organic and conventional alfalfa.
- the potential impacts of GT alfalfa introduction on agricultural lands other than alfalfa because it has been reported that alfalfa can be a weed problem in sugar beets, onions, vegetable seeds, orchards, vineyards and in rangeland plants grown for seed.
- according to an interest group, because a tendency to dormancy (i.e. hard seed) correlates with the weediness potential of a crop, the EIS should include a follow up on Monsanto's finding of a two to fourfold increase in the percentage of hard seed in GT alfalfa vs. controls.

Another commenter believed that, although introduced to North America hundreds of years ago, alfalfa is not a weed because alfalfa—

- is difficult to establish;
- does not tolerate unfertile soils, soils that are too acid or too alkaline or soils that are poorly drained; and
- must be nodulated with the proper strain of *Rhizobium*, which is seldom found off-farm.

3. Weed Management Practices in Alfalfa Production

Members of the public, some organic and conventional farmers, and interest groups stated that control of weeds in alfalfa is best done through:

- crop rotations;
- companion crops (oats or grass mixtures were suggested);
- stubble with no-till agriculture;
- vinegar;
- healthy stands of alfalfa;
- light use of glyphosate early in the growing season and between cuttings;
- fertile soil and proper soil pH;
- non-glyphosate herbicides;
- more phosphorus in soil; and
- adequate brix levels.

Interest groups also commented about:

- the assessment of voluntary weed resistance management or stewardship;
- use of mandatory herbicide resistant weed management programs administered by APHIS;
- an assessment of the success or failure of past efforts to limit the spread of resistant weeds through voluntary weed management or stewardship programs;
- why the great majority of alfalfa hay acreage is not treated with any herbicides

- an assessment of weed control should include “best management practices” in conventional and organic alfalfa production; and
- why is herbicide used on the minority of alfalfa hay acreage. One interest group stated that deficient soil fertility, unfavorable soil pH, overly prolonging the life of thinning alfalfa stands, and attacks by disease or nematodes are factors that may make alfalfa more susceptible to weed invasions.

GT alfalfa growers felt that glyphosate herbicide is less toxic, both to humans and the environment, than other herbicides used to control weeds in alfalfa, and needs to be applied less frequently than other, more harmful chemical herbicides. Alfalfa farmers growing GT alfalfa additionally commented on:

- Their compliance with the stewardship requirements for GT alfalfa grown for hay or seed
 - Some farmers mentioned the amount of oversight on the stewardship requirements
 - A seed production manager commented that the GT alfalfa growers he interacted with were good stewards of the technology and followed the strict guidelines imposed by Monsanto and FGI.
- Lack of weed problems related to GT or feral alfalfa in fields or road ways
- Using glyphosate with GT alfalfa allowed them to control weeds that were not easily controlled in conventional alfalfa production, particularly in areas of flood irrigation. A weed scientist notes that growers who have problems with perennial weeds cannot use conventional herbicides to control these weeds in alfalfa. The commenters felt that the use of glyphosate in these areas provides an opportunity to economically produce alfalfa and control perennial weeds. Some of the weeds mentioned include:

▪ Russian knapweed	▪ Chinese lettuce
▪ Tall white top	▪ Morning glory
▪ Field bindweed	▪ Canada thistle
▪ Jenny	
- Weed control using glyphosate allows growers an affordable and economical means of reducing weed pressure in alfalfa
- Some farmers farm in sandy soils and stated that no herbicides were available for acceptable weed control until this technology became available
- A certified crop advisor stated that prior to glyphosate, three different chemicals had to be used to control weeds that persisted in soil for far greater periods and had detrimental effects on alfalfa yields and quality
- The majority of commenters that grow GT alfalfa (and did not submit a form letter as discussed above), and some commenters representing conventional farming interests believe that GT alfalfa is the best option to control weeds in alfalfa stands, stating broadly that less chemical is required than growing conventional varieties
- GT alfalfa farmers and other commenters representing farming interests state that GT alfalfa is a potential solution to the various weed infestations in areas where alfalfa is grown and is preferable to other traditional herbicides as it does not stunt the growth of alfalfa stands
- A commenter from academia suggested that APHIS not only examine the impacts of chemical and non-chemical weed control practices, but also the impact of failing to control weeds by any method

- Another commenter stated that, like soybean, alfalfa already has some glyphosate tolerance to begin with, and as a consequence, glyphosate may not be the best control choice in a worst-case scenario of feral alfalfa in a natural area.
- A commenter suggested that the greatest problem with neighbors is that they moved “to the country” because “it’s so beautiful”, but they do not have the equipment and do not take time to take care of their weeds and help keep it beautiful. They let the weeds go to seed, then they break off and roll across our fields when it is windy and those weeds seed our alfalfa fields.

4. Glyphosate-Resistant Weeds

Some commenters discussed the historical aspects of herbicide resistance in weeds, stating that with each new chemical, there have always been shifts in weed composition and weeds which acquire resistance, and that this is an issue faced with all herbicides, not just glyphosate.

Some commenters suggested ways to prevent weed shifts or resistant weeds, including:

- rotating herbicides (some commenters believe that rotating pesticides has become more of a standard practice due to the understanding of resistance development)
- stacked herbicide resistance traits will add to the sustainability of herbicide use

Some GT alfalfa farmers stated that farmers recognize the potential of herbicide-resistant weeds, and use each herbicide only when necessary at labeled legal rates to control specific target weeds, and farmers would use the “best practices” approach in raising GT alfalfa to minimize glyphosate-resistance weed development.

A weed scientist believes that there is a low risk of glyphosate-resistant weeds developing in GT alfalfa due to glyphosate use during the year of stand establishment. The comment states that glyphosate does not injure the alfalfa and can be utilized as soon as weeds emerge, reducing weed competition with alfalfa and improves alfalfa stand establishment. The comment continues by stating that following the first harvest, alfalfa takes over weed management if a dense stand is achieved, thus, applying additional herbicide is not necessary until several years later when the alfalfa stand begins to thin. The comment concludes stating that with GT alfalfa the majority of growers will not apply multiple treatments of glyphosate and therefore selection for resistant weeds is of low risk. Other GT alfalfa farmers submitted comments that echoed the idea that GT alfalfa and the use of glyphosate would not result in glyphosate-resistant weeds because of the management practices and biology of alfalfa.

Some conventional and organic alfalfa farmers, along with members of the public and interest groups were concerned about glyphosate use on GT alfalfa leading to the development of glyphosate-resistant weeds. Some of these comments also voiced concern that different and expensive herbicides would eventually be required to control new weeds, and believed that these different and more potent herbicides pose risks to the environment and wildlife.

Some commenters were concerned about some poisonous weeds becoming more prevalent because of the use of glyphosate, including nightshade and field horsetail. A conventional seed grower in Montana believes that there is only a three year window before the weeds begin

building resistance to glyphosate. A conventional alfalfa grower was concerned about what might happen with the alfalfa plants that glyphosate cannot kill, and how burdensome the removal will be to the public.

Interest groups, organic and conventional growers, and members of the public described assessments they wished to see in the EIS, including:

- the effect of widespread use of GT crops;
- the impacts of glyphosate-resistant weeds due to GT alfalfa in combination with the:
 - growing adoption of other GT crops;
 - recent introduction of GT crops that allow for increased use of and expanded application window for glyphosate
 - likely introduction in the near future of GT crops
- rotation between different GT crops;
- the potential for spread of glyphosate-resistant weeds via resistant weed seed present in alfalfa seed, and how this might be exacerbated by introduction of GT alfalfa;
- an assessment that encompasses other weed species that have biotypes with confirmed glyphosate-resistance in other countries; and
- the cumulative impacts on weed control costs of the introduction of GT alfalfa against the backdrop of currently grown GT crops, for growers of alfalfa and other crops.

5. Potential Impacts of GT Alfalfa or Glyphosate on Wildlife

A state farm bureau stated that the NOI question regarding endangered species and critical habitat only considers the use of glyphosate on species or habitat; it does not consider that farmers actually have fewer passes in the field due to the use of GT alfalfa, which can have a beneficial impact on species and their habitat.

An alfalfa farmer states that additionally, there is no evidence that glyphosate will harm any threatened or endangered species or organisms that are beneficial to agriculture.

A commenter states that in the short time that we were allowed to plant GT alfalfa we have, in our pheasant hunting operation, been able to establish an alfalfa stand on parts of our farm that would not have let us otherwise as weeds and grasses would have smothered out the alfalfa plants. Alfalfa is second to none to be used for nesting habitat and is a great source of food for deer and other wildlife.

Organic farmers, conventional farmers, interest groups and members of the public requested the following information regarding the relationship between GT alfalfa and wildlife discussed in the EIS:

- the potential interaction of increasing levels of glyphosate in the environment on other animals and creatures, such as frogs and other sensitive animals;
- what happens to deer that eat GT alfalfa;
- the impact of insecticides and herbicides on the biodiversity and productivity of aquatic communities;

- what are the effects on insect breeding and on aerial spraying of insects should GT alfalfa be permitted to be used generally, and what are the health effects of increased spraying of toxic substances and poisons; and
- what range of organic chemical impurities and inorganic chemical impurities from the manufacturing process are detectable in glyphosate that may cause or contribute to negative impacts on threatened or endangered species, insects, or wildlife?

6. Pollinator Concerns

Beekeepers, conventional and organic alfalfa growers, members of the public and interest groups were concerned about the relationship between GT alfalfa and pollinators. Issues included:

- management practices for GT alfalfa prohibit bee colonies near GT alfalfa fields, which may result in adverse effect on honey bees, the beekeepers, and honey production;
- link between colony collapse disorder (CCD) and GE crops ;
- effects of GT alfalfa pollen on bees;
- the use of glyphosate will eliminate any pollinator forage habitat in agriculture; and
- effects of GT alfalfa on pollinators and insects was not well studied

One GT alfalfa grower states he raises leafcutter bees for alfalfa seed pollination, and is not afraid to exposed the bees to this crop.

One farm growing both conventional and GT alfalfa has had a long term relationship with a local beekeeper and has had bee colonies on the land for many years. The commenter states that we are trying to produce high quality alfalfa, we cut before the plant goes into bloom. The commenter notes that the beekeeper feels that GT alfalfa poses no threat to his bees and the beekeeper has seen no change in his colonies since we have planted the fields of GT alfalfa.

Interest groups, beekeeping interests, conventional alfalfa and organic alfalfa farmers wanted the following pollinator-related issues assessed in the EIS:

- establish whether there is any reduction in the nutritional value of GE alfalfa as relates to honeybees;
- what is the impact of variation in the nutritional value of pollen on the environment;
- show the economic impact of crowding out honey and pollinator industry for alfalfa seed production;
- test for safety of GE pollen in honey;
- will honey made by bees foraging on GE alfalfa continue to be readily accepted by consumers who are leery of all GE products;
- can honey obtained from GT alfalfa be sold as organic;
- does glyphosate use in GT alfalfa fields have negative impacts on bee populations and colonies;
- what are the effects of widespread use of GT alfalfa on insects which pollinate agricultural crops;
- what range of organic and inorganic chemical impurities are detectable in glyphosate that may cause or contribute to impacts on bee populations and colonies; and
- do we have scientific evidence showing that CCD is not caused from bees foraging on GT Alfalfa.

One scientist commented on the effects of GE crops CCD. The comment states that although the suggestion has been made that GE crops contribute to CCD, the Colony Collapse Disorder Action plan developed by the CCD Steering Committee and presented in June 2007 found that there is no evidence that the use of GE crops has contributed to CCD. The comment states that evidence against GE crops contributing to CCD include the fact that large bee die-offs have also occurred in Europe where GE crops are not widely grown and extensive laboratory and field testing has indicated a lack of acute and sub-lethal effects on bees exposed to GE-pollen.

7. Effects of Glyphosate in Agriculture

Some commenters pointed out the glyphosate is a salt-based herbicide and goes on to state that weeds like salt and it seems counterintuitive to use a salt-based herbicide to control populations of weeds that prefer salts.

Related to glyphosate use, interest groups, conventional and organic growers, members of the public, and organic farming interests wanted the following assessments conducted or questions answered in the EIS:

- What levels of glyphosate can be expected in the harvested alfalfa crop, and what is the animal exposure to glyphosate residuals in GT alfalfa
- The effect on 'sustainable' environment if glyphosate is widely used on GT alfalfa
- How long does glyphosate take to break down
- Assess potential adverse impacts from application of glyphosate to GT alfalfa with various glyphosate application methods
- Include projections of the amount of glyphosate applied to RR alfalfa in the future
- Assess the impacts on threatened or endangered species of glyphosate use associated with GT alfalfa on plants growing in or near alfalfa fields
- With the extensive use and frequent applications of glyphosate, what period of time will be required to dissipate glyphosate from these lower soil profiles, or prevent the leaching of water soluble glyphosate into ground water
- Are there data gaps in ground and surface water monitoring programs to adequately assess the impacts of glyphosate residues? If so how should these data gaps be addressed?
- How many states with glyphosate in agricultural use routinely conduct water testing that includes testing for the herbicide glyphosate and all known glyphosate residues present or have a potential to be present in the ground and surface water
- How frequently is glyphosate contamination and all known impurities like 1,4-dioxane detected in the ground and surface water monitoring programs in the United States
- How many drinking water alerts been issued by states or municipalities due to glyphosate contamination and glyphosate-related contaminants in the ground and surface water conduct testing
- How many public or private drinking water wells in the United States have been contaminated or permanently closed by glyphosate contamination
- Has Monsanto cooperated with local, state or federal agencies in cleaning up drinking water wells contaminated by glyphosate contamination
- What remediation steps were taken and what was the cost to cleanup drinking water wells in the United States contaminated by glyphosate contamination

- Will Monsanto pay any portion of the economic cost of remediation that may have to be made to cleanup drinking water wells in the United States contaminated by glyphosate contamination
- How much has Monsanto paid to date in cleanup costs for cleanup drinking water wells in the United States contaminated by glyphosate contamination? If Monsanto has not paid, where will the cleanup costs come from?
- Has the U.S. Environmental Protection Agency paid for any of the glyphosate contaminated drinking water cleanup costs in the United States for past contamination
- Has Monsanto or any farmers been sued by private individuals or governmental entities for allegations of glyphosate contamination in drinking water
- What is the cost of providing clean drinking water for residents who have had their drinking water contaminated by glyphosate
- Has Monsanto developed or funded a filtration process for remediating glyphosate from contaminated water?
- How much would it cost for a family with contaminated drinking water to filter 100% of their water adequately to remove glyphosate residues
- Will the U.S., state or local governments pay for any costs for a family for 10 years with contaminated drinking water to filter 100% of their water adequately to remove glyphosate residues
- Comprehensively review and consider all possible biological effects of glyphosate exposure
- Conduct a comprehensive literature review of medical and related studies investigating links between glyphosate and non-Hodgkin's lymphoma
- What is the minimum detectability limit that is performed, how many sample are collected, and what analytical chemical methods to test batches for the presence of organic or inorganic chemical impurities including 1,4-dioxane
- What purification and separation technologies are used, and what is the efficiency, to attempt to remove organic chemical impurities or other impurities from glyphosate production batches including 1,4-dioxane
- Will APHIS investigate and review all of this information in the EIS that glyphosate contains detectable concentrations of 1,4-dioxane evidently as impurities in the polyoxyethylene alkylamine inert ingredients?

A retired academic provided his concerns about the use of glyphosate. He believes that glyphosate:

- Increases disease, reduces nutritional quality, and enhances environmental degradation
- Increases the population of *Fusarium* and other soilborne pathogens
- Extends host range of pathogens
- Is released into the soil environment through plant root exudates where it is toxic to many beneficial soil microorganisms
- Persistence in some soils from common "weed burn down" applications is well documented and countries have a recommended delay period on the label before planting a susceptible crop
- Residual levels inhibit root uptake of the essential micronutrient manganese, and greatly restrict translocation of copper, iron, manganese, and zinc

- Resistant genes reduces the uptake or efficiency of Cu, Fe, Mn, and Zn that are essential trace mineral nutrients for plants, animals, and humans

A foreign citizen was concerned that glyphosate tests are done on the active ingredient only and states that the herbicide formulation has been found by some researchers to be more damaging than the active ingredient alone.

An interest group is concerned about the use of 1,4 dioxane as an impurity in surfactants in glyphosate formulations, the use of glyphosate on its effects on human health, animals, and the environment, and supplied references to studies.

An interest group notes that EPA established a tolerance of 0.5 ppm glyphosate on alfalfa seed to facilitate introduction of GT alfalfa; there were unaware of if glyphosate residues were permitted on alfalfa seed prior to this tolerance decision, and unaware if any tolerance has been established for glyphosate residues on alfalfa hay.

GT alfalfa growers were concerned about the use of other herbicides on alfalfa besides glyphosate, because they felt that glyphosate is safer, both for the plant and for the environment and other herbicides are more expensive and have little effect on weeds. They felt that GT alfalfa will lead to the reduction of more toxic herbicides being used to control weeds in alfalfa. Further, they felt that since glyphosate is so safe to use, harvest restrictions and grazing restriction intervals are all but eliminated.

8. Potential Economic and Social Impacts of GT Alfalfa

Impacts due to the Court-ordered injunction that halted new plantings of GT alfalfa

A regional bank is concerned because as a lending institution commitments are made to producers with the expectation that what they do provides a financial benefit to themselves, contributes to the economy of the region, provides employment, is a sound agricultural practice, and is of course legal. The comment continues: while issues are being explored that may change the decision in time, the fact remains that producers have already invested their capital, borrowed capital and structured their operation around the production of this crop. Because of the long stand life of an alfalfa crop, the negative financial impact of this order on the producer is a reality. In addition, what appears to be ignored is the fact that neither traditional (organic) alfalfa crop producers nor GT alfalfa crop producers benefit from any cross contamination of either crop from a marketing perspective. One can argue the issues surrounding genetic engineering and the environment all day long, but at the end of the day the court has determined with what appears to be a limited amount of information that a business engaged in the legal production of a crop should simply immediately cease to exist.

One alfalfa grower emphasized that farming is a very low margin business. The only way a farmer can stay in business is to be able to grow the best quality and the highest quantity of crops as possible with the most cost effective practices available. The comment states that using GT alfalfa is the only way to grow certifiable, weed-free hay that can be taken into the National Forest without spreading weed seeds as well as alfalfa seeds. Half of the commenter's farm is on hold, waiting for these proceedings to be completed to finish planting with GT alfalfa. The

commenter wishes to not continue our old practices to control the weeds as they do not work effectively on our farm even with spending huge amounts of money on fuel and chemicals and being in the fields 24-7. We believe we should have the right to make a choice as to the kind of alfalfa we plant.

Growers were concerned about the income loss from not being able to plant GT alfalfa seed, including the cost of controlling weeds in conventional seed as compared to GT alfalfa seed, loss of yield, the extra expense in labor of spraying and the cost of running the sprayers, the extra expense in cleaning out the weed seed, and the cost of freight in trucking dirtier seed.

One supply and marketing cooperative found that the regulation of GT alfalfa caused significant losses for alfalfa growers in the Midwest. The comment continues: the release of the first GT varieties drew the immediate attention of the farmer owners of our cooperative. All available GT alfalfa was sold in 2005 and 2006. The level of grower satisfaction surpassed expectations and the cooperative received no complaints about the product. This same commenter referenced the Iowa State University Hay Market News on January 7, 2008: the highest prices were paid for Supreme quality alfalfa hay and as the quality declined the price declined. The commenter noted that no where in this hay market report is there a premium for organic or conventional hay nor is there a discount on GT hay.

One alfalfa grower stated that the re-regulation of GT alfalfa have created a real problem for our farm plan for the next four years. The comment continues: as you know, this perennial crop is planted and grown for four - six years before rotation. After the decision to regulate GT alfalfa this summer, we had to go back in time and plant 900 acres of conventional seed for alfalfa hay production which was scheduled for GT alfalfa. In our area we have a real problem with noxious weeds which can not be transported across state lines in California where our market is located. In the past, we have had trucks rejected at state line due to noxious weeds. GT alfalfa has been the answer to this problem for us, not one rejected load; our quality and production has increased with GT alfalfa.

One commenter felt that the injunction preventing new plantings of GT alfalfa is costing the American farmer millions in lost revenue due the enhanced productivity of this product. In turn the economic impact to the communities in which these farms exist are suffering as well. Other commenters felt similarly, in that the injunction will result in financial harm to growers and seed dealers.

An alfalfa grower feels that this injunction is a crock, nothing more than a fight for a dollar, and guesses this bunch would have us ban tractors and start farming with mules and horses again.

One commenter was concerned that the inability to access GT alfalfa will put us back into the downward spiral of lower quality hay we were in before. The commenter states that in a very short time it will take from us our ability to produce premium grade Race Horse Timothy; it is the only crop that keeps our farms from becoming the subdivisions of another bedroom community to Seattle.

Compensation issues for growers of non-GT alfalfa

Commenters who either grow crops using organic methods or prefer to consume foods that have been grown using organic methods are concerned about who will compensate them for the loss of organic products or the increased cost consumers must bear to continue enjoying organic foods, and who will compensate conventional and organic producers for their losses and/or increased costs.

Alfalfa seed processors are concerned about their liability if they process alfalfa seed that inadvertently contains the GT trait.

An organic association wanted benchmarks developed that establish distinct mileposts and guidelines for compensation of organic farmers and the manufacturers of organic products should their welfare and livelihood be damaged by GE contamination.

An organic association wants a system developed to contain and halt the spread of such contamination should it occur as well as the establishment of remedial actions to address any contamination.

An alfalfa seed producer wanted to know the economic impact of making FGI responsible for the stewardship of their patented genetics of the GT alfalfa.

One commenter stated that GT alfalfa should only be allowed if a farmer who is not growing GE crops is allowed to sue the manufacturer if the GE crop contaminates his crop by whatever means.

One commenter stated that creator of GT alfalfa should be responsible for all adverse effects caused by adventitious presence. Many organic growers and interest groups feel that the non-GE seed grower should not be responsible for keeping GE pollen out of his/her field. That responsibility should fall upon the owner of the technology contained in said GE pollen.

A law professor states that organic growers who sign contracts promising that their alfalfa will be completely free of all detectable traces of GT-alfalfa have voluntarily contracted to meet product specification standards that are above and beyond those required by National Organic Program standards. The commenter continues by stating that organic growers who voluntarily sign contracts setting forth such product specification have obligated themselves to meet that product specification; they have no legal claim against anyone else if they then fail to satisfy the voluntarily accepted product specifications in their own contracts.

Other economic and social impacts

A sustainable agriculture group believes that when cross contamination does occur, it will result in the loss of organic certification.

A law professor states that so long as organic alfalfa growers do not intentionally use GT-alfalfa and take reasonable measures to avoid use and or contact, these organic growers do not lose organic status for their farmland or their organic alfalfa under National Organic Program (NOP) standards. NOP regulations and their accompanying comments make clear that organic farmers are not at risk of losing organic certification for the farm or the product so long as the organic

grower complies with the applicable organic grower plan.

One non-GT farmer feels that if a producer within pollen-drift range plants GT alfalfa my rights to grow conventional hay, seed, will be violated.

One commenter felt that it was very important to hear from organic hay producers and conventional hay producers about how the deregulation of this trait might affect their farms.

One commenter believed that organic farmers have the only true concern seen. The commenter believes that the economic impact to these farms can and should be documented, however, the same impact study should be one done on all the farms that produce alfalfa. The fractional acres of organic farms in the United States as a whole would suffer much less economic impact than if this product did not make it into the hands of all farmers. These farms and the towns they reside are not being supported by the additional revenues that will come.

An conventional alfalfa hay and seed grower states that to reduce fuel costs and unnecessary additional harvesting expenses, his stands grow into bloom, which is conducive for conventional alfalfa seed production on his hay ground. The commenter then states that this seed may be sold as common, vernal. Etc., and the source of income is important to growers such as myself.

Interest groups, organic growers, some conventional growers, and organic farming interests were concerned about various economic and social ramifications of GT alfalfa, and requests the following issues be addressed in the EIS:

- How will hay growers keep GE alfalfa separate from conventional alfalfa
- Who will pay for testing conventional hay to make sure it is GE free
- When the GE alfalfa escapes cultivation and become a weed along road sides, and in waste ground will it be possible to remove all contamination in the future? Who will be financially responsible for cleanup if in the future there is a problem?
- Can low-level presence of GT alfalfa can be marketed as “conventional” or “organic”
- What is the cost of testing to satisfy customers who prefer non-GT alfalfa, at whatever no-tolerance or low-tolerance levels desired
- Who has liability or reestablishment of productivity and beneficial micro flora, detoxifying residual glyphosate in the environment and subsequent non-target effects, and removal of the gene from non-target alfalfa
- The costs of implementing effective measures to prevent (not just mitigate) transfer of the GT trait to conventional, organic and feral alfalfa
- Survey domestic and foreign alfalfa purchasers to determine their rank-order preference for organic alfalfa, conventional alfalfa, and GT alfalfa
- Survey prices offered for each type of alfalfa
- Assess the loss of premiums for organic alfalfa resulting from the presence of the GT trait in non-GT alfalfa supplies
- Assess the financial viability of organic alfalfa or GE-free alfalfa cultivation with reduced premiums
- Assess opportunity costs from loss of the option to cultivate GE-free conventional and organic alfalfa occasioned by the introduction of GT alfalfa

- An assessment of the likely shift of organic/GE-free conventional alfalfa seed and forage production to countries whose farmers can guarantee GE-free supplies.
- Assess costs borne by conventional/organic farmers in attempting to avoid transgenic contamination, including but not limited to: purchase or lease of land to create larger buffers separating them from GT alfalfa producers; and any other changes in cultivation practices (e.g. temporal isolation) forced on conventional/organic growers to avoid transgenic contamination
- Formulate and analyze various mechanisms by which GT alfalfa growers and/or companies selling GT alfalfa can be required to compensate organic and conventional alfalfa farmers for loss of markets or loss of income (i.e. premiums) from transgenic contamination of alfalfa supplies for markets that reject such supplies due to presence of GE content
- Formulate and analyze various mechanisms by which GT alfalfa growers and GT alfalfa seed suppliers can be required to compensate organic and conventional growers for their increased expenses associated with GE content testing and attempts to avoid transgenic contamination of their alfalfa
- Assess the long-term consequences of GT alfalfa introduction on the viability of private and any remaining public-sector alfalfa breeding programs in the U.S.
- What are the costs of breeding out an inadvertently-introduced GT alfalfa trait?
- What are the financial consequences of contamination for United States breeders of conventional alfalfa?
- What losses may be expected from a shift of alfalfa breeding programs to other countries where transgenic contamination of experimental alfalfa varieties can be avoided?
- How much is 'low-level' presence of GT alfalfa in non-GT alfalfa?
- What is the negative economic impact to retailers and wholesalers if they lose sales of organic alfalfa sprouts and other organic alfalfa food products because the organic alfalfa food items are contaminated with GT alfalfa ingredients and little or no organic alfalfa is available?
- What is the negative economic impact to retailers and wholesalers if they lose sales of organic alfalfa sprouts and organic alfalfa food products because consumers are concerned about the threat of contamination by GT alfalfa ingredients?
- What is the negative economic impact to organic and conventional alfalfa growers if they lose sales of organic (and conventional) alfalfa sprouts and organic alfalfa food products because the organic (and conventional) alfalfa items are contaminated with GT alfalfa ingredients and no organic alfalfa is available?
- What is the negative economic impact to organic and conventional alfalfa growers if they lose sales of organic (and conventional) alfalfa sprouts and organic alfalfa food products because organic food retailer and wholesalers refuse to buy these food items due to their concerns about the threat of contamination by GT alfalfa ingredients?
- What is the negative economic impact to organic and conventional alfalfa growers if they lose sales of organic (and conventional) alfalfa sprouts and organic alfalfa food products because consumers refuse to buy these food items due to their concerns about the threat of contamination by GT alfalfa ingredients?
- What are the range of economic costs to organic or conventional alfalfa seed growers of having to conduct annual DNA tests of their alfalfa seeds for the presence of GT gene contamination?

- What is the range of economic costs to organic or conventional alfalfa farmers/growers of having to conduct annual DNA tests of their alfalfa seeds and alfalfa crops for the presence of GT gene contamination?
- What extent of alfalfa seed and alfalfa crop DNA testing will be needed to be performed each year by organic and conventional alfalfa farmers to sample their alfalfa seeds and alfalfa crops for the presence of GT gene contamination?
- What is the range of economic costs passed on to consumers who consume products derived from organic or conventional alfalfa if the farmers have to conduct annual DNA tests of their alfalfa seeds and alfalfa crops for the presence of GT gene contamination?
- What is the range of economic costs to organic or conventional food retail and wholesale companies of having to conduct annual DNA tests of their alfalfa seeds and alfalfa crops for the presence of GT gene contamination?
- What is the range of economic costs to organic or conventional alfalfa farmers if they had to label their GT contaminated alfalfa seeds and alfalfa crops when the presence of GT gene contamination is detectable?
- What are the economic costs to food retailers or wholesalers if they had to label their GT contaminated alfalfa seed products and alfalfa food items when the presence of GT gene contamination is detectable?
- What would be the costs borne by a company such as Monsanto to pay for GT testing if their GT alfalfa crop contaminates neighboring non-GT alfalfa crops?
- Examine historical data to evaluate trends in selling prices for conventional and organic alfalfa, in particular premiums offered for organic alfalfa. Based on these data and current trends, APHIS should project the selling price and premiums for organic alfalfa for at least one decade into the future.
- APHIS' analysis should accept the need to preserve the option of farmers to grow and market organic alfalfa free of unintended transgenic content in all alfalfa-growing areas, now and in the future.
- How will GT alfalfa affect the cattle market value?

One commenter believes that the need for establishing a GE Free or conventional production zone is to be able to continue to sell alfalfa seed to the organic seed markets with the lowest possible occurrence of adventitious presence. The commenter states that seed from this production area has been sent for the organic hay market for seed planting and the one thing that is requested by the organic growers and the organic certifier is a letter of verification of production of conventional seed production.

Seed producers, cleaners, and hay producers will all lose if common seed, which is less expensive, becomes contaminated and eventually eliminated.

One commenter believed that organic and non-organic producers have co-operated amiably to mitigate the potential for contamination.

From an alfalfa seed grower: alfalfa growers will have a difficult time competing with corn growers from a profitability standpoint if we are not allowed to utilize the genetic advances already available to corn growers. This schism will be accentuated as new genetically modified

traits become available for corn and future advances in alfalfa are squelched as a result of this action against alfalfa.

An alfalfa grower stated that our main goal is to supply high quality hay to our dairy customers. The commenter continues: of the 27,000 tons we produced in 2007, approximately 20% had enough grass to warrant a reduction in price. These reductions ranged from \$10-15 per ton and we lost approximately \$50,000 as a result of the deductions for grass. The commenter stated that grass is a prevalent problem in our area and dairymen closely scrutinize the bales and expect a deduction for any grass that is present: none of our GT fields had any grass present and we would expect this to be the case for the entire life of these stands.

An alfalfa producer states that GT alfalfa is essential to stay profitable in the alfalfa business, and to provide a quality product for consumers.

An alfalfa farmer believes that where sandy soils prevail organic farming is an insult; we do not desire to return to the dirty 30's, which is what organics would do. In the commenter's opinion, "organic farming" is only a smart marketing tool, and really is a method to sell sub-par quality products to an uninformed public at a premium price.

A GT alfalfa grower feels that GT alfalfa fields are much cleaner, produced more alfalfa, use less herbicide than the conventional alfalfa fields and less fuel is used in GT alfalfa fields because of the fewer trips across the field for spraying and raking the hay.

A group of academic pointed out that the primary commodity for alfalfa is forage hay and not seed. This group believes that there is no documented certified organic seed in the United States, although there is likely a small proportion grown organically. The commenters state that there is no doubt that the organic market will grow with demand from organic dairies, but it will likely remain the minority of total production, even if it grew 10 fold.

9. Potential Trade Impacts of GT Alfalfa

One commenter believes that because of the potential for disruption to the seed trade environment, GT alfalfa seed production needs government regulation and oversight.

A conventional alfalfa seed farmer, who has grown seed for Argentina, Saudi Arabia, France and Turkey, is cognizant of pollinators and the distance they travel and, because of those factors, does not raise any GT alfalfa seed in our area of over 8,000 acres. The commenter states he is aware of both the sensitivity of some markets of GE traits and the great benefits that genetic engineering has brought to American agriculture. The commenter believes that the Best Management Practices formulated by NAFA can lead to a coexistence between seed grown for organic agriculture, export markets, and GT markets.

A conventional seed grower group believes a GE Free or conventional production zone is needed to export conventional alfalfa, because alfalfa hay growers in the Pacific Northwest who export their hay to foreign countries want the reassurance that the seed that is planted is conventionally

grown so they can assure GE-free hay. This group states that they recognize that foreign governments have accepted GT alfalfa, but not all end-use buyers.

A regional hay grower group supports the advancement of technology and science to keep agriculture viable and productive, however they do not want GT alfalfa released until market acceptability and approval in all markets, assurances of public food safety, and proof that use of GT alfalfa will not contribute to the development of glyphosate resistant weeds rendering glyphosate useless for future use has been assured.

A hay exporter states although the Japanese government has approved the sale of GT alfalfa, Japan's marketplace (importers, agricultural cooperatives and dairymen) does not want to buy GT alfalfa.

An GT alfalfa grower states that his primary crop is Timothy hay, which he exports to Japan, but blue grass is beginning to infest fields. The blue grass infestation then reduces premium grade Race Horse Timothy to lower grade cattle hay. We have tried many types of crop rotations including regular alfalfa, and GT alfalfa is the first crop to show the potential solution to this blue grass problem. The commenter continues: while there seems to be a lot of talk about non-acceptance of GT alfalfa, we were able to export our crop last year to both Korea and Japan; both customers knew it was GT alfalfa and we have Japanese and Korean buyers standing in line to buy this product at a premium price.

Interest groups, some conventional alfalfa growers, some organic alfalfa growers, and some members of the public requested the following information or assessments regarding trade impacts of GT alfalfa included in the EIS:

- What will the effects of widespread contamination with unwanted GT alfalfa be on exports to Europe of organically certified dairy products and meat in situations where the importing country or group of countries does not permit feeding of GT alfalfa for these products
- What are the effects of other products of the widespread use of GT alfalfa
- One commenter stated that in 2007 FGI bought a seed production facility in Alberta, Canada to produce GE free alfalfa seed for sensitive markets. The commenter wants to know why would the company that is in charge of trait stewardship of GT alfalfa, that knows the GPS coordinates of every seed and hay field, and has placed every GE alfalfa seed production contract feel the need to purchase their first seed production facility in another country in order to produce alfalfa seed for sensitive markets?
- Will GT alfalfa eliminate sales of the beef to foreign countries
- A thorough economic review of the GT alfalfa trade impacts on export markets.
- Will APHIS avoid relying too extensively on economic data provided by Monsanto and FGI due to their vested interests in GT alfalfa

10. Mitigation/Coexistence/Farmer Choice Issues

Coexistence possibilities

Two national grower organizations commented on the issue of coexistence between GT, conventional and organic alfalfa. These organization stated concerns must be addressed in a

sensible, reasonable and practical manner, and detractors of biotechnology overlook the fact that coexistence is not an offshoot of biotech crops. Other comments

- For 10 years, biotech corn and other systems have coexisted with appropriate control measures
- Corn farmers have practiced coexistence for years through the side by side production of commodity corn and specialty corns such as white or food grade, or hybrid seed production
- Each of these non-commodity corns has distinct marketing specifications that require controlling pollen flow
- Although alfalfa has certain unique agronomic characteristics, coexistence is still managing pollen flow. Since the vast majority of alfalfa is harvested before a viable seed is produced, coexistence is not an issue.
- While alfalfa seed production does present some additional challenges, we are confident the seed industry can easily modify production systems to maintain seed purity
- Finally, we emphasize that the National Organic Standards still requires organic producers to demonstrate they are employing buffers or other control measures as part of their process
- Whether it is seed production, feed production or food production, we can and we have all existed together in the safe and continued advancement and expansion of these technologies in other commodities for many years, and we are confident that the alfalfa industry can and will do the same under the same responsible yet practical approaches employed by other commodities or industries utilizing the same technologies.

One commenter is very active in international alfalfa seed markets and believes that traditional markets, such as these, should not be unduly disrupted by the introduction of biotechnology. The commenter believes that over time these sensitivities will decrease, but in the interim the industry wants and needs to provide international customers with the products they call for, which requires developing methods, procedures and enforcement that enable coexistence.

A seed grower comments that he has seen the steps involved in minimizing the potential harm to growers who choose not to grow GT alfalfa. The commenter continues: FGI has been diligent in our Best Management Practices training, and in overseeing our production process, and believes the EIS process will further delineate the steps needed to assure that all concerned parties will be protected. The commenter feels that coexistence strategies should be developed that not only protect those who choose not to grow GT alfalfa, but also to protect my right to access the beneficial GE technologies that have been proven safe and effective in other crops.

A university researcher believes that it is more important to ask: 1) Is the risk of gene flow difference in magnitude or impact than any other common neighbor effects, and 2) Can steps be taken to keep contamination to a low enough level so that it does not impact neighbors' markets. The commenter states that there is a whole series of neighbor effects that could impact neighbors, including pesticide drift, runoff from manures, or other effects from neighbor to neighbor, and organic farmers are not immune either: they might have trouble controlling insects that move into neighbor's fields, causing harm. The commenter feels that coexistence between these two methods are technically feasible and steps have been taken by industry groups to assist in this process. However, for coexistence to work, the commenter believes that there must be a

willingness on the part of the parties to make it work: if parties state that coexistence is impossible, I suspect that indicates a lack of willingness to attempt to make it work.

One commenter believes that those who wish to use this technology should have the option. As a grower of both conventional and GE alfalfa for both hay and seed production, the commenter feels that it is possible for all parties to be able to coexist successfully: if this industry is going to compete in the world market and continue to meet the needs of our consumers then we must learn how to use the technology that is available to us.

One commenter believes that the American farmer is a good steward of the land and will use this technology as a management tool to insure delivery of a quality product to the market. The commenter supports this technology and will defend the right of the American farmer to choose to use this technology. The commenter feels that non users of this technology also have the right not to use this technology: user and non users can coexist providing both sides are good stewards of the inputs they choose or not use.

One commenter states that the economic loss to farmers would be great if GT alfalfa is not made available and it is clear the research and science being conducted by government agencies, private companies and universities show the GT technology as being safe to animals, humans and the environment. As an agronomist, it is the commenter's opinion that the current stewardship practices put in place for GT alfalfa can be effective so that all cropping systems can coexist in harmony .

An alfalfa seed product manager support growers rights to choose the right product to maximize profitability on their own farms, whether that is GT alfalfa, conventional alfalfa or organic alfalfa production. The commenter wants others to remember that the majority of producers who use or want to use biotech products have as much of a right to choose what products and technologies they grow as does the small minority of growers who want to grower organic crops and he believes that this point has been overlooked repeatedly in this whole situation.

A commenter states that the technology fees from GT alfalfa are used to finance research and development of agriculture products and crops that will enable the American farmer to be competitive in the future and that the value of the research reaches globally: all alfalfa growers, organic, conventional, and technology, should be allowed to coexist in American agriculture.

One commenter felt that organic and biotech agriculture can coexist and thrive, as they have already done so for many years with no major incidents.

In addition to the potential risks, one commenter believes that the economic and ecological benefits of GT alfalfa should also be addressed. The commenter asks to please remember that the operations potentially negatively are very, very small in number and acreage and therefore, coexistence strategies should be feasible through management measures. For example, the commenter asks if all the farmers east of the Rocky Mountains will be denied the use of the crop because a few operations west of those mountains may be affected, and believes that farmers should have the choice of growing GT alfalfa or non-transgenic alfalfa.

An alfalfa grower commented that growers in the United States should have the freedom to choose the type of forage production system they use whether it be GT, conventional or organic, each of these production systems can coexist with proper management. The commenter believes that proper management is the key to employing any advanced technology whether the result of crop chemicals, biological agents or genetically modified technologies to be able to use the new technologies sustainably.

One alfalfa grower stated that we definitely need the right to choose and there is definitely room for both those who want to grow crops and livestock as of one hundred years ago, and those who want to grow for the needs of the present and into the future. The commenter asks to please allow us that right to choose and when I say us, I mean me ,my son and my grandson, who farm this operation, along with those who choose the organic way.

One farmer wrote to say that there is certainly room to coexist and that should be the name of the game; the side that wants no new biotechnology is dealing with a perception that organic is the only good food produced and that anything else is bad.

Coexistence implementation

Many GT alfalfa growers, conventional growers, and other farming interest suggested various ways to implement coexistence:

- The Crop Improvement Associations in the states can help control or define the areas that the two crops are being grown
- Seed companies and NAFA can work together with the Crop Improvement Associations to help develop criteria for GT and conventional seed, similar to onion seed and carrot seed production.
- An in-depth industry discussion is needed to plan and provide coexistence. A plan should include best practices education for growers, open communication and cooperation regarding what is planted on alfalfa fields, suggestions from the non-GE industry to develop best practices guidelines for their industry, and respect for opposing viewpoints.
- “Best practices” to keep any contamination to feral alfalfa or a neighbor who may be an organic grower to a tolerable minimum. All farmers learn to tolerate their neighbors farming practices.
- Good stewardship, courtesy and communication, and separation of fields.
- Stewardship practices already exist will ensure GT alfalfa, traditional and organic alfalfas coexist successfully.
- GE-free production areas, independently funded research, industry cooperation and legal enforcement by State Dept of Agriculture or Certifying agencies
- Identify critical steps in the development, production, conditioning, and shipment of alfalfa seed and develop a working plan that specifies, in some level of detail, actions to be taken to ensure our ability to produce, condition, and ship GE-free seed.
- A three to five mile GE-free zone to isolate GT alfalfa and conventional production.
- Adoption of usual and ordinary agronomic practices, particularly with regard to the timing of cuttings of alfalfa in the field, to eliminate or reduce to minimal trace levels the presence of GT alfalfa in the fields of organic growers and, vice-versa, the presence of organic alfalfa in the fields of growers of GT alfalfa.

- Several state agricultural departments and university extension services have developed coexistence programs and guidelines that farmers can adopt to eliminate or reduce the presence of GT alfalfa in organic alfalfa and vice-versa.
- Before planting GT alfalfa, a grower went to the State Department of Agriculture and got a list of all certified organic growers, and informed all neighbors within a three mile radius. The growers stated that he received no complaints from neighbors.
- Common sense approach, practicality, and stewardship
- Good communication with neighbors, good seed, and requires an understanding of gene flow and how to maintain seed and hay purity
- A commenter stated that coexistence strategies for alfalfa production systems have been developed and tested by growers and the seed industry with input from seed and hay exporters, growers, processors, seed companies and public scientists. For example, the science-based information outlined above was published and disseminated at grower (National Alfalfa Seed symposiums) and seed industry (California Seed Association, American Seed trade Association) meetings prior to commercialization of GT alfalfa in 2005. For example, over 3000 publications were disseminated at the meetings over the past 3 years. Specific stakeholder meetings were held and reported on in ID and CA to develop Best Management practices. Recently (October 10th, 2007), a meeting was held by the National Alfalfa and Forage Alliance to specifically address coexistence in alfalfa. At these meetings and currently, best management practices are being refined that will allow farmers to coexist and have a choice in what production system is best for their particular markets.
- Multiple commenters suggested establishing a ‘tolerance’ or a ‘level’ that could be found in non-GT or organic alfalfa.
- Prohibit the production of GT alfalfa seed within 15 miles of conventional seed production and banning the production of GT hay within 10 miles, with the stipulation that any GT hay within 15 miles must be harvested before it is pollinated. Any remaining concerns can be dealt with by localized regulation for specific areas, such regulation should be implemented at the state or local level.
- Work with State Department of Agriculture to formulate a draft rule and establish a control zone for alfalfa production area.
- Coexistence across production systems is process driven as are the NOP and seed certification programs.

Coexistence concerns

One commenter felt that in the absence of both strong collaboration and cooperation between the industry stakeholders or the establishment of mandatory regulations enforceable by a recognized authority, the alfalfa industry will continue to struggle with the coexistence of biotech and conventional alfalfa.

A conventional seed grower recounted the efforts of a group of growers that petitioned a State Department of Agriculture to develop a GE-free production zone under the control of a local growers board, and that the zone was denied due to the fact that GT alfalfa was not considered a “pest” under state statute.

One commenter stated that the organic food industry is a growing sector in the agriculture community and for FGI and Monsanto along with APHIS to be so cavalier in expecting the organic industry to protect themselves from errant gene flow borders on being criminal.

One commenter felt that GT alfalfa would endanger conventional and organic producers by introducing a questionable technology in a crop that is not studied enough to know its impacts.

An academic states that the proposed topics for the EIS includes a number specifically addressing the potential impacts on the organic agricultural sector of the introduction of GT alfalfa and this is primarily directed toward the issue of potential impacts due to low level or adventitious presence of GT alfalfa in organic seeds or hay products. The commenter believes that it must be noted that NOP rules do not establish a threshold for such presence and specifically state that the organic status of such products is not affected by such inadvertent and low-level presence. The commenter states that the inclusion of a ban on use of GE crops in the NOP rules was not mandated by USDA or APHIS, but was rather demanded by the organic community, and therefore this is a self-imposed ban by a subset of agricultural producers with the intent to differentiate products in the marketplace. To the commenter, it seems inappropriate for a study whose mandate is to assess environmental issues to include impacts on voluntary marketing strategies in its scope.

An interest group states that GT alfalfa must not be deregulated absent a convincing demonstration that growers can be assured of their continued option of growing non-GE alfalfa. The group believes that the right to grow non-GE alfalfa is not limited temporally or geographically, and GT alfalfa is not to be deregulated if a reasonably foreseeable impact of the deregulation is the elimination of the option of farmers living in any region of the country to continue growing non-GE alfalfa, in the near or longer term future. The group feels that the right to grow non-GE alfalfa is also not synonymous with the right to grow alfalfa that is contaminated with GE alfalfa at “negligible levels” due to “inadvertent gene flow,” and thus, APHIS should formulate an alternative that analyzes the contamination issue where the standard is zero tolerance for contamination.

Coexistence assessments

Related to coexistence, interest groups, some organic farmers, and some academics requested the following assessment to be included in the EIS:

- What will the effects of widespread contamination of geographical areas with unwanted GT alfalfa be on farmers desiring to transition into certified organic operations that are for the purpose of growing organically certified alfalfa
- What are the environmental effects of making it more difficult for a farmer or rancher to operate as an organically certified produce, that result from widespread GT alfalfa production and contamination
- An academic stated that if, as implied by the court’s ruling and by its inclusion in the NOI, the impact of GT alfalfa on organic producers must be considered in this government action, then one must ask whether the certification of organic farms and farmers should also be subject to the same consideration
- How are the rights of ranchers, farmers and others to use their land affected by the unwanted invasion of the GT alfalfa products to be introduced into the markets

- If it is established as precedent that economic impacts of the introduction of new agricultural products or practices must be considered as environmental impacts, as per the court's ruling in the GT alfalfa case, then it follows that a new organic farmer should be required to assess the potential impact on neighbors of the decision to seek organic certification.
- What are all the environmental effects of driving family farms out of business by making the organic farming alternative more difficult due to permitting use of GT alfalfa, both alone and in the context of extensive use of GT corn, canola and other crops
- Can APHIS define what it means by the term "coexistence" of organic/conventional alfalfa as to whether its a scientific term or an APHIS policy position
- It is incumbent on APHIS to also consider the economic consequences of allowing the self-imposed marketing preferences of one sector of the agricultural landscape to restrict the economic opportunities of other sectors.
- Has APHIS conducted a survey of organic or conventional alfalfa farmers as to their views of the meaning of "coexistence" with GT alfalfa
- What is the difference in the perceptions of "Coexistence" between organic or conventional alfalfa farmers compared to GT alfalfa farmers
- Whether any of the potential negative environmental and economic impacts resulting from the deregulation of GT alfalfa can be mitigated and the likelihood that mitigation measures will be successful – that is, whether "coexistence" is practical or possible.
- If the EIS were to propose specific mitigation procedures that would restrict the opportunities for farmers to grow GT alfalfa due to proximity to organic farms, then the economic impacts of that decision should also be included in the study. Such an analysis might conclude that the NOP should be required to conduct an EIS before certifying additional organic farms if their presence would economically injure nearby conventional farms due to restrictions imposed on their crop choices.

11. Effects of GT Alfalfa on Animal Production Systems

A GT alfalfa farmer growing GT alfalfa for dairy cow production stated that GT alfalfa is free from weeds which defrayed the costs of production due to not having to purchase additional hay for their animals or add protein to supplement their feed as is needed in lower quality hay.

Some commenters felt that GT alfalfa brings improved RFV's, more milk to dairies, higher quality beef, and numerous other benefits. One grower attached a recent study that shows that GT alfalfa has no effect on feed intake, milk composition or milk production in dairy cattle.

GT alfalfa growers commented on the ability of GT alfalfa to keep out noxious weed that injure, maim or kill cows and cattle, including cheat grass and nightshade.

One commenter states that he would rather be eating meat from cattle that is eating alfalfa that has been sprayed with glyphosate than all of the other labeled chemicals, is in favor of the labeling of GT alfalfa because we will have a lot better quality feed for the meat that we eat.

Some animal producers feel that animals will refuse to eat GT alfalfa.

Interest groups, some organic and conventional farmers, and some members of the public requested the following information or assessments regarding animal production systems and GT alfalfa included in the EIS:

- What percentage of the pesticide formulation ingredients used on the alfalfa crop show up in the milk of dairy cattle fed this material
- Does the presence of this pesticide alter gene expression in livestock consuming GT alfalfa with the highest application levels of this herbicide and the adjuvants of the formulation
- If there is alteration in gene expression in livestock, can it be transmitted from one generation to the next
- Can the presence of glyphosate in the alfalfa crop alter the numbers of primary follicles in heifers, which would alter their reproductive output
- Should organic livestock agriculture gain the public perception, both domestically and internationally, that it has been contaminated by GE organisms, the public appetite for organic food may be substantially harmed and farmers economically injured
- To what extent will the level of production of organically certified livestock be affected by the use of GT alfalfa and what will the environmental effects of such changes in volume of production be
- An animal feeding trial for multi-generation should be conducted involving both male and female of the species. This should be done outside the influence of Monsanto or FGI.
- What are the effects upon producers and the public of making overall grazing and other use of lands by organically certified farmers and ranchers in circumstances where volunteer and stray GT alfalfa appear in fields which cause additional work or even cause disqualification of a field for organic production
- How will feeding GT alfalfa to beef affect the rating of the beef? Can it be sold as natural?

12. Effects on Food & Feed

Commenters representing organic farming interests, members of the public, and interest groups questioned the safety of GT alfalfa as food or feed. Issues raised and assessment requested for the EIS included:

- Feeding alfalfa to animals treated with glyphosate because glyphosate residues that may be harmful to them
- Use of alfalfa sprouts for human consumption and the use of the CaMV promoter
- What are the effects on children's and others' health nationwide from consumption of meat and, separately, milk where the livestock in question have consumed GT alfalfa including the effects of increased anxiety not knowing what the effects of GT alfalfa are
- What is the period of years likely to be needed for the scientific community to detect higher rates of allergies, cancer and other maladies that result from animal consumption of GT alfalfa and human exposure to GT alfalfa
- What are the effects on children's and others' health nationwide from driving organically certified ranchers and farmers out of business by making it more difficult to produce alfalfa that can be organically certified

- Some commenters were concerned about the effects of GT alfalfa, the nutritional quality of GT alfalfa, or the effects of GE foods in general, on livestock and human health, or were concerned that the effects were not well studied
- Genetic engineering corrupts organisms, and thus results in poisoned food
- GE alfalfa seed must not be sold to be used for alfalfa sprouts
- What is the impact of non-GT alfalfa mixed hay cut at bloom for balanced nutrition-beef cattle, horses, sheep, etc.
- One commenter felt that we need to stop genetically modifying products that go into our food chain because we are what we eat
- What is the effect of feeding GT alfalfa to the mother and calf, hogs, and poultry, and should include alfalfa in its most common forms
- Impact of the glyphosate-resistant gene in alfalfa, by direct comparison with isogenic non-glyphosate resistant lines, grown in various soil types on:
 - Nutrient uptake efficiency (N, P, K, Ca, B, Cu, Fe, Mg, Mn, Mo, Zn)
 - Root exudates impact on the rhizosphere micro flora
 - Nitrogen-fixing Mycorrhizae, pathogens, synergists
 - Nutrient cycling organisms for: Fe, K, Mn, S, etc.
- Impact of glyphosate applied to GT alfalfa compared with non-GT alfalfa on:
 - Yield, nutrient quality, mineral content
 - Rhizosphere organisms: nodulation, nutrient availability
 - Diseases - pathogens, biological control organisms
 - Sustainable production - soil fertility, drought stress, maturity, over-all cost differential with anticipated micronutrient and biological amendments, resistant weed control, etc.
- Impact on subsequent crops in the rotation:
 - Establishment, nutrition
 - Growth and productivity
 - Degradation and persistence of glyphosate and its metabolites from root exudates at root depths of alfalfa
- What are the negative impacts on food or feed value or quality from the use of glyphosate containing organic chemical impurities detectable in batch quantities of herbicide produced such as formaldehyde, N-Nitrosoglyphosate, and insolubles?
- Does the presence of detectable or undetectable glyphosate residues effect the taste of alfalfa when it is processed into food products?
- Does the presence of detectable or undetectable glyphosate residues effect the nutritional quality of alfalfa when it is processed into food products?
- An interest group states that a person has to be ignorant to believe that a smorgasbord of toxic agricultural chemicals in the foods is safe to consume.
- Compositional assessments submitted to USDA and FDA by Monsanto are not adequate
- Determine the current impact of weeds on animal production and animal health, and if this new technology decrease animal performance or welfare, or improve it
- One group wants carefully controlled, long-term animal feeding studies, with toxicological endpoints, to assess GT alfalfa for potential adverse effects on animal health

Alfalfa farmers growing GT alfalfa, members of the public, and farming interests commented on the benefits and safety of GT alfalfa. Issues include:

- GT alfalfa produces higher quality alfalfa with greater yields and improved quality that could be marketed to dairy farms for feed
- Glyphosate will kill certain weeds that are harmful if consumed by ruminants, thus increasing the safety of the feed
- GT alfalfa is safer to produce our meat or milk because of the proven safety and effectiveness with years of use of glyphosate in other crops
- Research indicates that GT alfalfa should be safe to use in the United States, and should be registered for use
- No peer reviewed scientific studies have presented any data suggesting or proving any health or safety risks in the use of (feeding) GT alfalfa
- Farmers goals are to improve the environment and feed for the animals they raise as far as that goes the people they feed as well. GT alfalfa is providing that tool for these producers to so that.
- The GT gene has been in our food chain since the release of GT soybeans. It is very likely that if you eat meat, drink milk, or eat eggs, those animals have been raised with protein sources derived from GT crops. It is a sound, proven technology that should be utilized in alfalfa.

13. Worker Safety

Many GT alfalfa farmers, public agencies, and members of the public believe that One chemical exposure to the application personnel and the growers is greatly reduced by being able to use the safe and reliable chemistry of glyphosate.

One farmer stated that using glyphosate not only minimizes the health risks to our employees, but it also reduces the amount of stronger chemicals that our operation uses. The reduction of chemicals and the types of those chemicals reduces environmental exposure and our costs of production.

An organic association believes it is important that the EIS study the potential health impacts of glyphosate exposure on the users of the chemical, which may include farmers, farm laborers, and the children of the applicators.

14. Alfalfa Agronomic (Farming) Practices

An academic states that alfalfa is grown in almost every state, and is a strategic crop for the United States not only because of its direct commercial value, but also because of its environmental-biological impact in developing soil fertility and structure through its deep tap-root growth habit, fixation of atmospheric nitrogen, and perennial leguminous nature for erosion control. The commenter believes that the value of these environmental functions in crop rotations and sequences may far exceed its commercial value for hay, and Any loss of alfalfa production efficiency or quality can have serious consequences for sustainable crop and animal production, with subsequent deleterious impacts on human nutrition, health, and well-being.

One commenter representing academia and another comment from a GT alfalfa farmer stated that GT alfalfa performed similarly to conventional alfalfa, could be managed similarly to conventional alfalfa, and could be controlled similarly to conventional alfalfa.

GT alfalfa farmers described how they use GT alfalfa and glyphosate on their farms:

- We must constantly monitor for noxious weeds. The highway department sprays a couple of times during the summer, may not spray before weeds go to seed. I can spray along the roadway and up to the edges of the alfalfa fields without worrying about the glyphosate killing the edge of the GT alfalfa fields.
- If thistles come up in GT alfalfa, we can take a hand sprayer and hit the thistles, and not kill the alfalfa. That sure beats taking a scythe and cutting that area by hand before the thistles bloom!
- I can grow higher quality hay with very few weeds in it. When the alfalfa does not have competition, it does not thin out as fast. So, I do not have to rotate crops as often. Hay is my main crop, so rotating crops is a detriment and is expensive.
- We can spray the field with glyphosate to kill all the kochia, pigweed, morning glory, thistles, quack grass, and other problem weeds while the alfalfa is small, so that we can get a good, thick stand of alfalfa that will not allow other weeds to compete with it. Then, the alfalfa controls the weeds so we do not have to spray again. Spraying all weeds cannot be done in a conventional field of alfalfa, so the small alfalfa plants must compete with all of the weeds to become established.
- The weed control provided by the applications of other herbicides besides glyphosate is very good for the spectrum of weeds in our area. The main problem we have seen is that the application of these herbicides is very hard on the young conventional alfalfa and it takes over a week for it to recover from the effects of these herbicides. Growth is minimal in the conventional fields during the recovery process and the GT alfalfa does not experience this, since the application of glyphosate does not affect the alfalfa.
- One of the largest problems we have in our alfalfa stands are grasses. Usually by the second or third year, all our fields have some level of grass present along the drain end of the field or in the higher traffic areas. Glyphosate is an excellent grass herbicide and we followed our establishment spray in the tolerant fields with a summer application to control any additional weeds.
- We often see water grass and nuts edge in isolated parts of a field and with the GT alfalfa, we can spot spray these areas very effectively.
- Winter weed control is very important for the longevity of our alfalfa stands, and we are always concerned when applying restricted use chemicals. We have a closed mixing system and other safety measures in place, but not using dangerous chemicals at all is by far the safest practice. We would also like to reduce our use of some other herbicides because of its potential to leach into the groundwater and move in field runoff. The GT varieties allow us to use only glyphosate to control weeds and its chemistry is much safer than that of some of the herbicides we use in our conventional fields.
- We remove our stands by mechanical means (a heavy stubble disc), so we are not concerned about not using glyphosate for stand removal.
- Alfalfa growers try and harvest their crop in the bud stage but due to weather conditions may have to delay harvest until the bloom stage. Even with late harvest the vast

majority of the alfalfa grown in Nebraska never goes to seed which dramatically reduces any chances of pollen flow.

- One commenter was concerned about whether weather plays a role in gene flow because he states that it takes at the very minimum, another thirty days of the most beneficial weather to make viable seed, in our area its closer to forty-five days. If the weather stays inclement, it will never make seed.
- One grower stated that glyphosate was an unreliable tool for alfalfa stand take-out
- A GT seed farmer practices strict sanitation practices in harvesting and handling seed with extensive cleaning of equipment and separation of seed lots between GT alfalfa and conventional. Seed is put in specially marked bins and separately stored, have three combines, and one is used only for GT alfalfa. Feral alfalfa on ditch banks, road sides and adjacent areas, is sprayed out with a non-glyphosate herbicide. We are very aware of our neighbors conventional both hay and seed fields and adhere to isolation distances that are in excess to what is acceptable, and they are monitored by seed certification officials and others.

GT alfalfa growers, researchers, scientists, and farming interests spoke to the benefits of using GT alfalfa in alfalfa agriculture:

- Significantly more hay in the seeding year when direct seeding
- Extra yield of high quality alfalfa in the seeding year alone pays for the cost of the technology and seed
- An alfalfa product manager of a seed company encouraged growers to plant GT alfalfa on their fields with the most severe weed problems to put it to the maximum test possible. He did not find any grower who was disappointed with their weed control using the technology in these situation.
- Primary benefits of GT alfalfa were considered to be higher tonnage, better weed control and better quality resulting in higher profitability for the grower. GT alfalfa is beneficial because it can increase the longevity of the alfalfa stand.
- A researcher discovered that weeds were more competitive and reduced stand and yield compared to GT technology, and there is more yield reduction to alfalfa from the commonly used herbicides than we had previously known, because now there is an additional control better than an untreated check.
- One alfalfa grower felt that because many alfalfa fields in southern Minnesota are right next to GT soybean and corn fields, farmers could spray glyphosate right next to the alfalfa field without injuring either crop and control the weeds.
- One alfalfa grower felt that GT alfalfa would reduce soil and water erosion, and the benefit to the environment will be greater than the weed control benefit in alfalfa.
- Some growers feel that GT alfalfa seed is just one example of raising more and better food per acre
- One commenter felt that the technology will keep growers in the East growing Alfalfa vs. trucking in alfalfa grown in the West, and GT alfalfa will save our entire system time, fuel and effort

A nationwide trade association representing alfalfa and forage producers in 23 states submitted the Best Practices for growing GT alfalfa.

An alfalfa grower states that with all of the alfalfa plants that are growing wild and plants that are not being harvested in a timely manner are really causing a problem, but only in GT alfalfa seed production. My question is why have all these issues not been brought up before? Growers have always paid a premium for pure seed or a certain variety. Why have we not had any issues in the past with alfalfa plant escapees or one variety of alfalfa getting crossed with another? The seed industry is very careful to isolate and control the potential of cross contamination with various guidelines and certain protocols. The seed industries standards are already tough regarding seed production and the rules that are applied to GT alfalfa are 90 times as tough.

A seed grower stated that his production contract states: "The Company" recognizes that circumstances outside the grower's control may lead to an adventitious presence from an unknown origin within the seed of a genetically modified organism ("GMO") or other. "The Company" considers any such presence up to 1 % to be adventitious. If an adventitious presence exceeds 1%, "The Company" will take possession of the seed and shall pay the grower a price to be negotiated.

One commenter states that the most important factor for hay growers to maintain purity is to begin with certified seed for planting.

One commenter felt that the de-regulation of GT alfalfa will have very little effect on the production of other crops because the primary factor in alfalfa acres is the demand for hay. The commenter believes that the need to feed dairy and beef cattle or an ever growing recreational horse market will determine alfalfa acres, not whether GT alfalfa is de-regulated or not, and that these are the same market influences that have driven corn acres: demand for ethanol, high fructose corn syrup, and animal feed have pushed the increase in corn, not the acceptance of the GT trait.

A cotton association wrote in to discuss the potential similarities between GT alfalfa and GT cotton. They felt that a decrease in herbicide use is found in GT cotton and expects the same for GT alfalfa.

Some conventional and organic alfalfa growers, members of the public, and interest groups commented on concerns or problems with the farming of GT alfalfa:

- Other herbicides besides glyphosate would be used to take out GT alfalfa, some conventional alfalfa growers do not want to lose glyphosate as a tool for stand take-out, and there would be damage caused by drift of these other non-glyphosate herbicides
- If the neighbor sprays glyphosate on his GT alfalfa, and the spray drifts, it will kill my alfalfa
- One group wanted company personnel on hand to assure minimum seed mixtures and felt that seed transported off farm should be tarped to avoid roadside propagation of feral plants
- One group wanted reporting of GT alfalfa plantings to local crop improvement no later than 7 days from date of delivery of parent seed to producer
- For a non-GT alfalfa grower, GT alfalfa is a weed just as damaging as morning glory, Canadian thistle, etc, depending on the buyers demand or seed contract stipulations

Related to agronomic practices in alfalfa farming, interest groups and members of the public requested the following assessments be conducted or information stated in the EIS:

- Volunteer alfalfa in seed production has not been addressed
- What plant back restrictions should be used for GT to conventional alfalfa seed rotations
- Is it possible to plant conventional alfalfa after a GT seed production
- Independent study is required to confirm that isolation distances are adequate
- Potential map of organic alfalfa usage extends across much of the United States and must be considered as an aspect of the EIS
- What about the hay grower or seed grower that has GT alfalfa contamination in his field. How can they eliminate the contamination in his crop?
- What are the environmental effects of prolonging alfalfa fields
- An interest group wants to know the role APHIS will play in surveying organic and conventional farmers on their preferences in regard to farming practices, impacts of GT alfalfa on their farming practices, their current, future, and past farming practices

15. Regional Production Differences

Some conventional alfalfa farmers were concerned because common production practices in South Dakota are to maximize the size of our first and sometimes only cutting of alfalfa; thus alfalfa is midbloom or sometimes full bloom before cutting. For them, the second cutting alfalfa is mostly nonexistent if rainfall is limited, and alfalfa is too short to cut but often blooms for several months then produces seed. Thus, for these commenters, seed crops of common alfalfa is a very good cash crop, often worth more than the hay crop.

One commenter was concerned about the bee restrictions for growing GT alfalfa. He felt that bee production in the northern United States is very dependent on alfalfa for honey production because sites of hives are positioned close to alfalfa fields. I believe GT alfalfa will wipe out the conventional common seed producers.

One beekeeper was concerned because in the Midwest, alfalfa is our major source of honey. When it is too dry in the Midwest to make hay, the commenter believes that farmers still have the option to go for a seed crop, and this has been a great source of additional revenue in an already dry year: we make honey off the blooming alfalfa and they get a seed crop.

One commenter from the Midwest stated that alfalfa grown in this area is grown for feed, and the highest feed value from alfalfa hay is when it is cut in the pre-bud or bud stage. The commenter believes that with this strategy, no viable seed can be produced nor is any pollen available for bees to carry to non-glyphosate fields. His comment continues: if harvest is delayed and the alfalfa blooms, viable seed is still not produced because harvest and drying of the hay prevent development of viable seed. If the weather is so bad that harvest cannot take place, the commenter feels that the conditions also limit the ability of bees to forage.

One commenter felt that GT alfalfa would be a good choice for Tennessee and mid-South alfalfa growers without impacting their neighbors. Most of our alfalfa growers are dairy farmers and use the hay on farm, or sell to their neighbors.

A conventional alfalfa farmer write that although the argument has been made that a "barrier" could be created, this would be impossible with alfalfa in the Imperial Valley because of pollen flow and alfalfa is planted in a patch-work manner where someone could rotate a crop out in a surrounding field and plant GT alfalfa and contaminate a conventional alfalfa field. The commenter believes that if GT alfalfa was to be planted in the Imperial Valley, due to cross-pollination, we would automatically lose 85% of our market because we sell to GE-sensitive markets and this would effective destroy our market for our conventional alfalfa seed.

16. Agri-business Concerns

Some commenters question the long term security of the nation's food supply in light of Monsanto's quest for monopolizing control of seed through the patents of hybrid, genetically engineered & pesticide dependent products and the purchase of existing vegetable seed company's nation wide. Some commenters were also concerned that alfalfa seed was only held by FGI and/or Monsanto.

Some commenters were concerned that USDA is only deregulating GT alfalfa because it is a product of big agribusiness, specifically Monsanto.

One commenter was concerned about the legal system of patents on artificially manipulated plant genetics that allows holders of such patents to seek damages against farmers who harvest seed that may have been contaminated by plants on which there is a patent. Further, the commenter believes that actions have been taken by holders of such patents and farmers have been significantly damaged economically.

One commenter believes Monsanto has been issued many fines for the work they do and so in my opinion it is risky to allow this profiteer to let this product be used in a wide area so quickly.

One commenter is concerned that the governments of world are shoving genetically engineered food down our throats with no labeling or vote on that we even wish to be eating, and that the government has helped Monsanto by letting them get away with false tests that where done by Monsanto own employees.

One commenter's concern is that if we continue to regulate and over regulate everything, it will not be long and American agriculture will be done with; the fact of the matter is that without progression (GE crops, better chemicals, and the best technology available), it will not be long and we will not be able to compete on the world market far less be a leader.

An interest group was concerned about the value of studies provided by Monsanto and wanted to know the funding source of all authors on publications and felt that the public would be better served with this information. One commenter believes that Monsanto can hire an army of people to manufacture crop safety data, as well as post comments.

An interest group felt that APHIS possesses a governmental zeal trumping science and consumer interests in supporting GE crops such as GT alfalfa despite serious questions about Monsanto's own glyphosate studies and whether GT alfalfa is needed at all. The commenter believes that

there is the inherent bias in Monsanto's research studies, that they are flawed by design, and flawed by analysis, therefore, questions arise over how much of Monsanto's glyphosate research has actually been subjected to external peer-review and published in journals.

One comment wanted the EIS to show the economic impact on seed and feed costs if all alfalfa were controlled by GE seed monopoly, and this commenter also felt that property rights are impacts on growers of non-GT alfalfa.

One commenter feels that it is unreasonable that the government would allow introduction of a situation that puts significant power in the hands of a large corporation to materially harm large numbers of small businessmen (farmers) in situation where these small businessmen have no malicious intent.

17. Continuing the Use of Biotechnology

Some commenters felt that as world demand for food increases and available land and resources decrease, higher yields per acre must account for this deficit. Advances in technology, such as GT alfalfa, must be integrated into agriculture in order to move towards sustainability. The commenters feel that the bottom line is that this technology is safer for the environment, the grower, and the consumer, and it is also can help increase production on the current acres farmed. One commenter even felt that the American farmer wants the ability to use this great technology in their quest to continue to grow high quality alfalfa to feed their herds and feed the world.

Some growers are concerned that the removal of GE crops would not allow the country to feed itself and cut down the use of foreign oil.

One commenter only wanted genetic-engineering to be used for disease resistance and flavor enhancement.

One commenter felt that the whole situation with GT alfalfa is similar to BST; we have a safe technology and a few pin heads screw up the whole works. The commenter feels that if GT alfalfa is not approved for use, we can blame of our government for failing to use common sense.

A academic stated that herbicide-tolerant crops produced by other methods (e.g., mutation) did not require an EIS prior to commercialization, yet the potential for development of weeds resistant to those herbicides is greater than that for glyphosate. The commenter asks why should those questions be included in an EIS only required of crops developed using recombinant DNA methods, while the same environmental issues arise with crops having similar traits developed by other methods? The commenter stated that the underlying principle of the GE regulation in the United States is claimed to be based on the product, not on the process, and by including these questions about development of herbicide-resistant weeds only for GE crops and not for those developed by other means, APHIS is not being guided by its stated principles.

A seed grower stated that throughout the history of modern agriculture there has been resistance to transformative technologies, such as steel plows, sprinkler irrigation, commercial fertilizer,

tractors, and reduced tillage practices, and asks how could we feed the world if new technology was not available to expand productivity.

An alfalfa grower believes that the American consumer wants quality food that is affordable and safe, and the American agricultural producer wants to supply the food to meet these criteria and needs to make a profit. To meet the increasing demand for food and fiber in the United States and abroad, the commenter believes that the American producer needs all of the tools available to produce an economical, safe, quality product at a reasonable profit and GT alfalfa is one of these tools. Further, the commenter believes that if all American producers were to switch to “organic” farming methods and abandon the new technology that has been made available this past 100 years we could not even feed the United States, let alone the rest of the world.

One commenter stated their contention that growers in the United States should have the ability to choose GT alfalfa varieties if they are to remain competitive in the world today and still be able to efficiently meet the demands for quality hay products.

Many farmers commented that if the soybean and corn plants can be modified with no problems feeding it to animals, why not alfalfa.

Some commenter felt strongly that farmers are held captive a minority (“environmentalists” and “so-called do-gooders”) that tell the farming community what to raise. These commenters felt that the regulations and court orders make it harder to make a living.

An alfalfa producer believes that we need GT alfalfa as one of the tools to help supply high quality forages to an ever increasing market, there is a shortage of quality alfalfa hay, and GT alfalfa will enable us to get maximum production the seeding year and encourage producers to keep alfalfa as part of a diversified crop production system.

One commenter believes that there is lots of room in this world if we just learn to be tolerant and accept new ideas.

18. Comments on the EIS Process

APHIS received requests for extension to the Notice of Intent public comment period, and numerous scientific publications demonstrating the potential for gene flow between alfalfa fields, pollinator behavior, food and feed issues related to GT alfalfa, weed management issues in GT alfalfa, glyphosate safety studies, and studies related to various environmental impacts.

Some commenters stated that the questions posed in the NOI were adequately developed by APHIS.

One commenter felt that the EIS should address a fuller range of topics than is required in the court order, and discussion should be open to findings and reports completed after the EA was completed in 2004. One aspect requiring fuller comment, according to the commenter, is an apparent bias toward unsupported opinions rather than references to relevant empirical studies, therefore, is imperative that the new EIS should be produced by a fresh group of APHIS staff

members who had not been involved in the original EA, those new members should be committed towards full and unbiased reporting based on empirical evidence.

A farmer using organic methods to grow alfalfa felt that the proposed scope of Environmental Impact Statement was excessively narrow.

A farmer using organic methods to grow alfalfa asked what alternatives for regulation exist other than those set forth in the Notice (whether or not such alternatives require legislation or revised regulations of the USDA)? What is the balance of pros and cons of the USDA authorizing the use of the GE products in question.

One commenter wondered why the comment site did not show some of the comments and regulations website seems inadequate and negligent.

One commenter wanted better public announcement of dockets open for public comment.

One commenter wants to know that a comment comes from the heart and from a protective instinct for American citizens, and not from money and greed desire, thus the commenter asks that APHIS require that a commenter identify whether he has any financial interest in what he is commenting on.

One commenter feels that considerations should be trait-based rather than process-based and that the EIS should address scientifically valid risks, not perceived or precautionary risks.

A farmer growing organic alfalfa asked what role should scientific uncertainty and numerous issues dealing with genetic modification (health issues, production issues, marketing issues, pest and weed issues, and others) have upon assessing environmental impact of the decisions in question that are the subject of the EIS.

An interest group stated that APHIS needs to ensure that legitimate external peer-review is conducted of the scoping process so the EIS is good science and not as inadequate as the Environmental Assessment was on GT Alfalfa.

A law professor stated that NEPA, and EISs under NEPA, are not meant to provide an analysis of creating a protected or protectionist market for any economic group, including for organic farmers, and NEPA does not and should not guarantee that organic farmers can satisfy any particular market demand. The commenter feels that if there is a market demand for 100 percent free organic alfalfa or alfalfa seeds, it is the responsibility of organic growers and their marketing agents to bear the costs and the burdens of meeting that market demand.

A farm bureau stated that while marketing and export concerns are extremely important, and NEPA requirements must be met, it is our view that these issues are best addressed primarily by the market place.

A commenter believes that GT alfalfa may have the potential to increase the acreage of alfalfa grown in the United States, and therefore, the possible benefits of expanded alfalfa acreage due to GT alfalfa should be assessed.

19. General Concerns or Other Potential Impacts Not Mentioned

A beekeeping group urge not only that genetically engineered (GE) Roundup Ready alfalfa not be deregulated, but also that existing plantings of GE alfalfa be destroyed.

The president of a seed grower association states that he had the opportunity to raise organic alfalfa for seed, but has declined because the negative weed and insect impacts that would have occurred without the use of herbicides and pesticides, and only being able to raise just a few acres because of the hand labor required. The commenter believes that this is not something a real farmer can afford to do.

One commenter felt that GT alfalfa would endanger conventional and organic producers by introducing a very questionable technology in a crop that is surely not studied well enough to determine its impacts. Other commenters were concerned about diminished biodiversity.

A GT alfalfa grower stated that currently all of my alfalfa seed production is GT and he follows all of the “best practices” guidelines set forth by the USDA and FGI. The commenter also stated that in the past 3 years of dealing with this GT crop I have not had one complaint from any neighbor, farmer, rancher, or consumer in my area.

An organic alfalfa grower asked if GT alfalfa is a product for which there is no legitimate use.

A grower believes that most environmental concerns about GT alfalfa are without adequate merit, there are many millions of acres of GT corn and soybeans grown in America every year, and this has not lead to any environmental catastrophe, although that was predicted by many of the same groups who oppose GT alfalfa. The commenter believes that, GT crops have become an integral part of farming practices that reduce the tillage and environmentally harsh and persistent herbicides, and GT alfalfa will be no different.

One commenter felt that a key aspect of the deregulation decision is to compare current practices (organic, conventional), with practices which are enabled by this technology (GT), and to understand the relative advantages and disadvantages of current conventional methods with the GT approach in terms of environmental and market impacts. The commenter feels that the risk is not only from the new technology, (which are in some cases unknown or speculative), but the risks of current (chemical and non-chemical) weed control methodology must be taken into account, as well as the (not unsubstantial) risks of failing to control weeds by any method.

One commenter was concerned that a genetically modified crop seed be eaten by a bird; if that bird got ill, and subsequently infected poultry, and then spread to humans, if that is what caused avian influenza.

One commenter stated that growers of GT alfalfa found no negative impacts to surrounding fields or animals for growing and feeding GT alfalfa.

A university scientist submitted his testimony given during the court case that ultimately ended with the decision to complete this EIS. His testimony covered gene flow, stewardship, and coexistence strategies.

An organic farmer wants to know:

- What are the environmental effects of introducing into the general environment GT alfalfa which, once introduced, will never be eliminated from the environment.
- What are the environmental effects of damage to the public perception of organically certified products where testing is perceived to be inadequate to detect GT alfalfa as to many products.
- How are all environmental impacts of the various possible decisions affected by the impacts upon production of organically available grain and other production (other than alfalfa) due to past approvals by the government to use GE products with consequent effect on the production of those crops organically.
- What will be the effects on the ability of people of limited means, as well as the public in general, to purchase organically certified products after production of organically certified alfalfa is made more difficult (and expensive) by invasion of unwanted GT alfalfa.

A public interest group requested the following assessments be included in the EIS:

- What is the negative impact to consumers whose preference is to purchase organic alfalfa sprouts and organic alfalfa food products because they seek more certified organic nutritional foods in their diet and seek to avoid eating genetically engineered alfalfa products and will have to avoid all alfalfa products in the future if they become contaminated with GT alfalfa ingredients and no organic alfalfa is available.
- If certified organic alfalfa nutritional food items are contaminated, what will be the economic impacts to the organic food sector and to consumers who want the certified organic alfalfa nutritional food items.

One non-GT alfalfa grower wanted the EIS to consider these environmental impacts (from 0% contamination to 1 % contamination):

- Will this percent be okay to be marketed if between 0 and 1%?
- Due to no fault of my own, if this adventitious presence goes to 10%, is this the point at which FGI sues me for patent infringement, even if they are at fault for the contamination?
- Who pays the tech fee on this? Will I have to pay the full 10% of the tech fee or will FGI pay at the rate at which I pay for the original testing?
- Will these questions have different answers if the percentage grows to 20%?

A conventional seed farmer believes that our government has an obligation to preserve the small niche markets that we have been encouraged to develop over the 27 years that I have been involved in the alfalfa seed business, and we need to respect and preserve the market that the "organic" folks have also worked hard to develop.

An exporter stated that Monsanto has yet to join with the Washington State hay exporters in an educational effort in Japan, to help develop Japanese-language media materials for distribution to Japan's forage industry, and to accompany us to Japan to make face-to-face presentations, answer questions in detail and generally allay the fears and concerns the Japanese forage industry has. The commenter feels that Monsanto is ignoring the concerns of the Washington State hay industry and intends to proceed with their sales plan, whereas we believe Japan's reaction to Monsanto's sale of GT alfalfa seed in Washington State could be extreme, including chances of a boycott or other negative reaction. The commenter feels that the consequences of such a reaction will fall primarily on the shoulders of the Washington State hay industry and on the state's economy, not Monsanto, and Monsanto either does not appreciate, or is not concerned about, the heightened level of Japanese consumer awareness of, and phobia for, GT products, particularly with regard to milk and dairy products and the perceived danger to their children's diets.

One grower considered surface and ground water pollution, potential worker safety issues, and that alfalfa field is in the riparian zone of a river when selecting alfalfa seed. The commenter stated that he is practicing sustainable agriculture, and the use GT technology fit well to my soft/integrated pest management program.

An interest group wants APHIS to conduct a comprehensive study of the extent genetically GE alfalfa has already contaminated organic and conventional alfalfa seed, because such testing would allow the alfalfa seed and forage industries to identify contamination, understand the scope of segregation problems, and educate their customers accordingly.

On commenter asked if there is no evidence of harm after all these years of use how can the USDA possibly recognize something that does not exist.

Appendix C. Distribution Lists

Distribution Lists

Print

Beyond Pesticides
701 E Street, SE, Suite 200
Washington, DC 20003

National Family Farm Coalition
110 Maryland Ave. N.E., Suite 307
Washington, DC 20002

Cornucopia Institute
P.O. Box 126
Cornucopia, Wisconsin 54827

Reding, Keith
Monsanto
800 N. Lindbergh Boulevard
Mail zone C3S
St. Louis, MO 63167

Dakota Resource Council
PO Box 1095
Dickinson, ND 58602

Schmidt, Donald R.
Past President
American Beekeeping Federation
858 West 9th Street
Winner, SD 57580

Fitzpatrick, Sharie
Forage Genetics, Inc.
N52592 S. Gills Coulee Road
West Salem, WI 54669

Seeley, Kenneth R.
Chief, Environmental Services
USDA-APHIS-PPD
4700 River Road Unit 149
Riverdale, MD 20737

Fore, Troy
American Beekeeping Federation, Inc.
P.O. Box 1445
Jesup, Georgia 31598-1445

Sierra Club
Legislative Office
408 C St., N.E.
Washington, DC 20002

Geerston Seed Farms
P.O. Box 205
Greenleaf, Idaho 83626

Tiegs, Leland
10971 Chicken Dinner Rd.
Caldwell, ID 83607

Golden, Zelig Kevin
c/o Center for Food Safety
2601 Mission Street, Suite 803
San Francisco, CA 94110

Trask Family Farms
18166 Smithville Rd
Elm Springs, SD 57791

Haff, Kenneth
604 3rd Avenue SE
Mandan, ND 58554

Vasquez, Vanessa
Programs Intern
Californians for Alternatives to Toxics
315 P Street, Eureka, CA

Kimbrell, George
17206 SE 32nd St
Vancouver WA 98683

Western Organization of Resource
Councils
220 South 27th Street
Billings, MT 59101

Compact Disc (CD)

Burely, Silvia
Chairperson
California Valley Miwok Tribe
1163 E. March Lane
Suite D - PMB#812
Stockton, California 95210-4512

Munier, Douglas, J.
Agronomy Farm Advisor
UC Cooperative Extension
P.O. Box 697
821 E. South Street
Orland, CA 95963

Fitzpatrick, Sharie
Forage Genetics, Inc.
N52592 S. Gills Coulee Road
West Salem, WI 54669

Reding, Keith
Monsanto
800 N. Lindbergh Boulevard
Mail zone C3S
St. Louis, MO 63167

Golden, Zelig Kevin
c/o Center for Food Safety
2601 Mission Street, Suite 803
San Francisco, CA 94110

Simmons, Carl V.
A Thousand Hills Ps 50:10
Valentine, NE 69201

Haff, Kenneth
604 3rd Avenue SE
Mandan, ND 58554

Smith, Ceal
Tierra Consulting
P.O. Box 316
Crestone, CO 81131
(719) 256-5780

Johnston, Andrea
Director Innovation and Growth Policy
Agriculture and Agri-Food Canada
1341 Baseline Road, Tower 7- 5th floor-
231
Ottawa, Ontario
K1A0C5

Wilson, Dr. Robert
Panhandle Research & Extension Center
4502 Avenue I
Scottsbluff, NE 69361

Kimbrell, George
17206 SE 32nd St
Vancouver WA 98683

Appendix D. References

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Appendix E. Acronyms and Glossary

Acronyms and Glossary

A

Abiotic	Non-living, environmental factors such as cold, heat, drought, flooding, salinity, toxic substances, and ultraviolet light.
Acute exposure	Single or short-term exposure to a substance.
Acute toxicity studies	Acute toxicity studies are those that study the effects of a single or short-term exposure to a substance.
a.e.	Acid equivalent; refers to the weight of an herbicidally-active acid.
a.i.	Active ingredient; refers to the weight of an herbicidally-active acid plus its salt.
<i>Agrobacterium tumefaciens</i>	A bacterium that causes crown gall disease in some plants. The bacterium characteristically infects a wound and incorporates a piece of its own DNA into the host plant genome, causing the host cell to grow into a tumor-like structure. This DNA-transfer mechanism is commonly exploited in the genetic engineering of plants.
<i>Agrobacterium</i>-mediated transformation	The process of DNA transfer from <i>Agrobacterium tumefaciens</i> to plants, which occurs naturally during crown gall disease and can be used as a method of transformation.
Allelopathic	Effects to reduce the growth of one plant due to chemicals released by another.
Allelochemical	A chemical produced by a plant of one species that has a detrimental effect on plants of other species.
AMPA	Aminomethyl phosphonic acid; byproduct of the degradation of glyphosate.
AMS	Agricultural Marketing Service.
AOSCA	American Organization of Seed Certifying Agencies.

Allergen	Any substance that causes an allergic reaction.
Autotoxicity	Self-destruction of a species through the production of chemicals that escape into the environment and directly inhibit the growth of that species.
APHIS	Animal and Plant Health Inspection Service.
B	
Bioaccumulate	To increase in the concentration of a chemical in biological systems over time as compared to the chemical's concentration in the environment.
Biotechnology	Making specific modifications to the genome of an organism using techniques based on molecular biology, such as genetic engineering, gene transfer, DNA typing, and cloning of plants and animals.
BNF	Biotechnology Notification File.
Breeding	The process of sexual reproduction and production of offspring. Plant breeding is an applied science for the development of plants suited for the use of humans, rather than their ability to survive in the wild.
BRS	Biotechnology Regulatory Services (USDA–APHIS).
Burndown	Application of herbicide to kill weeds and prepare field for seeding.
C	
CAS	Chemical Abstracts Service. CAS numbers are unique numerical identifiers for chemical elements, compounds, polymers, biological sequences, mixtures and alloys.
CCD	See Colony Collapse Disorder.
CDMS	Crop Data Management System.

CEQ	Council on Environmental Quality.
Certified seed	Seed produced to specific standards to assure purity and freedom from weed seeds and seedborne pathogens, which is used for commercial production of the crop.
CFR	Code of Federal Regulations (U.S.).
Chlorination	A water purification and disinfection process.
Chronic exposure	Exposure to a substance over a large percentage of the subject's life span.
Chronic toxicity studies	Chronic studies are those that study the effects of exposure on a large percentage of a subject's life span, such as daily exposure received by workers.
Colony Collapse Disorder (CCD)	Phenomenon in which worker bees from a beehive or European honey bee colony abruptly disappear.
Companion crop	A crop different than the primary crop for harvest grown in close physical proximity to the primary crop, on the theory that they assist each other in nutrient uptake, pest control, pollination, and other factors necessary to increasing crop productivity.
Conspecific	Belonging to the same species.
Conservation tillage	A broad range of soil tillage systems that leave crop residue on the soil surface, substantially reducing the effects of soil erosion from wind and water.
CP4	Strain of <i>Agrobacterium</i> .
CP4-EPSPS	Bacterial gene (from <i>Agrobacterium</i> sp. strain CP4), responsible for the production of 5-enolpyruvylshikimate-3-phosphate synthase (CP4-EPSPS) that has been inserted into the alfalfa genome to create GT alfalfa.
Cross-pollination	Occurs when pollen is delivered to a flower from a different plant.
D	
DEIS	Draft Environmental Impact Statement.

Deoxyribonucleic acid (DNA)	A nucleic acid that carries the genetic information of a cell. The structure of DNA is two long chains, consisting of chemical building blocks called ‘nucleotides,’ twisted into a double helix. The order of nucleotides determines hereditary characteristics.
DNA	See Deoxyribonucleic Acid.
Donor	An organism that provides a gene or gene fragment used in the genetic transformation of another organism, called the “recipient.”
Dormant variety	Varieties of alfalfa that go dormant in the fall, with reduced growth in response to low temperatures and shorter days.
Dryland seed	Alfalfa seed produced in areas that receive little rainfall.
E	
EIS	Environmental Impact Statement.
EIQ	Environmental Impact Quotient.
EPA	U.S. Environmental Protection Agency.
EPSPS	An enzyme; 5-enolpyruvylshikimate-3-phosphate synthase.
ESA	Endangered Species Act.
EUP	End Use Product.
Event	See Transformation Event.
Expression	The means by which a gene’s information stored in DNA (or RNA in some viruses) is turned into biochemical information such as RNA or protein.
F	
FAS	Foreign Agricultural Service.
FDA	Food and Drug Administration.
Feral	An animal or plant that has escaped from domestication and returned, partly or wholly, to a wild state.
FFDCA	Federal Food, Drug, and Cosmetic Act.

FGI	Forage Genetics International.
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act.
Foundation seed	Seed of a particular plant variety that is produced from breeder seed and is then planted to produce certified seed used for commercial production. (See Breeder Seed and Certified Seed.)
G	
GE	See Genetically Engineered.
Gene	The basic unit of heredity transmitted from generation to generation during sexual or asexual reproduction; an ordered sequence of nucleotide bases comprising a segment of DNA. A gene contains the sequence of DNA that encodes an individual RNA or protein.
Gene flow	The spread of genes from one population to another by the movement of individuals, pollen, seeds, or spores.
Gene insertion	The incorporation of one or more copies of a gene into a chromosome.
Gene product	A RNA or a protein (e.g. an enzyme), the production of which is directed by the corresponding gene.
Genetic engineering	Genetic engineering refers to the process in which one or more genes and other genetic elements from one or more organism(s) are inserted into the genetic material of a second organism using recombinant DNA techniques.
Genetically engineered (GE)	Modified in genotype and, hence, phenotype using recombinant DNA techniques.
GE organism	Genetically engineered organisms. (See Genetically Engineered.)
GE plant	Genetically engineered plant. (See Genetically Engineered.)
GENEEC	Generic Estimated Exposure Concentration.
Genome	All of the hereditary material in a cell including DNA present in the cell nucleus, as well as in other locations such as plant chloroplasts and mitochondria.
Genotype	The total genetic makeup that an individual receives from its parents.
GIS	Geographic information system.

GRAS	Generally recognized as safe.
GT	Glyphosate tolerant.
H	
Haylage	Alfalfa baled at a higher moisture content than dry hay.
Herbicide	A chemical that kills plants.
Herbicide resistance	The ability of a plant to remain relatively unaffected by the application of what would otherwise be a highly damaging dose of an herbicide.
Human environment	According to the Council on Environmental Quality, the term human environment "shall be interpreted comprehensively to include the natural and physical environment and the relationship of people with that environment." 40 CFR § 1508.14
Hybrid	The offspring of two genetically dissimilar organisms.
Hybridization	When two species interbreed to form hybrid offspring.
I	
Interfertile	Two plants or groups of plants capable of interbreeding and producing offspring.
Interseed	Seeding a crop after a crop has already been established.
Interspecific	Arising or occurring between species.
Intraspecific	Arising or occurring within the same species.
Introgression	The introduction of genes from one species into the gene pool of another via sexual crossing. The process begins with hybridization between the two species, followed by repeated backcrossing to one of the parent species.
IPA	Isopropylamine.
IPCC	Intergovernmental Panel on Climate Change.
Isopropylamine	An organic amine. Used in glyphosate herbicides.

	K
kg	Kilogram.
	L
LOC	Level of concern.
	M
Meristem	A tissue in plants consisting of undifferentiated cells (meristematic cells) and found in zones of the plant where growth can take place - the roots and shoots.
Microorganism	An organism that is microscopic (too small to be seen by the human eye).
MJD	Multi-jurisdictional Database.
mg	Milligram.
MOU	Memorandum of Understanding.
Multiparous	Animals that have given birth more than two or more times.
	N
NAFA	National Alfalfa and Forage Alliance.
NASS	National Agricultural Statistics Service.
NEPA	The National Environmental Policy Act of 1969 and subsequent amendments.
NOI	Notice of Intent.
Non-dormant varieties	Alfalfa varieties that grow through the winter.
Nontarget organism	Organisms that are not the target of a pesticide.
NOP	National Organic Program.
NRCS	Natural Resources Conservation Service.

O

OMRI	Organic Materials Review Institute.
OSTP	Office of Science and Technology Policy.
Outcrossing	The tendency of a plant species to produce offspring that result from the mating of two different individual plants. (See Self-pollinated.)
Ozonation	A water purification and disinfection process.

P

Perennial	Perennials are plant species that live more than two years. They may die in the winter, but grow back from their root-stock the following spring.
Permits	An application to BRS for the introduction of GE organisms that pose a plant pest risk, including plants, insects, or microbes.
Pesticide	A chemical that kills pests. These chemicals include herbicides and insecticides.
Plant pest	Any living stage of any of the following that can directly or indirectly injure, cause damage to, or cause disease in any plant or plant product: protozoan, nonhuman animal, parasitic plant, bacterium, fungus, virus or viroid, infectious agent or other pathogen, or any article similar to or allied with any of the articles specified in the preceding subparagraphs. (7 U.S.C. 7702(14)).
PNW	Pacific Northwest.
POEA	Polyethoxylated tallowamine; a surfactant that may be added to the herbicide formulations to increase leaf penetration.
Post-emergent	Used or occurring in the stage between the emergence of a seedling and the maturity of the crop plant.
PPA	Plant Protection Act.
Pre-plant	Occurring or used before planting a crop.
Pre-emergent	Used or occurring before emergence of seedlings above the ground.

R

Recombinant DNA	DNA, including DNA from different organisms, that has been cut apart and recombined using enzymes.
RED	Reregistration Eligibility Decision.
Regulated article	Subject to APHIS regulation under 7 CFR part 340.
RfD	Reference Dose.
Risk assessment	A scientifically based process consisting of the following steps: (i) hazard identification; (ii) hazard characterization; (iii) exposure assessment; and (iv) risk characterization.
Rotation	In crop production, the cycle of crops grown in successive years in the same field.
RQ	Risk quotient.

S

Secondary seedling	Seedlings that are not planted directly by the farmer but rather sprout unintentionally.
Seedbank	Natural storage of seeds, often dormant, within the soil.
Self-pollinate	The tendency of a plant species to produce offspring that result from a flower pollinating itself. (See Outcrossing.)
Shikimate pathway	Biochemical pathway in plants that produces aromatic amino acids.
Soil tilth	A measure of the health of soil. Good tilth is a term referring to soil that has the proper structure and nutrients to grow healthy crops.
Subchronic toxicity studies	Subchronic toxicity studies are those that study the effects on a small percentage of a subject's life span.

T

T&E	Threatened and Endangered Species.
Trait	A characteristic of an organism that manifests itself in the phenotype. Traits may be the result of a single gene or may be polygenic, resulting from the simultaneous expression of more than one gene.

Transformation	The uptake and integration of DNA in a cell's genome, in which the introduced DNA is intended to change the phenotype of the recipient organism in a predictable manner.
Transgene	A foreign gene that is inserted into the genome of a cell via recombinant DNA techniques.
TSCA	Toxic Substances Control Act.
U	
U.S.C.	United States Code.
USGS	United States Geological Survey.
V	
Vector	The agent, such as a plasmid, used by researchers to carry new genes into cells.
Volunteer	Plants resulting from crop seed that escapes harvest and remains in the field until subsequent seasons, where it germinates along with the succeeding crop.
W	
Weediness	The ability of a plant to colonize a disturbed habitat and compete with cultivated species.
Winterhardy	Those plants that are able to grow during the winter, or at least remain healthy and dormant.

Appendix F. Index

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Appendix G. Effects of Glyphosate-Resistant Weeds in Agricultural Systems

Effects of Glyphosate-Resistant Weeds in Agricultural Systems

Executive Summary

Alfalfa is grown for forage, grazing, seed production (forage and sprouts), human consumption, and honey production. The most acreage is for dry hay forage. In 2005, 22,439,000 acres of dry hay alfalfa was harvested and 204,380 (0.9%) of those acres were certified organic. In addition to mechanical and cultivation techniques, conventional farming allows the use of 16 different herbicides to control weeds in alfalfa. Organic farming does not allow synthetic pesticides or the use of crop varieties produced through genetic engineering. Glyphosate-tolerant (GT) alfalfa allows for the application of glyphosate directly onto growing plants, which provides increased options for weed control over conventional and organic systems. GT alfalfa allows for flexibility in timing of glyphosate application to control weeds. In the two years that GT alfalfa seed was on the market ~200,000 acres were planted in 1,552 counties in 48 states.

Alfalfa Growing Regions

The seven growing regions in the United States have varying optimal alfalfa varieties and farming practices, such as frequency of cutting, companion cropping, and irrigation. California, South Dakota, Idaho, Nebraska, Montana, and Wisconsin are the top six alfalfa hay producing states (in 2007). South Dakota, Montana, Wisconsin, and North Dakota, have the largest acreage of alfalfa hay. California's acreage is highly productive.

Crop Rotations

Crop rotation options may be different between conventional and GT farming systems. Many of the non-glyphosate herbicides have follow-up planting restrictions that limit crop rotation choices in conventional farming. Farmers using GT cropping systems are advised to include some years of non-GT crops in rotation, so there may be limitations in the use of other GT crops if GT alfalfa is used in a rotation plan.

Alfalfa Stand Removal

Glyphosate is the primary tool used to remove conventional alfalfa stands. Use of herbicides other than glyphosate for removal of GT alfalfa is a major difference between GT alfalfa and conventional alfalfa. Non-glyphosate herbicides and tillage are recommended for effective GT alfalfa stand removal.

Volunteer Alfalfa

Farmers are not able to use glyphosate to control volunteer GT alfalfa in other GT crops. However, 11 other herbicides and mixtures of those herbicides are available to control volunteer GT alfalfa. These are the same herbicides that are used to control non-GT alfalfa with the exception that glyphosate can be used to control non-GT alfalfa.

Weeds in Alfalfa

Weeds are controlled in conventional alfalfa with chemicals (herbicides), cultural methods (rotation, companion crops, monitoring), and mechanical methods (tillage). The cultural and mechanical methods are permitted for organic farmers. GT systems allow for the use of one additional herbicide, glyphosate. Weeds are undesirable because they compete with crops, leading to lower yields, can lower the nutritional value of crops, can be poisonous or unpalatable to livestock, can cause off flavors in milk, and can cause trouble with bailing. At least 129 different weed species are identified as minor or major problems in alfalfa. Out of 14 new glyphosate resistant weeds found since 1998, eight are known to be weeds in alfalfa. Out of at least 21 weeds that have natural resistance to glyphosate, ten are known to be a problem in alfalfa. These 18 weeds that are both resistant to glyphosate and traditionally listed as problems in alfalfa include: common ragweed, horseweed, Italian ryegrass, Johnsongrass, Palmer Amaranth, buckhorn plantain, goosegrass, junglerice, bermudagrass, burning nettle, cheeseweed, common lambsquarters, field bindweed, filaree, large crabgrass, morningglory, nutsedge, and purslane. Although the composition of weed shifts is based on the local seedbank, these 18 weeds are candidates for becoming more prevalent than glyphosate-resistant sensitive weeds in rotations that include GT alfalfa.

Glyphosate Resistant Weed Distribution

Nineteen states and over two million acres of cropland contain new glyphosate resistant weeds. The heaviest infestation is in the Southeast and Midwest. Overlap with the major alfalfa producing states in the Intermountain regions (Washington, Oregon, Idaho, Montana, Wyoming, Colorado, Utah, Nevada, and parts of California) seems to be minimal at this point. However, given that there is overlap between glyphosate resistant weed locations and alfalfa hay acreage there is potential for rapid shifts of glyphosate resistant weeds into GT alfalfa fields if GT alfalfa were to be widely adopted. California is a concern because glyphosate resistant weeds are present and alfalfa is a major crop in California.

1.0 Introduction

The scope of this report covers how glyphosate-tolerant (GT) alfalfa could impact weed dynamics in agricultural systems. Gene flow from GT alfalfa is covered in another technical report in this series (Appendix J). In this report, different types of alfalfa crops and cropping systems are described. Regional differences in alfalfa farming are summarized and discussed within the context of weed management. Glyphosate resistant weeds and the potential risks from volunteer GT alfalfa are also discussed. This report is limited to weed dynamics in agricultural systems. Potential effects of farming with GT alfalfa on ecosystems is discussed in other technical reports. This report is limited to practices involving weed management and does not include discussion of control of diseases, insects, nematodes, and vertebrate pests and management of field fertility and soil conservation.

Weed management is an important aspect of alfalfa production. Some of the negative effects of weeds include the following (Canevari et al., 2007; Canevari et al., 2006; Van Deynze et al., 2004; Loux et al., 2007; Miller et al., 2006; Orloff et al. 1997):

- Competition with weeds can reduce yield and cause thinning in the stand.
- Weeds can lower the nutritional quality of alfalfa hay because many weeds are lower in protein (50 percent less protein than alfalfa) and higher in fiber compared to alfalfa.
- Poisonous weeds containing toxic alkaloids (e.g., common groundsel, fiddleneck, yellow starthistle, and poison hemlock) can make alfalfa hay unmarketable.
- Under some conditions weeds can accumulate toxic nitrate concentrations (e.g., lambsquarters, kochia, and pigweed).
- Some weeds with a spiny texture can cause mouth and throat ulcerations in livestock (e.g., foxtail, wild barley, cheatgrass, and bristleglass).
- Weeds that are unpalatable to livestock result in less feeding and, therefore, less productivity (either beef or milk).
- Some weeds can contribute to off flavors in milk (wild celery, Mexican tea, creeping swinegrass, and mustards).
- Weeds that contain higher moisture content than alfalfa (dandelion) can cause bail problems such as mold, off-color hay, and high bale temperatures, which are a fire hazard.

Without weeds, alfalfa can grow at a density of about 12 plants per square foot. Heavily infested stands can have less than one alfalfa plant per square foot (Canevari et al., 2007). In California, if weeds are not effectively controlled weeds can represent up to 76 percent of the first cutting yields (Gianessi et al, 2002). The limiting factor for weed control in alfalfa is that, by the time alfalfa reaches the stage of growth that is tolerant to herbicides, weeds are also beyond their susceptible stage (Gianessi et al., 2002). Glyphosate-tolerant alfalfa was developed so that the broad spectrum herbicide, glyphosate, could be applied directly to alfalfa fields to control weeds. The glyphosate-tolerant (GT) trait was introduced through genetic engineering. Although glyphosate-tolerance has arisen naturally in some plants due to decades of glyphosate use, so far, all crops with glyphosate-tolerance have had the trait introduced through genetic engineering.

1.1 Methodology

A literature search was designed to identify peer review articles and grey literature (e.g., government reports, State Agricultural Extension Office publications) on weeds in alfalfa (Appendix G-2 of this technical report). Several DIALOG databases were searched. Google, Google Scholar, Scirus, and Yahoo search engines supplemented the DIALOG search. Calculations for percentages of harvest were done with Microsoft Excel. Alfalfa harvest statistics were obtained from USDA's National Agricultural Statistics Service (<http://www.nass.usda.gov/index.asp>). In addition, USDA's Economics, Statistics and Market Information System (ESMIS), which is a collaborative project between Albert R. Mann Library at Cornell University and USDA, provided information on alfalfa harvesting (<http://usda.mannlib.cornell.edu/MannUsda/homepage.do>). USDA's Agricultural Marketing Service also provided information on harvests (<http://www.ams.usda.gov>). The common and scientific names for weeds (Appendix G-3 of this technical report) were found in the USDA Plants database (<http://plants.usda.gov/java/invasiveOne>).

2.0 Alfalfa Cropping Systems

This chapter discusses how alfalfa is used, the farming practices for growing alfalfa, and the alfalfa growing regions in the United States.

2.1 Alfalfa Uses

Alfalfa is grown for seed production, human food, honey, grazing, and forage. Forage comprises the largest acreage for alfalfa stands. In 2007, 72.5 million tons of dry hay alfalfa was produced from 21.6 million acres harvested (www.nass.usda.gov).

2.1.1 Forage

Alfalfa is considered the “Queen of Forages” because of its high nutritional content when fed to cattle and horse livestock (Putnam et al., 2001). Due to climate and other differences, farming practices differ regionally. However, some farming characteristics are shared among growing regions. Alfalfa stands have two growing phases, establishment of seedlings (first year) and established (two to eight years). Weed management differs for each phase (Orloff et al., 1997). During the seedling establishment phase, companion or nursery crops, such as oats, wheat, and barley can be used to help shelter the alfalfa seedlings, help prevent soil erosion, and suppress weeds because they germinate and grow faster than alfalfa (Canevari et al, 2007). Well established alfalfa that is not thinning has fewer issues with weeds because established alfalfa is a good competitor. Alfalfa can be harvested (mowed) every 30 to 50 days depending on growth conditions in the region, local weather patterns, and alfalfa variety. In most of the growing regions, alfalfa is only cut three to four times a year, but in the Southwestern U.S. growers can cut up to 10 or 11 times per year (Putnam et al., 2001). To determine when to harvest, farmers balance yield and nutritional content. Yield increases as plants grow and peaks at 100% bloom, but nutritional content is highest in young vegetative plants and decreases until full flower. There is no optimal harvest schedule, because farmers make different decisions based on changing market demand. Farmers may choose to harvest between late bud stage and full bloom, however, alfalfa hay production experts recommend cutting alfalfa for hay at 10% bloom, as this stage provides the most valuable and nutritious forage (e.g., Sheaffer et al. 2000). The highest quality hay (bud stage) is generally used for active dairy cows. Whereas hay that is lower in protein and higher in fiber, is fed to beef cattle, horses, heifers (too young to milk) and non-lactating dairy cows (Ball et al., no year). Alfalfa for livestock feed can be stored in a variety of forms:

- Hay - dry baled at 18-20% moisture
- Haylage - round bale silage, baled at 50-60% moisture, wrapped in plastic
- Silage - chopped and blown into a silo or a truck

2.1.2 *Grazing*

Grazing is sometimes used as an alternative to harvesting alfalfa. Grazing allows for high nutritional gains per animal, but the risks include animal losses due to bloating and difficulties in alfalfa stand maintenance if continuous grazing is present. Farmers may choose grazing for dormant-season alfalfa stubble, a substitute for early or late season cutting, and rotational grazing during the growing season. It is strongly recommended that animals not graze before flowering begins. Alfalfa root carbohydrate reserves may not be sufficient if early grazing is permitted and the potential for bloat decreases with flowering (Orloff et al., 1997).

2.1.3 *Seed Production (Hay and Sprouts)*

Alfalfa is also consumed by humans (e.g., sprouts, dietary supplements, and herbal teas). Sprouts have been the source of several foodborne outbreaks due to bacterial contamination (FDA 1999). Epidemiological investigations suggest that seeds are the likely source in most, if not all, sprout-associated illness outbreaks. Seed grown for sprouts have more stringent restrictions for chemical applications during growing since the chemicals must be evaluated as food residues. Sources of animal waste in fields, such as grazing areas and irrigation water, must also be controlled to reduce the likelihood of pathogens from animal waste coming into to contact with seeds. For these reasons, sprout seed and hay seed are usually grown separately (FDA 1999).

FDA considers GT alfalfa not materially different from conventional alfalfa; therefore it is permitted for human consumption (FDA 2004). However, Monsanto does not allow GT alfalfa to be planted for sprouts (Hubbard 2008). If GT alfalfa was present in human food, it would not be considered adulterated and would not need to be removed from the market.

2.1.4 *Honey*

Alfalfa and clover are common nectar sources for honey bee hives. Although alfalfa is not specifically grown for bees, both managed and wild bee hives are often associated with alfalfa fields (Hammon et al., 2007).

2.2 **Alfalfa Farming Practices**

Alfalfa farming practices are broken into three categories, organic, conventional, and glyphosate-tolerant alfalfa. Only aspects of farming related to weed control are discussed. Practices for controlling disease, insects, nematodes, and vertebrate pests and management of field fertility and soil conservation are not discussed.

2.2.1 *Organic Farming*

For this report, organic production is only those cropping systems that fall under the USDA National Organic Program (NOP) definition of organic farming and are certified organic production systems. In organic systems, the use of synthetic pesticides, fertilizers, and genetically engineered crops is strictly limited. NOP publishes a list of approved substances for organic farming inputs (<http://www.ams.usda.gov/AMSV1.0>).

GT alfalfa is not approved for use in organic systems because it is genetically engineered and because glyphosate application is not permitted in organic systems.

In organic systems, where herbicides are not permitted, alfalfa is tilled and allowed to sit for seven to ten days. Two or more disking passes may be necessary if weed germination is observed. The field should also be treated with nutrients, such as compost and boron, and left for a week to check for further weed germination. Planting can occur once weed growth potential is minimized (Guerena and Sullivan 2003). Manure fertilizer should be composted to kill weed seeds (Canevari et al., 2007).

2.2.2 Conventional Farming

Conventional farming includes any farming system where synthetic pesticides or fertilizers are used. The definition of conventional farming usually includes the use of genetically engineered crops, but genetically engineered GT alfalfa is considered separately for this report (Harker et al., 2005). Conventional farming covers a broad scope of farming practices, ranging from farmers who only occasionally use synthetic pesticides to those farmers whose harvest depends on regular pesticide and fertilizer inputs. The 16 herbicides that may be used in conventional farming are summarized in table G-1 (based on OMAFRA 2008; Canevari et al., 2007; Rogan and Fitzpatrick 2004; Loux et al., 2007).

Table G-1. Herbicides Used in Conventional Alfalfa Farming

Herbicide (Brand)	Stand Stage	Weed	Notes
2,4-DB (Butyrac, Butoxone)	1-4 trifoliolate or established stands	Prickly lettuce Annual sowthistle Mustards Curly dock	• No harvesting or grazing allowed for 60 days following treatment
Benefin (Balan)	Before seeding	Annual grasses Broadleaf	• Not for use on soils high in organic matter
Bromoxynil (Buctril)	2-4 trifoliolate	Coastal fiddleneck Mustard0s Common groundsel Annual sowthistle	• Often tank mixed with other herbicides
Clethodim (Prism, Select)	2-4 trifoliolate or established stands	Summer grasses Yellow foxtail Green foxtail Barnyardgrass Bermudagrass Johnsongrass Goosegrass Volunteer cereals	• Well established perennials require multiple applications • Allow 15 days between application and grazing, feeding, or harvesting of alfalfa
Diuron (Karmex, Direx)	Established stands	Winter annuals Broadleaf Some grasses	• Persists in soil for one year, so cannot be used in last year of stand
EPTC (Eptam)	Established stands	Summer grasses Nutsedge	• Applied before germination • Controls for 30 to 45 days so repeated applications may be necessary

Hexazinone (Velpar)	6 inches of root growth in new stands or established stands	Broadleaf Grasses Common groundsel Chickweed miners Lettuce annual Bluegrass dandelion Buckhorn plantain Speedwell	• Many crops cannot be planted for 18 months without yield damage
Imazamox (Raptor)	2-4 trifoliolate or established stands	Winter annual Grasses Broadleaf	• Preharvest interval is 20 days
Imazethapyr (Pursuit)	2-4 trifoliolate or established stands	Winter annuals Mustards Shepherd's purse Creeping swinecress Chickweed	• Follow-up planting restrictions range from 4 to 40 months
Metribuzin (Sencor)	Established stands	Lamb's-quarters Wild mustard Redroot pigweed Common ragweed Shepherd's-purse Lady's-thumb Velvetleaf Jimsonweed Prostrate pigweed Russian thistle Yellow wood-sorrel Prickly mallow Chickweed Cocklebur Carpetweed Dandelion seedlings Barnyard grass Crab grass Foxtail Fall panicum Witch grass Johnson grass Cheat grass	• No grazing or harvesting allowed for 28 days following application
Norfluzon (Solicam)	Established stands	Broadleaf Grasses Nutsedge	• Cannot be applied within 28 days of harvest • Does not control emerged weeds • 24 month rotation interval
Paraquat (Gramoxone Inteon)	3, 6, or 9 trifoliolate; established stands	Broad spectrum	• Rescue treatment when weeds form a canopy over alfalfa • No harvest or grazing until 60 days after application • Often used in the last year of the stand
Pronamide (Kerb)	First trifoliolate leaf stage	Perennial grasses Quack grass Annual grasses Volunteer cereals Common chickweed	• No grazing or harvesting allowed for 120 days following application
Sethoxydim (Poast)	2-4 trifoliolate or established stands	Summer grasses Yellow foxtail Green foxtail Barnyardgrass Bermudagrass Johnsongrass Goosegrass	• Well established perennials require multiple applications
Terbacil (Sinbar)	Established stands	Barnyard grass Bluegrass Crab grass Foxtail Chickweed Cheat grass Perennial rye grass Wild barley Mustard Prickly lettuce Stinkweed Annual sow-thistle Henbit Lamb's-quarters Pigweed	• Can not plant any other crop for 2 years after Sinbar application

		Purslane Ragweed Partial control of: Quack grass Horsenettle Vetch Yellow nut sedge	
Trifluralin (Treflan/TR-10)	Established stands	Summer grasses	<ul style="list-style-type: none"> • Applied before germination • Rainfall or sprinkler irrigation is required within 3 days after irrigation to incorporate the herbicide • Controls dodder before germination

2.2.3 GT Farming

GT alfalfa can be integrated into conventional farming practices. Farming GT alfalfa is mostly the same as farming conventional alfalfa, with two important exceptions. Weeds can be controlled by the application of glyphosate directly on top of growing alfalfa and, when alfalfa stands reach the end of their life cycle (typically after 3-8 years depending on growing region), glyphosate cannot be used to kill the stand to prepare for another rotation (Miller et al., 2006). In GT alfalfa, herbicides other than glyphosate combined with tillage are required to obtain 100 percent removal. Several of the recommended GT alfalfa stand removal herbicides result in restrictions regarding what crops can be planted next, so careful crop rotation plans are necessary when using GT alfalfa. Stand removal is discussed in the technical report *Effects of Changes in Farming Practices on Water, Soil and Air Due to Use of Glyphosate-Tolerant Alfalfa* (appendix J).

Another important difference to some farmers is that non-GT crops cannot be used as companion crops for GT alfalfa. For farmers that plant pure alfalfa stands this difference does not matter. For farmers that traditionally use companion crops, this difference is important. Companion crops can increase overall forage yield but decrease hay quality (McCordick et al., 2008).

2.2.4 Crop Rotation in Alfalfa

For weed, insect, and disease management, it is recommended that alfalfa be used in rotation with other crops. It is also advised to rotate alfalfa because mature alfalfa produces medicarpin, which is auto toxic to seedling alfalfa (Guerena and Sullivan 2003). This autotoxicity is the primary problem for alfalfa seeded after alfalfa (Jennings, no year). Table G-2 presents rotation recommendations for control of several common alfalfa pests.

Table G-2. Recommended Rotations for Pest Reduction (Goodell 2006)

Pest	Recommended Rotation
Root knot nematode	1 year rotation with cotton
Stem nematode	3-4 year rotation with small grains, beans, cotton, corn, sorghum, lettuce, carrots, tomatoes, or forage grasses.*
Diseases: Bacterial wilt Anthracnose Spring blackstem Common leafspot Stagonospora	3-4 year rotation with small grains, beans, corn, sorghum, forage grasses.*
Winter weeds	A minimum of 1 year (preferably longer) in crops such as small grains, wheat, oats, winter forage grasses that allow the use of selective herbicides that are not registered in alfalfa.
Summer weeds	A minimum of 1 year (preferably longer) in crops such as small grains, beans, cotton, corn, sorghum, summer forage grasses that allow the use of selective herbicides that are not registered in alfalfa.
Dodder	At least 2 years with cotton or other nonhost crops such as small grains, beans, corn, sorghum, or forage grasses. Avoid rotations with crops such as tomatoes, onions, and carrots that also serve as a host for this weed.
Nutsedge	Two year rotation with corn or sorghum rotation that includes application of herbicide to control nutsedge.

* Three to four-year rotations give satisfactory results. A rotation for fewer years will provide minimal suppression.

Herbicides that can be used to remove GT alfalfa have rotation restrictions. For example, following clopyralid (Curtail® or Stinger®), pea, lentil, potato, and dry bean cannot be planted for 18 months. Picloram (Tordon®) can only be followed by grasses for the year after application. Sunflower, dry bean, and potato should not be planted for several years following picloram (Miller et al., 2006). Dicamba (Banvel®) should not be used prior to soybean and is also limited seasonally in California (Dillehay and Curran 2006). Because of these restrictions, alfalfa stand removal and rotation schedules should be closely coordinated. Non-glyphosate herbicides are available to manage alfalfa volunteers in wheat, oats, barley, sugar beet, and corn. Therefore rotations from GT alfalfa to those crops should be similar to rotations with non-GT alfalfa (Rogan and Fitzpatrick 2004).

Smother crops planted before alfalfa can suppress weeds. For example, sorghum-sudangrass hybrid or foxtail millet both suppressed weeds and enhanced subsequent alfalfa establishment (Forney et al., 1985).

No-till GT corn can be planted directly into alfalfa. In a study comparing no-till GT corn planted into cut or uncut alfalfa and various herbicide applications to control the alfalfa, corn yield was 13% higher following herbicide applications to uncut alfalfa. Application of glyphosate and dicamba at planting resulted in the greatest corn yield. Given that alfalfa is also a valuable crop, whether the corn yield gain is worth the loss of an alfalfa harvest should be weighed (Glenn and Meyers 2006).

2.3 Alfalfa Growing Regions



Figure G-1: Alfalfa growing regions (Rogan and Fitzpatrick 2004)

The Association of Official Seed Certifying Agencies, National Alfalfa and Miscellaneous Legumes Variety Review Board and USDA Plant Variety Protection Office recognizes seven growing regions in the United States, Moderately Winterhardy Intermountain, Winterhardy Intermountain, Southeast, Great Plains, North Central, East Central, and Southeast (figure G-1) (<http://www.aosca.org/VarietyReviewBoards/Alfalfa.html>). In addition, the Pacific Northwest, which includes Moderately Winterhardy Intermountain and Winterhardy Intermountain, is also sometimes recognized as a distinct growing region.

Table G-3 and table G-4 summarize the winter survival and fall dormancy ratings for alfalfa varieties. The National Alfalfa & Forage Alliance (NAFA) publishes a list of varieties and their winter survival ratings, fall dormancy ratings, and susceptibility to 17 different crop stresses (e.g., diseases, insects, grazing). The list is updated yearly and the 2007/2008 version lists 242 varieties of alfalfa (NAFA 2008). When selecting a variety, farmers consider yield, stand persistence, dormancy, pest and disease resistance, herbicide resistance, hay quality, price, seed certification, and other factors that may be specific to their farming situation (Orloff et al., 1997).

Table G-3. Winter Survival Ratings

Category	Check Variety	Score
Superior	ZG 9830	1
Very Good	5262	2
Good	WL325HQ	3
Moderate	G-2852	4
Low	Archer	5
Non Winterhardy	Cuf 101	6

Table G-4. Fall Dormancy Ratings

Check Variety	Rating
Maverick	1
Vernal	2
5246	3
Legend	4
Archer	5
ABI 700	6
Dona Ana	7
Pierce	8
CUF 101	9
UC-1887	10
UC-1465	11

1 is very dormant, 11 is extremely non-dormant

Table G-5 presents the U.S. states in order of percentage of alfalfa harvest (in 2005). For each state, the growing region, the percentage of the total national harvest of all alfalfa are presented for 2002, 2005, and 2007; and the percentage of the national organic certified harvest are presented for 2002 and 2005. In 2005, the most recent USDA organic harvest report, 22,439,000 acres of dry hay alfalfa was harvested and 204,380 (0.9 percent) of those acres were certified organic. The number of acres harvested in a state does not indicate the quantity of the harvest. For example, as shown in table G-5, because of the growing season length, California ranks top in production (in 2007, ~11 percent of the national harvest and ~7 million pounds) and South Dakota ranks second (in 2007, ~6.8 percent of the national harvest and ~4 million pounds) even though South Dakota has ~2 million acres and California has less than 1 million acres of alfalfa. In addition, even though the Northeastern states rank low in the percentage of acres and quantity of harvest, alfalfa is the number one crop for several of those states (NAFA 2007).

Table G-5. Alfalfa Growing Regions and Percentage of Dry Hay Harvest by State

State	Growing Region	Percent of harvest acres			Percent of organic harvest	
		2002	2005	2007	2002	2005
South Dakota	North Central	10.57	10.70	9.86	8.58	6.82
Montana	Winter Hardy Intermountain	6.76	7.80	9.23	3.66	2.60
North Dakota	North Central	6.13	7.35	7.20	11.22	10.09
Wisconsin	North Central	7.32	6.91	7.50	16.34	14.38
Minnesota	North Central	5.59	6.02	4.67	6.40	10.44
Iowa	North Central	5.16	5.57	4.10	6.11	4.50
Nebraska	North Central	5.92	5.57	5.36	2.71	4.01
Idaho	PNW-Intermountain	4.57	5.08	5.12	24.69	24.22
California	Moderate Winter Hardy Intermountain/ Southwest	5.19	4.63	4.88	2.92	6.48
Michigan	East Central	3.56	4.01	3.45	2.07	0.35
Kansas	Great Plains	4.14	3.79	3.92	1.40	0.32
Colorado	Winter Hardy Intermountain	3.40	3.57	4.25	3.45	4.38
Wyoming	Winter Hardy Intermountain	2.16	2.67	3.33	0.19	0.84
Utah	Moderate Winter Hardy Intermountain	2.48	2.41	2.71	0.60	0.45
Ohio	East Central	2.71	2.27	2.16	1.89	0.50
Pennsylvania	East Central	2.96	2.27	2.35	0.96	0.60
Missouri	East Central	1.77	2.01	1.46	0.23	0.58
New York	East Central	2.90	2.01	2.22	1.34	0.16
Washington	PNW-Intermountain	2.37	2.01	2.22	1.19	0.56
Illinois	East Central	1.84	1.78	1.59	0.80	1.22
Oregon	PNW-Intermountain	2.15	1.78	2.12	0.42	3.23
Indiana	East Central	1.41	1.52	1.19	0.03	0.29
Oklahoma	Great Plains	1.54	1.43	1.65	0.00	0.04
Kentucky	East Central	1.37	1.16	1.33	0.00	0.01
Nevada	Moderate Winter Hardy Intermountain	1.34	1.16	1.35	1.25	1.47
Arizona	Moderate Winter Hardy Intermountain/ Southwest	1.03	1.16	1.27	0.91	0.24
New Mexico	Moderate Winter Hardy Intermountain	0.83	1.07	1.17	0.14	0.33
Texas	Great Plains/ Southwest/ Southeast	0.72	0.67	0.76	0.18	0.55
Virginia	East Central	0.62	0.49	0.44	0.31	0.14
Vermont	East Central	0.20	0.20	0.16	0.00	0.00
Maryland	East Central	0.25	0.18	0.20	0.00	0.01
Tennessee	East Central	0.13	0.16	0.10	0.00	0.00
West Virginia	East Central	0.23	0.16	0.14	0.00	0.00
New Jersey	East Central	0.12	0.11	0.10	0.00	0.00
Arkansas	East Central	0.07	0.09	0.06	0.00	0.00
Massachusetts	East Central	0.07	0.06	0.05	0.00	0.00

State	Growing Region	Percent of harvest acres			Percent of organic harvest	
		2002	2005	2007	2002	2005
Maine	North Central	0.06	0.05	0.05	0.00	0.17
North Carolina	Southeast	0.10	0.05	0.05	0.00	0.00
Connecticut	East Central	0.04	0.04	0.04	0.00	0.05
New Hampshire	East Central	0.04	0.04	0.03	0.00	0.00
Delaware	East Central	ND	0.02	0.02	0.00	0.00
Rhode Island	East Central	0.01	0.01	0.01	0.00	0.00
Florida	Southeast	0.02	0.00	0.03	0.00	0.00
Georgia	Southeast	0.01	0.00	0.01	0.00	0.00
Louisiana	Southeast	0.03	0.00	0.01	0.00	0.00
Mississippi	Southeast	ND	ND	0.02	ND	ND
South Carolina	Southeast	0.01	0.00	0.02	0.00	0.00
Alabama	Southeast	0.04	ND	0.04	0.00	ND
Alaska		0.00	ND	0	0.00	ND
Hawaii		ND	0.00	0.00	0.00	0.00

ND = no data provided by USDA

Other differences in alfalfa farming are revealed by examining the number of farms that grow alfalfa and the number of farms that irrigate. Comparison of California and Wisconsin (table G-6) shows that in California ~97 percent of the farms irrigate, whereas in Wisconsin only 0.5 percent of the farms irrigate. In addition, the average farm size in California is much larger than in Wisconsin. It should be noted that the average farm size calculation is a bit misleading because in California mainly two farm sizes exist, small and very large (4,000 acres). In general, because farm size does not fit a normal distribution, the average farm size does not give a full picture of farm sizes. However average farm size does relay the general trend of farm size in a state. Like any census, these data may not include all alfalfa farms.

Table G-6. Alfalfa Dry Hay Harvest 2007 U.S. Agricultural Census

State	Number of Farms	Acres Harvested	Quantity (pounds) Harvested	Farms Irrigated	Acres Irrigated	% of Acres	% of Pounds	Avg. Acres per Farm
United States	290,726	20,244,497	65,349,074	56,390	6,556,652	100.0	100.0	70
California	3,587	986,982	7,057,014	3,488	963,086	4.9	10.8	275
South Dakota	12,653	1,996,599	4,414,338	716	75,913	9.9	6.8	158
Idaho	8,817	1,037,520	4,254,543	7,605	861,092	5.1	6.5	118
Nebraska	14,820	1,085,921	3,955,881	4,405	389,516	5.4	6.1	73
Montana	9,711	1,868,756	3,936,445	5,444	703,960	9.2	6.0	192
Wisconsin	30,810	1,517,522	3,673,619	171	8,809	7.5	5.6	49
North Dakota	8,985	1,457,604	3,072,682	240	21,773	7.2	4.7	162

Iowa	22,040	830,440	3,054,729	62	1,198	4.1	4.7	38
Kansas	9,643	793,140	2,986,134	1,115	207,455	3.9	4.6	82
Colorado	8,648	861,053	2,887,865	7,347	707,234	4.3	4.4	100
Minnesota	20,398	944,775	2,671,173	384	15,603	4.7	4.1	46
Washington	4,294	448,588	2,192,001	2,822	334,005	2.2	3.4	104
Utah	7,780	548,570	2,172,218	7,413	507,798	2.7	3.3	71
Arizona	943	257,407	1,968,043	920	257,263	1.3	3.0	273
Oregon	3,569	428,812	1,777,894	3,043	380,679	2.1	2.7	120
Michigan	16,431	698,595	1,707,036	291	8,080	3.5	2.6	43
Wyoming	4,007	674,284	1,696,438	3,357	471,126	3.3	2.6	168
Pennsylvania	14,402	475,873	1,357,225	109	462	2.4	2.1	33
Ohio	15,354	437,658	1,256,174	17	536	2.2	1.9	29
Nevada	1,128	274,004	1,217,586	1,128	274,004	1.4	1.9	243
New Mexico	4,272	236,103	1,176,242	4,091	222,018	1.2	1.8	55
Illinois	12,913	322,339	1,138,512	47	906	1.6	1.7	25
Oklahoma	3,781	334,990	1,131,938	294	33,000	1.7	1.7	89
New York	7,707	450,144	1,119,421	31	901	2.2	1.7	58
Missouri	8,229	295,021	782,847	63	1823	1.5	1.2	36
Texas	2,391	153,763	721,303	1,154	98,831	0.8	1.1	64
Indiana	10,775	241,129	665,767	139	2,185	1.2	1.0	22
Kentucky	10,538	269,610	524,565	109	1,210	1.3	0.8	26
Virginia	3,063	89,213	233,807	76	679	0.4	0.4	29
Maryland	1,429	40,576	120,402	49	712	0.2	0.2	28
Vermont	571	31,769	68,624	2	(D)	0.2	0.1	56
West Virginia	1,185	28,465	62,484	5	(D)	0.1	0.1	24
New Jersey	728	20,310	51,483	39	799	0.1	0.1	28
Tennessee	1,655	20,074	45,819	28	(D)	0.1	0.1	12
Arkansas	278	11,732	28,647	15	932	0.1	0.0	42
Maine	246	10,089	23,876	0	0	0.0	0.0	41
Massachusetts	406	9,921	22,537	1	(D)	0.0	0.0	24

Connecticut	349	8,343	18,441	0	0	0.0	0.0	24
Alabama	340	7,526	16,944	13	91	0.0	0.0	22
North Carolina	758	10,322	16,755	67	360	0.1	0.0	14
Florida	141	6,951	14,993	13	1,071	0.0	0.0	49
Delaware	177	3,687	13,530	22	421	0.0	0.0	21
New Hampshire	218	5,373	13,475	5	(D)	0.0	0.0	25
South Carolina	143	4,070	8,860	20	274	0.0	0.0	28
Mississippi	159	3,931	7,113	4	35	0.0	0.0	25
Georgia	134	1,655	4,810	18	243	0.0	0.0	12
Louisiana	52	2,164	4,768	2	(D)	0.0	0.0	42
Rhode Island	63	1,035	1,806	1	(D)	0.0	0.0	16
Hawaii	5	89	267	5	89	0.0	0.0	18

D = data withheld to protect identity of individual farms

2.4 Summary of Findings

Alfalfa is grown for forage, grazing, seed production (forage and sprouts), human consumption, and honey production. The most acreage is for dry hay forage. Alfalfa is currently grown through conventional farming practices, organic farming, and in glyphosate-tolerant systems. In addition to mechanical and cultivation techniques, conventional farming allows the use of 16 different herbicides to control weeds in alfalfa. Organic farming does not allow synthetic pesticides or the use of crop varieties produced through genetic engineering. GT alfalfa allows for the application of glyphosate directly onto growing plants, which provides increased options for weed control over conventional and organic systems. In 2005, 22,439,000 acres of dry hay alfalfa was harvested and 204,380 of those acres were certified organic.

Crop rotation options may be different between conventional and GT systems. Many of the non-glyphosate herbicides have follow-up planting restrictions that limit crop rotation choices in conventional farming. Farmers using GT cropping systems are advised to include some years of non-GT crops in rotation, so there may be limitations in the use of other GT crops if GT alfalfa is used in a rotation plan.

The seven growing regions in the United States have varying optimal alfalfa varieties and farming practices, such as frequency of cutting, companion cropping, and irrigation. California, South Dakota, Idaho, Nebraska, Montana, and Wisconsin are the top six alfalfa hay producing states (in 2007). South Dakota, Montana, Wisconsin, and North Dakota, have the largest acreage of alfalfa hay. California's acreage is highly productive.

3.0 Glyphosate-Tolerant Alfalfa (Roundup Ready®)

Glyphosate-tolerant (GT)²³ alfalfa was deregulated in 2005 and by 2006, ~80,000 ha (~200,000 acres) were planted in the United States (Beckie and Owen 2007).²⁴ USDA APHIS lists all the counties in the United States where GT alfalfa has been planted (<http://www.aosca.org/VarietyReviewBoardsAlfalfa.html>). GT alfalfa has been planted in 1,552 counties and 48 states. Alaska and Hawaii do not have GT alfalfa. In March of 2007 USDA published notice in the Federal Register that GT alfalfa is a regulated article and GT alfalfa seed sales and plantings were halted. GT alfalfa planted in the 2005 and 2006 growing seasons is still permitted to be harvested, but has court ordered stewardship practices to minimize risk of co-mingling GT and non-GT alfalfa (Hubbard 2008).

3.1 Using GT Alfalfa

Van Deynze et al., (2004) reported that in field trials when Roundup® (glyphosate) was applied during alfalfa stand establishment at the 3 to 4 trifoliolate stage, weeds were controlled and usually no second application was needed. Early applications allowed for late germination of weeds and later applications allowed weeds to compete with alfalfa. For example in the intermountain region applications at the unifoliolate to first trifoliolate stage resulted in invasion by prickly lettuces and henbit and required a second application. In the Southwest annual bluegrass and canarygrass germinated in early December and required a second application of glyphosate for control. The effectiveness of the first application during stand establishment is a function of which weed species are present and their germination period as well as how soon after application the alfalfa canopy covers the soil surface. In California there is period of time in the winter when alfalfa stands are dormant and rain causes winter weeds to germinate.

Recommended application of glyphosate to GT alfalfa is 0.75 to 1.5 pounds acid equivalent per acre (22 to 44 fluid ounces Roundup Weathermax 4.5S® per acre) at the three to five trifoliolate stage during stand establishment and up to five days before harvest in established stands (Dillehay and Curran, 2006). The maximum labeled rate for a single use of glyphosate on GT alfalfa is 1.55 pounds glyphosate acid equivalent per acre.

Alfalfa is polyploid (tetraploid), so small percentages (three to seven percent) of the seedlings do not have the GT trait. This is similar for other genetic traits. If glyphosate is sprayed early enough, plants containing the GT trait will fill in gaps left by dead weeds and non-GT alfalfa that was killed (Van Deynze et al., 2004). Up to six percent injury was observed after the first glyphosate application in a new stand, but was gone by the time of first harvest (McCordick et al., 2008). In GT alfalfa, crop injury from glyphosate application is much less than for other herbicides (Canevari et al, 2007).

GT alfalfa is an option for weed control; however it may not be appropriate in the following situations (Dillehay and Curran, 2006):

²³ "Resistance" and "tolerance" are usually synonyms and are often used interchangeably. In this report "tolerance" is used to indicate crop varieties that are intentionally engineered to withstand glyphosate application. "Resistance" is used to indicate weeds and weed biotypes that can withstand glyphosate application.

²⁴ 2.471 acres = 1 ha = 104 m²

- Alfalfa-grass mixtures and alfalfa seeded with companion/nursery crops
- Fields that have a history of low weed populations
- Fields that are rotated between alfalfa and other GT crop varieties (e.g. Roundup Ready® soybean)

McCordick et al. (2008) tested GT alfalfa in 2004 and 2005 growing seasons in field studies in Michigan. Two seeding regimes were used, clear seeded (only alfalfa seed) and oat companion crop. In both of these seeding regimes glyphosate, imazamox, and untreated conditions were tested. For the oat companion crop stands, clethodim was added to the imazamox treatment to increase control of oat. In the first year (stand establishment), temporary stunting was observed with glyphosate treatment, but it did not affect yield or stand density. Clear seeded alfalfa treated with glyphosate yielded the highest alfalfa dry matter in both years, even though combined forage yield was higher in the oat companion crop. When no herbicide was applied the oat companion crop had lower weed biomass than clear seeded alfalfa.

3.1.1 *Stand Establishment*

Forage alfalfa is planted in the spring and in the early fall in the Southwest and western regions. Currently trifluralin, EPTC, imazethapyr, imazamox, sethoxydim, clethodim, and bromoxynil herbicides are sometimes used during spring stand establishment and could be replaced with glyphosate if GT alfalfa is used. Use of GT alfalfa also allows weed control during late-summer and fall establishment (Rogan and Fitzpatrick 2004).

3.1.2 *Stand Removal*

One of the major differences between conventional alfalfa and GT alfalfa occurs during stand removal. Whereas glyphosate is often used to kill old stands of conventional alfalfa for crop rotations, GT alfalfa has to be removed through other mechanisms. Application of an herbicide (e.g., 2,4-D, dicamba (Banvel®), and clopyralid (Stinger®)) and tillage is effective. In no-till systems 2,4-D and dicamba can be applied together. However dicamba cannot be used before planting soybean (Dillehay and Curran, 2006).

Renz 2007 reported that dicamba and 2,4-D (WeedMaster®) applied at 2 pt/A achieved zero resprouting of alfalfa in the spring following herbicide application. Lower concentrations of WeedMaster resulted in 0.3 to 2.5 percent resprouting. The other herbicides applications (dicamba or 2,4-D only) resulted in 0.5 to 26.5 percent resprouting. In another study, picloram and 2,4-D was more effective than dicamba and 2,4-D (Miller et al., 2006). Combined with plowing, clopyralid, clopyralid plus 2,4-D, dicamba plus 2,4-D, picloram, and picloram plus 2,4-D all controlled alfalfa 100 percent. Plowing alone provided 75 percent control (Miller et al., 2006).

Potential effects of changes in tillage practices due to the use of GT alfalfa are discussed in the technical report *Effects of Changes in Farming Practices on Water, Soil and Air Due to Use of Glyphosate-Tolerant Alfalfa* (appendix K).

Figure G-2 shows Monsanto's guidance for GT alfalfa stand removal (Monsanto 2008).

STAND TAKEOUT AND VOLUNTEER MANAGEMENT	
<p>Crop rotations can be divided into two main groups, alfalfa rotated to: 1) grass crops (e.g. corn and cereal crops); and 2) broadleaf crops. More herbicide alternatives exist for management of volunteer alfalfa in grass crops. The recommended steps for controlling volunteer Roundup Ready Alfalfa are:</p> <p>Diligent Stand Takeout</p> <p>Use appropriate commercially available herbicide treatments alone for reduced tillage systems or in combination with tillage to terminate the Roundup Ready Alfalfa stand. Refer to your regional technical bulletin for specific stand takeout recommendations. NOTE: Roundup agricultural herbicides are not effective for terminating Roundup Ready Alfalfa stands.</p> <p>Start Clean</p> <p>If necessary, utilize tillage and/or additional herbicide application(s) after stand takeout, and before planting of the subsequent rotational crop to manage any newly emerged or surviving alfalfa.</p>	<p>Plan for Success</p> <p>Rotate to crops with known and available mechanical or herbicidal methods for managing volunteer alfalfa, keeping in mind that Roundup agricultural herbicides will not terminate Roundup Ready Alfalfa stands.</p> <ul style="list-style-type: none"> • Rotations to certain broadleaf crops are not advisable if the grower is not willing to implement recommended stand termination practices. • In the event that no known mechanical or herbicidal methods are available to manage volunteer alfalfa in the desired rotational crop, it is suggested that a crop with established volunteer alfalfa management practices be introduced into the rotation. <p>Timely Execution</p> <p>Implement in-crop mechanical or herbicide treatments for managing alfalfa volunteers in a timely manner; that is, before the volunteers become too large to control or begin to compete with the rotational crop.</p>

Figure G-2: Monsanto's guidance for GT alfalfa stand removal (Monsanto 2008)

3.2 Volunteer GT Alfalfa

Crop rotation is the practice of alternating crop species in the same field in different years. Crops are considered volunteer when they grow in a field during a year when they have not been planted intentionally. Volunteer crops are weeds because they compete with the current crop for resources and they may harbor insect and disease pests. For example, volunteer GT cotton in GT soybean can harbor boll weevil. Boll weevil is a serious cotton pest and is monitored aggressively in cotton for eradication. However boll weevil is not monitored in soybean (York, et al., 2004).

Volunteer GT crops have to be controlled through the use of other herbicides. For example GT wheat and canola is best controlled through paraquat and diuron (Rainbolt et al., 2004). Volunteer GT canola needs to be controlled before replanting canola because cultivars with different resistance genes can cross and result in multiple herbicide resistance (Rainbolt et al., 2004).

Herbicides that are used to control alfalfa, including GT alfalfa include (Rogan and Fitzpatrick 2004; Renz 2007; Dillehay and Curran, 2006; Miller et al., 2006):

- 2,4-D
- Clopyralid
- Dicamba
- Dicamba and diflufenzopyr
- Glufosinate
- Primsulfuron-methyl

- Mixtures of dicamba, 2,4-D, and clopyralid
- Picloram
- Picloram and 2,4-D
- Halosulfuron and dicamba
- Acetochlor
- Acetochlor and atrazine
- Acetochlor and atrazine and dicamba
- Atrazine and dicamba
- Clopyralid and flumetsulam

Monsanto demonstrated in their Deregulation Petition that the last five herbicides and mixes on the above list can control volunteer GT alfalfa in corn (Rogan and Fitzpatrick 2004). Clopyralid is effective at controlling volunteer alfalfa in broccoli (Tickes 2002). Clopyralid or 2,4-D provide control of volunteer alfalfa in 33 different crops. Exceptions include potatoes and popcorn (Rogan and Fitzpatrick 2004).

Feral alfalfa (alfalfa not in fields) is discussed in more depth in the technical report *Effects of Glyphosate-tolerant Weeds in Non-agricultural Ecosystems* (appendix H).

3.3 Summary of Findings

GT alfalfa allows for flexibility in timing of glyphosate application to control weeds. In the two years that GT alfalfa seed was on the market ~200,000 acres were planted in 1,552 counties in 48 states.

Glyphosate is the primary tool used to remove conventional alfalfa stands. Use of herbicides other than glyphosate for removal of GT alfalfa is a major difference between GT alfalfa and conventional alfalfa. Non-glyphosate herbicides and tillage are recommended for effective GT alfalfa stand removal.

Farmers are not able to use glyphosate to control volunteer GT alfalfa in other GT crops. However, eleven other herbicides and mixtures of those herbicides are available to control volunteer GT alfalfa. These are the same herbicides that are used to control non-GT alfalfa with the exception that glyphosate can be used to control non-GT alfalfa.

4.0 Weeds in Alfalfa

Although weeds can be a problem in alfalfa, once alfalfa is established, it acts as a suppressor of weeds and is commonly used in rotations for weed reduction. For example, prior rotation in alfalfa can reduce weed densities in sunflower to the same level as herbicide treatment and alfalfa in corn rotations also benefited corn yield and suppressed weeds (Clay and Aguilar 1998). Fields with a history of perennial weed infestation are not well suited for alfalfa (Canevari et al, 2007).

Wilson (1981) tested seven herbicides on dormant alfalfa in Nebraska and found good weed control that resulted in increased protein and total digestible nutrients (except for hexazinone application) compared to untreated control plots. Weeds that were successfully controlled included kochia, downy brome, tansymustard, Russian thistle, and prickly lettuce. Out of 48 weeds in alfalfa listed by the University of California Pest Management Guidelines, five weeds are not controlled by glyphosate: green foxtail, filed bindweed, yellow nutsedge, buckhorn plantain, and burning nettle. There was no data on pepperweeds. Three weeds stand out (field bindweed, yellow nutsedge, and buckhorn plantain) because they are not controlled well by glyphosate or any of the other 16 herbicides evaluated (table VII-3 in Rogan and Fitzpatrick 2004).

A list of 129 weeds that are known to infest alfalfa are in Appendix G-3 of this technical report, including the U.S. region where they are most prevalent as well as their scientific and common names.

General rules for managing weeds at establishment or in the seedling year include (Loux et al., 2007):

- Weeds that emerge with the crop are generally more destructive.
- Maintain the forage relatively weed-free for the first 60 days.
- Weeds that emerge beyond 60 days will not influence that year's forage yield.
- Later-emerging weeds may still influence forage quality.
- Winter annual weed competition in early spring is most damaging to forages.
- Broadleaved weeds are generally more competitive against legumes than grassy weeds.

4.1 Glyphosate Resistance in Weeds

Herbicide resistance can be defined as the inherited ability of a weed population to survive and reproduce following a herbicide application that is normally lethal to the vast majority of individuals of that species (lethal to the wild type) (Puricelli and Tuesca, 2005; Stoltenberg and Jeschke, no year). Farmers are concerned about glyphosate-tolerant weeds (Johnson and Gibson 2006). Figure G-3 represents the different weed populations in alfalfa. Since 1998, 14 new glyphosate resistant weeds have been found globally. Nine of these have glyphosate resistant biotypes in the United States. Eight of the new glyphosate resistant weeds known globally are also known to be weeds in alfalfa stands (see Appendix G-3 in this technical report for list of weeds in alfalfa). At least 21 weeds that have natural resistance to glyphosate exist. Ten of these naturally glyphosate resistant weeds are known to be a problem in alfalfa. Table G-7 lists

the weeds known to be glyphosate resistant in general or have glyphosate resistant biotypes. Figure G-4 summarizes the results of a recent farmer survey regarding their satisfaction with GT alfalfa and which weeds were controlled.

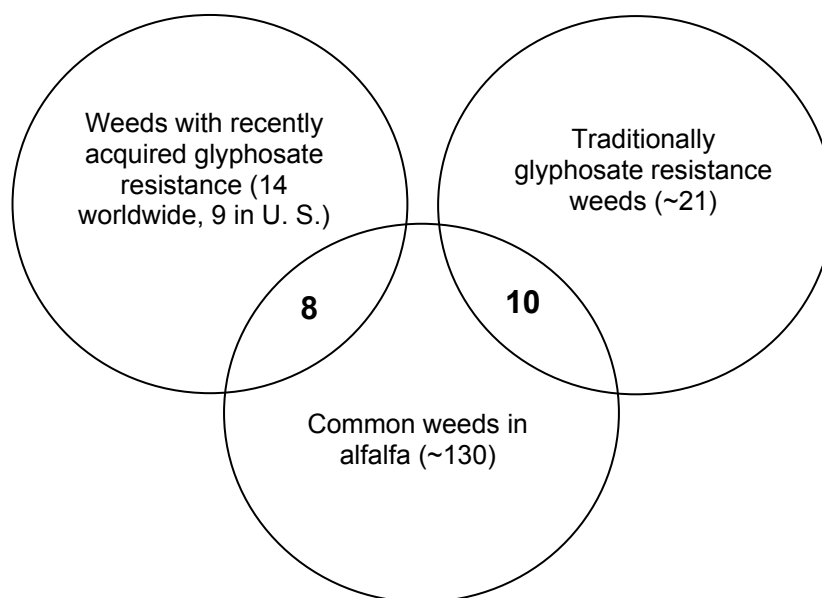


Figure G-7: Weeds in alfalfa

Table G-7. Glyphosate-resistant weeds

Common Name	Scientific Name	Resistant Biotype Reported in U.S.	Identified Problem in Alfalfa (Appendix G-3)	Listed on Roundup® Label	Source
Recently Evolved or Selected Resistant Biotypes					
Common Ragweed	<i>Ambrosia artemisiifolia</i>	Yes	Yes	Yes (with resistant biotype note)	Heap et al., 2008
Common Waterhemp	<i>Amaranthus rudis</i> and <i>Amaranthus tuberculatus</i>	Yes	No	Yes (with resistant biotype note)	Heap et al., 2008; Nandula et al., 2005
Giant Ragweed	<i>Ambrosia trifida</i>	Yes	No	Yes (with resistant biotype note)	Heap et al., 2008
Hairy Fleabane	<i>Coryza bonariensis</i>	Yes	No	Yes	Heap et al., 2008; Nandula et al., 2005
Horseweed	<i>Coryza canadensis</i>	Yes	Yes	Yes (with resistant biotype note)	Heap et al., 2008; Nandula et al., 2005

Italian Ryegrass	<i>Lolium multiflorum</i>	Yes	Yes	Yes (with resistant biotype note)	Heap et al., 2008; Nandula et al., 2005
Johnsongrass	<i>Sorghum halepense</i>	Yes	Yes	Yes (mixture also recommended)	Heap et al., 2008
Palmer Amaranth	<i>Amaranthus palmeri</i>	Yes	Yes	Yes (with resistant biotype note)	Heap et al., 2008
Rigid Ryegrass	<i>Lolium rigidum</i>	Yes	No	Yes (with resistant biotype note)	Heap et al., 2008; Nandula et al., 2005
Buckhorn Plantain*	<i>Plantago lanceolata</i>	No	Yes	No	Heap et al., 2008
Goosegrass	<i>Eleusine indica</i>	No	Yes	Yes	Heap et al., 2008; Nandula et al., 2005
Junglerice	<i>Echinochloa colona</i>	No	Yes	Yes (mixture also recommended)	Heap et al., 2008
Sourgrass	<i>Digitaria insularis</i>	No	No	No	Heap et al., 2008
Wild Poinsettia	<i>Euphorbia heterophylla</i>	No	No	No	Heap et al., 2008

Historically Naturally Resistant					
Asiatic dayflower	<i>Commelina communis</i>		No	No	Nandula et al., 2005
Birdsfoot trefoil	<i>Lotus corniculatus</i>		No	No	Nandula et al., 2005
Bermudagrass	<i>Cynodon dactylon</i>		Yes	Yes (partial control notes)	Cerdeira and Duke 2006
Burning nettle	<i>Urtica uren</i>		Yes	No (mixture recommended)	Van Deynze et al., 2004; Canevari et al., 2004
Cheeseweed	<i>Malva parviflora</i>		Yes	No (mixture recommended)	Van Deynze et al., 2004
Chinese foldwig	<i>Dicliptera chinensis</i>		No	No	Nandula et al., 2005
Common lambsquarters	<i>Chenopodium album</i>		Yes	Yes (mixture also recommended)	Nandula et al., 2005

Field bindweed*	<i>Convolvulus arvensis</i>	Yes	No (mixture recommended)	Nandula et al., 2005
Filaree	<i>Erodium</i> spp.	Yes	Yes (mixture also recommended)	Van Deynze et al., 2004
Florida pellitory	<i>Parietara debilis</i>	No	No	Cerdeira and Duke 2006
Hemp sesbania	<i>Sesbania exalta</i>	No	Yes	Cerdeira and Duke 2006
Large crabgrass	<i>Digitaria sanguinalis</i>	Yes	Yes (mixture also recommended)	Cerdeira and Duke 2006
Morning glory	<i>Ipomoea purpurea</i>	Yes	Yes (mixture also recommended)	Hilgenfeld et al. (2004; Cerdeira and Duke 2006
Nutsedge*	<i>Cyperus</i> spp.	Yes	Yes	Cerdeira and Duke 2006
Oval-leaf false buttonweed	<i>Spermacoce latifolia</i>	No	No	Cerdeira and Duke 2006
pillpod sandmat	<i>Chamaesyce hirta</i>	No	No	Cerdeira and Duke 2006
Purslane	<i>Portulaca oleracea</i>	Yes	Yes (mixture also recommended)	Van Deynze et al., 2004
Tropical Mexican clover	<i>Richardia brasiliensis</i>	No	No	Cerdeira and Duke 2006
Tropical spiderwort	<i>Commelina benghalensis</i>	No	No	Nandula et al., 2005
Velvet leaf	<i>Abutilon theophrasti</i>	No	Yes (mixture also recommended)	Nandula et al., 2005
Waterhemp	<i>Amarathus rudis</i> and <i>A. tuberculatus</i>	No	Yes (with resistant biotype note)	Cerdeira and Duke 2006

Cline 2004 reports that fleabane and henbit are also difficult to control with glyphosate. * These 3 weeds are not fully controlled by any of the 16 herbicides listed in the University of California Pest Management Guidelines (Rogan and Fitzpatrick 2004).

Survey of GT Alfalfa Farmers

Canevari (2007) reported survey results from interviews with alfalfa growers and industry representatives from California, Idaho, Nevada, Arizona, Washington, and New Mexico (43 respondents). The major weeds in alfalfa that were controlled by using a GT alfalfa system are listed below. Weeds that were cited as causing problems in alfalfa but were not mentioned by farmers as being controlled by glyphosate are highlighted in grey. A more comprehensive list of weeds in alfalfa is in appendix B.

Of the 24 growers surveyed all were satisfied with GT alfalfa. Advantages included less herbicide needed, yield increase, control of volunteer crops, excellent weed control, hay quality increase, better stand and water efficiency. Farmer concerns were that the seed is no longer available, the need for bale identification due to court order, and reluctance of the horse market. For the pest consultants, dealers, and researchers, concerns included export concerns, seed costs, weed resistance, weed shifts, market acceptance.

Bindweed	Dandelion	Knapweed	Morningglory
Bur clover	Dodder	Knotweed	Nutsedge
Canada thistle	Fiddleneck	Kochia	Pepperweed
Cocklebur	Foxtail	London rocket	Plantain
Common groundsel	Hoary cress	Lovegrass	Pigweed
Curly dock	Johnson grass	Mexican tea	Quackgrass
			Water grass

Figure G-4: Survey of GT alfalfa farmers

The 18 weed species (table G-7) that are both resistant to glyphosate and traditionally present problems in alfalfa likely pose the greatest threat for weed shifts in a GT cropping system. Eight weeds with newly identified resistance and ten weeds known to have some natural resistance to glyphosate are briefly described below.

4.1.1 New Glyphosate Resistant Weeds

Glyphosate resistant biotypes have recently been identified for the following eight weeds that are also common in alfalfa: common ragweed, horseweed, Italian ryegrass, Johnsongrass, Palmer Amaranth, buckhorn plantain, goosegrass, and junglerice. Each is briefly discussed below.

Common ragweed (*Ambrosia artemisiifolia*) germinates in May and early June, flowers in August to September, and sets seed in September. Each plant can release more than 30,000, three mm-long seeds, which can remain viable for more than 39 years buried. Seeds are dispersed by water and animals and can be blown across crusted snow in the winter. Common ragweed can thrive in soil containing high amounts of clay, gravel, or sand. It is found in cropland, abandoned fields, vacant lots, fence rows, waste areas, and along roadsides and railroads. Because it can accumulate large quantities of trace metals, it is very competitive and can cause nutritional deficiencies in crops. Not only does it taste bitter to livestock but it also causes nausea and mouth sores in livestock. It is very difficult to control as it can tolerate mowing, trampling, and grazing (Lanini, no year a). Common ragweed has a biotype that has multiple herbicide resistance to acetolactate synthase (ALS) inhibitors and PPO inhibitors (Heap et al., 2008).

Horseweed (*Conyza canadensis*) is a summer or winter annual that grows 1.5 to 6 feet tall (Loux et al., 2006). It produces a large number of seeds (200,000 per plant) that are wind-

dispersed. Seed dispersal in a corn field ranged from 12,500 seeds per square yard at 20 feet from the seed source, to more than 125 seeds per square yard at 400 feet from the seed source (Loux et al., 2006). Seeds can disperse a quarter mile when winds are only 10 miles per hour (Barnes et al., 2003). Seeds are able to germinate in no-till fields (undisturbed soil, includes non-crop sites) and tilled fields. Outcrossing among horseweed occurs at 1.2 to 14.5 percent which facilitates the spread of resistance traits (Stoltenberg and Jeschke, no year; Nandula et al., 2005; Loux et al., 2006). The known cases of glyphosate-resistant horseweed are characterized by frequent use of glyphosate, little or no use of alternative herbicides that control horseweed, and long-term no-tillage crop production practices (Loux et al., 2006). In addition to direct competition for light, water, and nutrients, horseweed can host the tarnished plant bug, an alfalfa pest, and the viral disease aster yellows, which is transmitted by aster leafhoppers to a wide variety of plants (Loux et al., 2006). Horseweed contains volatile oils, tannic acid and gallic acid that may cause mucosal and skin irritation in livestock (especially horses) and humans (Steckel, no year a). There are horseweed biotypes that are also resistant to ALS inhibitors. Several herbicides are effective at the rosette stage, but once horseweed is over six inches tall a three-way mixture of glyphosate, plus 2,4-D ester, plus chlorimuron or cloransulam, is recommended. Biotypes that are resistance to glyphosate and/or ALS inhibitors cannot be effectively controlled (Loux et al., 2006). In Ohio, a biotype that is resistant to both ALS inhibitors and glyphosate and a biotype in Michigan that is resistant to photosystem II inhibitors and ureas and amides have been identified (Heap et al., 2008). Over 500,000 acres in the Midwest are reported to be infested with glyphosate-resistant horseweed (Cline 2004). Others estimate that over two million acres in the U.S. are infested (Heap et al., 2008).

Italian Ryegrass (*Lolium multiflorum*) is an annual grass and is related to perennial ryegrass (*Lolium perenne*). Italian ryegrass can be intentionally cultivated with alfalfa as a companion crop and is good for grazing, hay, and silage (Hall 1992). However in cool, wet environments, it may outcompete alfalfa and, in very dry situations, it might not provide adequate ground cover (Schneider and Undersander 2008). Italian ryegrass is a weed in wheat because it stays green longer than wheat and causes cut wheat to heat and spoil (Peeper 2000). There are biotypes that exhibit multiple herbicide resistance to acetyl-CoA carboxylase (ACCase) inhibitors, ALS inhibitors, and Chloroacetamides (Heap et al., 2008). At least 5,000 acres in CA are reported to be infested with glyphosate resistant ryegrass (Cline 2004).

Johnsongrass (*Sorghum halapense*) is one of the ten most noxious weeds in the world. It is a fast-growing competitive perennial grass. Established Johnsongrass can be seven to nine feet tall and releases chemicals that inhibit surrounding plant growth. A plant produces 100 to 400 seeds that withstand silage and passage through livestock digestive systems. Seeds can germinate from 6 inches deep and are viable for three years. Stresses that interrupt normal growth, such as freezing, cutting, wilting, trampling, and herbicide exposure, can cause the release of toxic amounts of hydrocyanic acid which are poisonous to livestock. Johnsongrass is thought to be introduced from Egypt sometime after the Revolutionary War and was previously grown as forage in the south. If herbicides are not used it can be controlled by intense grazing and mowing for two years until the rhizomes are depleted. (CDFA, no year a; Lanini no year b). There are separate biotypes of Johnsongrass that have resistance to ACCase inhibitors, Dinitroanilines and ALS inhibitors (Heap et al., 2008).

Palmer amaranth (*Amaranthus palmeri*) is closely related to waterhemp and is the dominant pigweed in the Southwest. It is the most competitive and rapidly growing species of the weedy pigweeds and can reach a height of six feet (Steckel no year b). It is susceptible to herbicides when it is 4 to 6 inches tall (Scarpitti et al., 2007). Biotypes of Palmer amaranth have been identified with resistance to Dinitroanilines, photosystem II inhibitors, and ALS inhibitors (Heap et al., 2008).

Buckhorn Plantain (*Plantago lanceolata*) competes with crops for soil nutrients, water, and light and does well in droughts. It reproduces by seed and by tap root. Buckhorn plantain establishes slowly in alfalfa, but, once established, is difficult to control because of its extensive crown system (Wall and Whitesides, 2008). Glyphosate resistance is the only identified herbicide resistance in buckhorn plantain and has only been found in South Africa, so far (Heap et al., 2008).

Goosegrass (*Eleusine indica*) is an annual grass with an extensive root system that can produce 50,000 seeds per plant (Duble, no year). It is one of the five most troublesome weeds worldwide. It is found in agricultural fields, homeowner lawns, waste areas, roadsides, pastures, and golf courses. When it emerges with or shortly after a crop it can be a very competitive weed. Later in the growing season, it can produce enough biomass to hinder harvest (Steckel no year c). Some goosegrass biotypes exist that are known to be resistant to ACCase inhibitors, Bipyridiliums, Dinitroanilines, and ALS inhibitors. In Malaysia, a case of multiple resistance to ACCase inhibitors and glyphosate was found (Heap et al., 2008).

Junglerice (*Echinochloa colonum*) is a summer annual grass that is invasive in Tennessee, Hawaii, and Arizona (NPS 2007). It has little or no dormancy in tropical areas and germinates throughout the year. It can grow two to three feet high (Virginia Tech, no year). In Costa Rica, a biotype has been identified that has multiple resistance to ACCase inhibitors, ALS inhibitors, and ureas and amides. A glyphosate resistant biotype has been identified in Australia (Heap et al., 2008).

4.1.2 Traditionally Glyphosate Resistant Weeds

Ten weeds that are common in alfalfa and historically have some tolerance for glyphosate include bermudagrass, burning nettle, cheeseweed, common lambsquarters, field bindweed, filaree, large crabgrass, morningglory, nutsedge, and purslane. Each is briefly discussed below.

Bermudagrass (*Cynodon dactylon*) is a perennial grass that propagates through seed, root, or stem cuttings. If bermudagrass is cultivated, the soil should be dry because, if it is moist, the cut shoots will form new plants (Cudney and Elmore 2007). Bermudagrass is also grown as a forage crop (Undersander and Pinkerton 1988).

Burning nettle (*Urtica urens*) is a summer annual that flowers from June to November and is wind-pollinated. One plant can produce from 1,000 to 40,000 seeds. When left undisturbed in soil for six years, germination declined by 61 percent. However, 20 to 100 year-old seeds from excavations have been known to germinate. Seeds can also survive livestock digestive systems (Organic Garden 2007). Burning nettle stinging hairs contain histamine, formic acid, acetylcholine, acetic acid, butyric acid, leukotrienes, 5-hydroxytryptamine, and other irritants.

Dermal contact with the hairs leads to a mildly painful sting and itching or numbness for a period lasting from minutes to days (Thorne Research 2007). In Australia, a biotype resistant to photosystem II inhibitors has been identified (Heap et al., 2008).

Cheeseweed (*Malva neglecta*) is an annual or biennial dicot that reproduces from seeds. It is found on cultivated ground, new lawns, farmyards, and waste places (Mitich, no year). It is very competitive in alfalfa and, once established, is difficult to control. The fatty acids malvalic acid and sterculic acid may cause the plant to be toxic to horse, cattle, and sheep (Canevari 1997). Selenium or nitrate concentration has also been cited as the cause of toxicity (Hill 1993; USU, no year; Barnard, 1996).

Common lambsquarters (*Chenopodium album*) is a summer annual dicot that is adaptable to many environments. A plant can produce 100,000 seeds which can survive 30 to 40 years in soil (Lanini, no year c). Biotypes that are resistant to photosystem II inhibitors and ALS inhibitors have been identified in the United States (Heap et al., 2008). Glyphosate resistant lambsquarters has been reported in the Midwest and in a Madera, CA almond orchard (Cline 2004).

Field bindweed (*Convolvulus arvensis*) is a perennial dicot that reproduces by seed and vegetatively from deep-creeping roots and rhizomes. Young plants seldom produce seed in the first year, but one plant can produce 500 seeds. In fields, seeds can survive 20 years or more. Field bindweed can harbor the viruses that cause potato X disease, tomato spotted wilt, and vaccinium false bottom. In addition, it contains tropane alkaloids and can cause intestinal problems in grazing horses (CDFA no year b).

Filaree (*Erodium cicutarium*) is a winter annual dicot that grows two to five inches high. It is adapted to a broad range of soil types and is found in oak woodlands, semi-desert grassland, desert shrublands, fields, lawns, and wastelands. Redstem filaree can be excellent forage for livestock and wildlife, but can cause bloating under heavy grazing (Pratt et al., 2002). It is competitive with crops and can cause yield reductions (Trainor and Bussan 2001).

Large crabgrass (*Digitaria sanguinalis*) is a summer annual that reproduces by seeds (Stritzke, no year). It is primarily a turfgrass weed, but can be founding thinning alfalfa stands (Elmore 2002). A biotype with multiple resistance to ACCase inhibitors and ALS inhibitors has been identified in Australia. Photosystem II inhibitor resistant biotypes have also been identified (Heap et al., 2008).

Morning glory (*Ipomoea purpurea*) is a perennial climbing vine that reproduces by seed (Pittwater Council, no year). It is a problem in crops because of competition. Morning glory seeds are toxic to humans (Filmer, no year). Morning glory foliage is toxic to livestock due to nitrates. Symptoms of acute nitrate poisoning are trembling, staggering, rapid breathing, and death. Chronic poisoning may result in poor growth, poor milk production and abortions. In cattle, there is evidence that vitamin A storage is affected (Robinson and Alex 1989).

Nutsedge (*Cyperus* spp.) is a hardy weed due to tubers that grow 8 to 14 inches below the ground and, when mature, can re-sprout 10 to 12 times after cutting before tuber resources are depleted. In addition, many herbicides are not translocated to tuber, and, therefore, do not

effectively control growth (Wilén et al., 2003). Alfalfa should not be planted in a field where nutsedge is a known problem (Canevari et al., 2003). In a study in California, nutsedge was reduced 96 to 98 percent using crop rotation and herbicides. The rotation was two years alfalfa with applications of EPTC herbicide, two years of barley double-cropped with corn and application of thiocarbamate herbicide, and two years of barley followed by fallow glyphosate applications (Canevari et al., 2007). Biotypes of *Cyperus difformis* that are resistant to ALS inhibitors have been found in California and globally (Heap et al., 2008).

Purslane (*Portulaca oleracea*) is a summer annual dicot that produces 240,000 seeds per plant and can survive five to 40 years. It can re-root after cultivation or hoeing, so it is difficult to control mechanically. It is a minor crop in the United States because it is edible and is used in ethnic cooking. In other crops, it is a weed because of competition (Cudney et al., 2007).

4.1.3 Mechanisms of Glyphosate-Tolerance

Glyphosate inhibits 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase, which is a key enzyme in the shikimate pathway in plants and is required for plant growth. The effects of glyphosate can be stopped in several ways (Cerdeira and Duke, 2006; Stoltenberg and Jeschke, no year; Nandula et al., 2005):

Resistant EPSP synthase - A version of EPSP synthase that is not affected by glyphosate has been found in bacteria (*Agrobacterium*) and has been transferred into crop plant genomes. Also, the maize version of EPSP synthase has been modified by site directed mutagenesis to be resistant to glyphosate. A version of EPSP synthase with decreased binding to glyphosate has been found in the weed goosegrass (*Eleusine indica*).

Degrade glyphosate - A glyphosate-degrading enzyme has been found in bacteria (*Ochrobactrum ananthropi*) and has been transferred into crop plant genomes.

Inactivate glyphosate - An enzyme found in bacteria (*Bacillus licheniformis*) has a weak ability to inactivate glyphosate through N-acetylation. The efficiency of this enzyme was increased by directed evolution in the lab and, when transferred to plants, confers resistance to glyphosate in field settings. A fungal gene encoding glyphosate decarboxylase has been discovered and patented for eventual use in crop plants.

Altered translocation of glyphosate – There is limited evidence that, in some glyphosate resistant ryegrass, glyphosate accumulates in mature leaf tissue rather than in the growing parts. Although the mechanism of resistance in horseweed is unknown, translocation experiments suggest that resistant biotypes do not translocate glyphosate to the growing parts of the plant (e.g., roots, young leaves, and crown).

Other – Resistant plants exist for which the mechanism of glyphosate resistance is not known. In addition, it is likely that there are mechanisms of resistance that have yet to evolve.

4.2 Weed Shifts in GT Alfalfa

Adopting new weed control strategies eventually leads to shifts in the weeds that are of greatest concern. Weed shifts can occur due to changes in tillage, irrigation, soil fertility, planting date, crop rotation, and herbicide use (Hilgenfeld et al., 2004). Changes to a no-till system results in a more diverse seedbank. Within weedy species variations in characteristics help weeds escape or tolerate weed management. These characteristics include seed dormancy, emergence patterns, growth plasticity, life cycle, life duration, shade tolerance, late-season competitive ability, seed dispersal mechanisms, and morphological and physiological variations (Hilgenfeld et al., 2004).

Because weed seedbanks in the soil can contain large reservoirs of dormant weed seed, short-term studies (a few years) might not detect the full potential shift in weed communities (Harker et al., 2005). However sometimes weeds shift can be observed within a few years. For example, in a field trial in an established GT alfalfa stand in the Southwest (San Joaquin Valley) burning nettle was not controlled and the population of burning nettle increased significantly over the three-year trial period (Canevari et al., 2004; Van Deynze et al., 2004). Tank mixtures with Velpar (hexazinone) or paraquat controlled burning nettle. Weeds that are difficult to control with glyphosate, such as dodder and cheeseweed, may need to be treated early and require a second application. Van Deynze et al (2004) recommend that the best way to prevent weed shifts is to avoid using the same herbicide year after year, rotate herbicides and crops, and include non-herbicide strategies to control weeds.

Puricelli and Tuesca (2005) found that continuous (once before planting, once at 40 days after planting, once in winter fallow in August) glyphosate application in field studies on three crop rotation sequences and two tillage systems lead to quantitative and qualitative changes in weed communities. They found that glyphosate application was a more important factor than crop sequence to explain weed community changes in summer crops. They also predicted that continual glyphosate application for longer than the five years in their study might lead to the development or higher increases in abundance of weeds tolerant to glyphosate. Weed species diversity in conventional versus no-tillage plots did not differ significantly.

Harker et al., (2005) reported that field studies of spring wheat-canola-spring wheat rotations of various combinations of GT and non-GT varieties under conventional tillage or low soil disturbance direct seeding systems indicate that weed community shifts are dependent on rotation pattern in a site-dependent manner. In the western Canada field locations, within 3 years, crop systems without GT varieties were associated (using canonical discriminant analysis) with green foxtail, redroot pigweed, sowthistle spp., wild buckwheat, and wild oat. The specific weeds associated with all GT variety systems included Canada thistle at the Brandon site, henbit at the Lacombe site, and volunteer wheat, volunteer canola, and round-leaved mallow at the Lethbridge site. One surprising finding was that high variability in wild buckwheat between the systems. Glyphosate is not very effective on wild buckwheat, so the authors propose that wild buckwheat seed production or viability may be restricted by glyphosate more than the wild buckwheat biomass. Therefore after glyphosate application the plant may appear visually robust, but its ability to reproduce has been effected, so in following years less wild buckwheat is observed (Harker et al., 2005).

It is plausible that the 18 weeds discussed in section 4.1 are the first candidates for weed shifts in GT alfalfa. However, as discussed in the studies summarized above, weed shifts are dependent on the composition of the weed seedbank in the soil and surrounding sources of weeds.

4.2.1 Weed Management Options

Weed management strategies in organic alfalfa systems, conventional alfalfa systems, and glyphosate-tolerant alfalfa systems differ. Management options for conventional systems include (Nandula et al., 2005; Guerena and Sullivan 2003):

- Chemical (See table G-6)
 - Alternating herbicides with different modes of action
 - Tank mixing herbicides
 - Sequences of herbicides
 - Application timing
- Cultural
 - Rotation between GT cultivars and non-GT cultivars
 - Winter crops in rotation
 - Companion crops/co-cultivation/interseeding/nurse crop)
 - Cover crops (smother crops) (prior to planting alfalfa)
 - Field scouting for early detection
 - Monitor for weed species and population shifts
- Mechanical
- Tillage cultivation

Organic alfalfa systems can use the cultural and mechanical strategies (except for use of GT cultivars). Nurse crops of peas or oats produce good hay for the horse market (Guerena and Sullivan 2003). GT alfalfa systems can use all of the strategies of conventional systems plus application of glyphosate directly on growing alfalfa. Options for rotating between GT cultivars and non-GT cultivars are reduced with GT alfalfa, since GT corn and GT soybean are popular rotation crops for alfalfa.

Cutting intervals affect weed infestation. For example, if alfalfa is cut too frequently (20 to 25 days) there is not enough time for root storage of carbohydrates so growth after cutting is not vigorous and weeds have a competitive advantage. However sometimes early harvest can rescue a heavily weed-infested new stand if the weeds are beyond the stage of optimum herbicide treatment (Canevari et al, 2007). Alternating long and short intervals between cuttings enables alfalfa to maintain root reserves so plants can recover from defoliation quickly and more vigorously compete with weeds (Canevari et al, 2007).

4.3 Distribution of Glyphosate Resistant Weeds

Table G-8 shows that currently 19 U.S. states are affected by glyphosate resistant weeds. The majority of new glyphosate resistant weeds are located in the Southeast and Midwest. The overlap with the major alfalfa producing states in the Intermountain regions seems to be minimal at this point (table G-6). However, given that there is overlap between glyphosate resistant weed locations and alfalfa hay acreage there is potential for rapid shifts of glyphosate resistant weeds

into GT alfalfa fields if GT alfalfa were to be widely adopted. California is a concern because glyphosate resistant weeds are present and alfalfa is a major crop in California. More detailed records of local weed infestations may be kept by state extension offices.

Table G-8. Glyphosate-Resistant Weed Infestations by State (Heap et al., 2008)

State	Weed species	~ Number of Sites in State Infested	~ Number of Acres in State Infested	Situation	Year Reported
Arkansas	<i>Conyza canadensis</i> Horseweed	6-10 increasing	1,001-10,000 increasing	Cotton	2003
	<i>Ambrosia artemisiifolia</i> Common Ragweed	1	11-50	Soybean	2004
	<i>Ambrosia trifida</i> Giant Ragweed	6-10 increasing	101-500 increasing	Soybean	2005
	<i>Amaranthus palmeri</i> Palmer Amaranth	1 increasing	unknown	Soybean	2006
	<i>Sorghum halepense</i> Johnsongrass	1	unknown	Soybean	2007
California	<i>Lolium rigidum</i> Rigid Ryegrass	11-50 increasing	1,001-10,000 increasing	Almonds	1998
	<i>Conyza canadensis</i> Horseweed	1	unknown	Roadside	2005
	<i>Conyza bonariensis</i> Hairy Fleabane	2-5	unknown	Roadside	2007
Delaware	<i>Conyza canadensis</i> Horseweed	101-500	10,001-100,000	Soybean	2000
Georgia	<i>Amaranthus palmeri</i> Palmer Amaranth	101-500 increasing	100,001-1,000,000 increasing	Cotton Soybean	2005
Illinois	<i>Conyza canadensis</i> Horseweed	1,001-10,000 increasing	10,0001-1,000,000 increasing	Soybean	2005
	<i>Amaranthus rudis</i> Common Waterhemp***	1 increasing	51-100 increasing	Corn Soybean	2006
Indiana	<i>Conyza canadensis</i> Horseweed	2-5 increasing	101-500 increasing	Soybean	2002
	<i>Ambrosia trifida</i> Giant Ragweed	1 increasing	11-50 increasing	Soybean	2005
Kansas	<i>Conyza canadensis</i> Horseweed	51-100 increasing	10,001-100,000 increasing	Cotton Soybean	2005
	<i>Ambrosia trifida</i> Giant Ragweed	2-5 increasing	501-1,000 increasing	Soybean	2006
	<i>Amaranthus rudis</i> Common Waterhemp	2-5 increasing	101-500 increasing	Soybean	2006
	<i>Ambrosia artemisiifolia</i> Common Ragweed	1 increasing	11-50 increasing	Soybean	2007
Kentucky	<i>Conyza canadensis</i> Horseweed	2-5 increasing	51-100 increasing	Soybean	2001
Maryland	<i>Conyza canadensis</i> Horseweed	6-10 increasing	501-1,000 increasing	Soybean	2002
Michigan	<i>Conyza canadensis</i> Horseweed	1 increasing	51-100 increasing	Nursery	2007

Minnesota	Ambrosia trifida Giant Ragweed	2-5 increasing	101-500 increasing	Soybean	2006
	Amaranthus rudis Common Waterhemp	2-5 increasing	51-100 increasing	Soybean	2007
Mississippi	Conyza canadensis Horseweed	101-500 increasing	1,001-10,000 increasing	corn, cotton, rice, and soybean	2003
	Lolium multiflorum Italian Ryegrass	unknown	1,001-10,000 increasing	Cotton Soybean	2005
Missouri	Conyza canadensis Horseweed	101-500 increasing	10,001-100,000 increasing	Cotton	2002
	Ambrosia artemisiifolia Common Ragweed	1	11-50	Soybean	2004
	Amaranthus rudis Common Waterhemp**	1 increasing	1,001-10,000 increasing	Corn Soybean	2005
New Jersey	Conyza canadensis Horseweed	6-10 increasing	101-500 increasing	Soybean	2002
North Carolina	Conyza canadensis Horseweed	2-5 increasing	6-10 increasing	Cotton	2003
Ohio	Conyza canadensis Horseweed	101-500 increasing	1,001-10,000 increasing	Soybean	2002
	Conyza canadensis Horseweed*	2-5 increasing	101-500 increasing	Soybean	2003
	Ambrosia trifida Giant Ragweed	2-5 increasing	101-500 increasing	Soybean	2004
Oregon	Lolium multiflorum Italian Ryegrass	1 stable	1-5 stable	Orchards	2004
Pennsylvania	Conyza canadensis Horseweed	2-5 increasing	101-500 increasing	Soybean	2003
Tennessee	Conyza canadensis Horseweed	501-1,000 increasing	>2,000,000 increasing	Cotton Soybean	2001
	Amaranthus palmeri Palmer Amaranth	2-5 increasing	101-500 increasing	Cotton	2006
	Ambrosia trifida Giant Ragweed	101-500 increasing	1,001-10,000 increasing	Cotton Soybean	2007

* resistant to chlorimuron-ethyl, cloransulam-methyl, and glyphosate ** resistant to acifluorfen-Na, cloransulam-methyl, fomesafen, glyphosate, imazamox, imazethapyr, and lactofen *** resistant to chlorimuron-ethyl, glyphosate, and imazethapyr

Monsanto's guidance for weed resistance management in GT alfalfa is as follows (Monsanto 2008):

- Scout fields before and after each herbicide application.
- Use the right herbicide product at the right rate and at the right time.
- To control flushes of weeds in established alfalfa, make applications of Roundup WeatherMAX herbicide at 22 to 44 oz/A before weeds exceed 6", up to 5 days before cutting.
- Use other herbicide products tank-mixed or in sequence with Roundup agricultural herbicide if appropriate for the weed control program.
- Report repeated non-performance to Monsanto or your local retailer.

4.4 Summary of Findings

At least 129 different weed species are identified as minor or major problems in alfalfa. Out of 14 new glyphosate resistant weeds found since 1998, eight are known to be weeds in alfalfa. Out of at least 21 weeds that have natural resistance to glyphosate, ten are known to be a problem in alfalfa. These 18 weeds that are both resistant to glyphosate and traditionally listed as problems in alfalfa include: common ragweed, horseweed, Italian ryegrass, Johnsongrass, Palmer Amaranth, buckhorn plantain, goosegrass, junglerice, bermudagrass, burning nettle, cheeseweed, common lambsquarters, field bindweed, filaree, large crabgrass, morningglory, nutsedge, and purslane. Although the composition of weed shifts is based on the local seedbank, these 18 weeds are candidates for becoming more prevalent than GT sensitive weeds in rotations that include GT alfalfa.

Mechanisms of glyphosate resistance include resistant EPSP synthase, degradation of glyphosate, inactivation of glyphosate, and altered translocation of glyphosate.

Nineteen states and over two million acres of cropland are infested with new glyphosate resistant weeds. The heaviest infestation is in the Southeast and Midwest. Overlap with the major alfalfa producing states in the Intermountain regions seems to be minimal at this point. However, given that there is overlap between glyphosate resistant weed locations and alfalfa hay acreage there is potential for rapid shifts of glyphosate resistant weeds into GT alfalfa fields if GT alfalfa were to be widely adopted. California is a concern because glyphosate resistant weeds are present and alfalfa is a major crop in California.

Weeds are controlled in conventional alfalfa with chemicals (herbicides), cultural methods (rotation, companion crops, monitoring), and mechanical methods (tillage). The cultural and mechanical methods are permitted for organic farmers. GT systems allow for the use of one additional herbicide, glyphosate.

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Appendix G-2. Literature Search

1.0 Literature Search Strategy

The following literature search was done for two of the technical reports:

Effects of Glyphosate-tolerant weeds in agricultural systems (former title: Increase in RR resistant weeds in crops)

Effects of Glyphosate-tolerant weeds in non-agricultural ecosystems (former title: Increase in RR resistant weeds in non-crop ecosystems)

1.1 Purpose

The purpose of this literature search is to locate references about the potential impacts of glyphosate-tolerant weeds in agricultural systems and in natural ecosystems.

The following DIALOG databases were included in the search:

- ☐ File 10:AGRICOLA 70-2008/Jun
- ☐ (c) format only 2008 Dialog
- ☐ File 156:ToxFile 1965-2008/Jun W2
- ☐ (c) format only 2008 Dialog
- ☐ File 266:FEDRIP 2008/Feb
- ☐ Comp & dist by NTIS, Intl Copyright All Rights Res
- ☐ File 245:WATERNET(TM) 1971-2008Apr
- ☐ (c) 2008 American Water Works Association
- File 55:Biosis Previews(R) 1993-2008/Jun W2
- ☐ (c) 2008 The Thomson Corporation
- File 6:NTIS 1964-2008/Jun W4
- ☐ (c) 2008 NTIS, Intl Cpyrght All Rights Res
- File 41:Pollution Abstracts 1966-2008/May
- ☐ (c) 2008 CSA.
- File 40:Enviroline(R) 1975-2008/Apr
- ☐ (c) 2008 Congressional Information Service
- File 76:Environmental Sciences 1966-2008/Jun
- ☐ (c) 2008 CSA.
- File 24:CSA Life Sciences Abstracts 1966-2008/Mar
- ☐ (c) 2008 CSA.
- File 117:Water Resources Abstracts 1966-2008/Mar
- ☐ (c) 2008 CSA.
- File 144:Pascal 1973-2008/Jun W2
- ☐ (c) 2008 INIST/CNRS
- File 50:CAB Abstracts 1972-2008/Apr

□ (c) 2008 CAB International
File 44:Aquatic Science & Fisheries Abstracts 1966-2008/Mar
(c) 2008 CSA.

□ File 71:ELSEVIER BIOBASE 1994-2008/May W4
□ (c) 2008 Elsevier B.V.
File 143:Biol. & Agric. Index 1983-2008/Apr
(c) 2008 The HW Wilson Co
□ File 203:AGRIS 1974-2008/Feb
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Descriptions of these files are available at <http://library.dialog.com/bluesheets/>.

1.2 Scope of Search

The search focused on any published references between 2000 and the present. A list of titles was screened followed by screening of abstracts for relevant titles. There were no limits on language for titles but only English language publications were retrieved for evaluation.

1.3 Keywords

A list of search parameters is listed below.

Synonyms of key topic
Glyphosate toleran*
Glyphosate resistan*
Roundup® Ready

Key words in combination with key topic Weed management Weed mitigation Weed control
Alfalfa
Medicago
Evolution

1.4 Results

**S1 4711 GLYPHOSATE()(TOLERAN? OR RESIST?) OR ROUNDUP()READYS2 3534 S1/2000:2008S3
121649 ALFALFA OR MEDICAGO S4 1796168 WEED? OR EVOLUTION
S5 27 S2 AND S3 AND S4
S6 14 RD S5 (unique items)**

□ 7/K,6/1 (Item 1 from file: 144)DIALOG(R)File 144:(c) 2008 INIST/CNRS. All rts. reserv.
17594709 PASCAL No.: 06-0183713
Alfalfa management in no-tillage corn
2006
Glyphosate-*resistant* corn was no-till planted into *alfalfa* that was in the early bud stage (UNCUT) or had been cut 3 to 4 d earlier and baled for hay (CUT). *Alfalfa* control and corn yield were measured in nontreated plots as well as plots treated with.....or tank-mixed with 2,4-D or dicamba applied at planting (AP) or POST. *Alfalfa* control was greater for all AP treatments of UNCUT compared to CUT *alfalfa*. Glyphosate plus dicamba applied AP controlled *alfalfa* better than the other AP treatments resulting in increased corn yield compared with other

AP...Postemergence applications of glyphosate alone or tank-mixed with 2,4-D or dicamba controlled *alfalfa* better 6 weeks after treatment than AP applications of the same herbicides; however, corn yield..... same herbicides. Corn yield averaged 13% higher following herbicide applications to UNCUT compared with CUT *alfalfa*, so the value of *alfalfa* hay must be weighed against the loss of corn yield when making decisions concerning the management of an *alfalfa*-corn rotation. Descriptors: Zero tillage; *Weed* control; *Weed* science; *Medicago* sativa

□ 7/K,6/2 (Item 2 from file: 10) DIALOG(R) File 10:(c) format only 2008 Dialog. All rts. reserv. 4712341 43956730 Holding Library: AGL

Comparing *Roundup* *Ready* and Conventional Systems of *Alfalfa* Establishment

2007

URL: <http://dx.doi.org/10.1094/FG-2007-0724-01-RS>

Roundup *Ready* (RR) technology provides a new approach for *weed*

□ control during *alfalfa* (*Medicago* sativa L.) establishment. We determined the effect of RR and conventional establishment systems on *alfalfa* yield, *weed* yield, and forage quality when *alfalfa* was established using solo-seeding or oat mulch methods. A RR system was a RR *alfalfa* in combination with glyphosate (Roundup) and a conventional system was a non-RR variety with imazamox (Raptor). Non-RR and RR alfalfas were also seeded with an oat companion crop. *Alfalfa* yields, plant populations, and forage quality were similar for the RR and conventional systems within solo-seeding and oat establishment methods in the seeding year. Total seeding-year *alfalfa* yield was greater when solo-seeded using an herbicide than when seeded with an oat companion crop harvested at boot. *Alfalfa* yield for the oat mulch and oat companion crop treatments were not consistently different over...

DESCRIPTORS: *Medicago* sativa..... *alfalfa*; *weeds*; *weed* control;

Identifiers: *Roundup* *Ready* *alfalfa* Section Headings: F120 PLANT PRODUCTION-FIELD CROPS; F900 *WEEDS*

□ 7/K,6/3 (Item 3 from file: 55) DIALOG(R) File 55:(c) 2008 The Thomson Corporation. All rts. reserv. 18335235 BIOSIS NO.: 200510029735 Influence of *Roundup* *Ready* (R) soybean production systems and

glyphosate application on pest and beneficial insects in wide-row soybean *2004* ABSTRACT: *Roundup* *Ready* (R) soybean, *Glycine max* (L.) Merrill, in widerow planting systems were investigated in 1997 and...

□ ...pest and beneficial insects. Populations of adult bean leaf beetle, *Cerotoma trifurcata* (Forster), and three-cornered *alfalfa* hopper, *Spissistilus festinus* (Say), and larvae of green cloverworm, *Hypenascabra* (F.), and velvetbean caterpillar, *Anticarsia gemmatilis* (Hubner), were not affected by genetically altered *Roundup* *Ready* soybean or by applications of glyphosate. Numbers of adult big-eyed bug, *Geocoris punctipes* (Say)...influenced *G. punctipes* densities in 3 of 11 weeks. These

1.0 effects were attributed to increased *weed* densities having a positive effect on *G. punctipes* numbers during this 3-week period. Increased...

□ ...1 of 2 years. These elevated numbers, however, were also related to higher densities of *weeds*. The results presented herein demonstrated that the *Roundup* *Ready* soybean system, including applications of glyphosate, had no detrimental effects on pest and beneficial insects..... ORGANISMS: *Spissistilus festinus* {three-cornered *alfalfa* hopper} (Homoptera..... strain- *Roundup* *Ready*;

□ 7/K,6/4 (Item 4 from file: 55) DIALOG(R) File 55:(c) 2008 The Thomson Corporation. All rts. reserv. 17883376 BIOSIS NO.: 200400254133 Influence of *Roundup* *Ready* soybean production systems and glyphosate

application on pest and beneficial insects in narrow-row soybean. *2004* ABSTRACT: *Roundup* *Ready* (R) soybeans, *Glycine max* (L.) Merrill, in narrow-row planting systems were investigated in 1998...

...numbers for meaningful analysis included adult bean leaf beetle, *Cerotoma trifurcata* (Forster); adult three-cornered *alfalfa* hopper, *Spissistilus festinus* (Say); adult big-eyed bug, *Geocoris punctipes* (Say), and; larvae of green...

...C. trifurcata, S. festinus, P. scabra and A. gemmatilis were not reduced in genetically altered *Roundup* *Ready* soybean, or by recommended (by label) or delayed applications of glyphosate. Numbers of G. punctipes also were not reduced in *Roundup* *Ready* soybean, but were reduced by recommended applications of glyphosate during weeks three and four following.....been indirectly reduced by glyphosate within sample weeks two and three because of variations in *weed* densities after treatment with the herbicide.

...ORGANISMS: Spissistilus festinus { *alfalfa* hopper } (Homoptera.....oil crop, *Roundup* *Ready* line... *Roundup* *Ready* production systems..... *weed* densities

□ 7/K,6/5 (Item 5 from file: 10)DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.4598987 43898530 Holding Library: AGL

□ Evaluating Glyphosate Treatments on *Roundup* *Ready* *Alfalfa* for Crop

2.0 Injury and Feed Quality*2007* URL: <http://dx.doi.org/10.1094/FG-2007-0201-01-RS>*Weed* control is one of the factors that impact *alfalfa* producers, with negative effects on quality often in the year of establishment. Glyphosate is a broad-spectrum herbicide that controls many troublesome annual and perennial *weeds* , and new cultivars that are tolerant of glyphosate application have been developed. The crop response of glyphosate on these new varieties has not been reported. This research examined *alfalfa* tolerance under field conditions, and high rates were used to challenge the plants to determine.....ranging from 0.75 to 3 lb a.e./acre sprayed before each of four *alfalfa* harvests had no meaningful crop injury in the establishment year or in the subsequent two...of 9 lb a.e./acre over a 3-year period caused no reduction in *alfalfa* yield or nutritive value at any cutting in any of the three years.

DESCRIPTORS: *Medicago* sativa..... *alfalfa*;

.....postemergent *weed* control; Identifiers: *Roundup*

Ready *alfalfa*

□ 7/K,6/6 (Item 6 from file: 55)DIALOG(R)File 55:(c) 2008 The Thomson Corporation. All rts. reserv.0020265061 BIOSIS NO.: 200800312000 Establishment systems for *glyphosate*-*resistant* *alfalfa* *2008* ABSTRACT: Glyphosate-resistant *alfalfa* offers new *weed* control options for *alfalfa* establishment. Field studies were conducted in 2004 and 2005 to determine the effect of establishment method and *weed* control method on forage production and *alfalfa* stand establishment. Seeding methods included clear seeding and companion seeding with oats. Herbicide treatments included...reduce forage yield or stand density in 2004. No

glyphosate injury was observed in 2005. *Weed* control with glyphosate was

3.0 more consistent than with imazamox or imazamox + clethodim. In 2004, total seasonal forage yield, which consisted of *alfalfa* , *weeds* , and oats (in some treatments), was the highest where no herbicide was applied in the...

...was reduced where herbicides were applied in both establishment systems. In 2005, seeding method or *weed* control method did not affect total seasonal forage production. *Alfalfa* established with the clear-seeded method and treated with glyphosate yielded the highest *alfalfa* dry

matter in both years. Imazamox injury reduced first-harvest *alfalfa* yield in the clear-seeded system in both years. When no herbicide was applied, *alfalfa* yield was higher in the clear-seeded system. The oat companion crop suppressed *alfalfa* yield significantly in both years. *Alfalfa* established with an oat companion crop had a lower *weed* biomass than the clear-seeded system where no herbicide was applied in both years....ORGANISMS: *Medicago* sativa { *alfalfa* } (Leguminosae)

□ 7/K,6/7 (Item 7 from file: 10)DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.4823604 44034732 Holding Library: AGL

Glyphosate-*resistant* crops: adoption, use and future considerations*2008* URL:

<http://dx.doi.org/10.1002/ps.1501> BACKGROUND: *Glyphosate*-*resistant* crops (GRCs) were first introduced

in the United States in soybeans in 1996. Adoption has.....13.2 million ha), cotton (5.1 million ha), canola (2.3 million ha) and *alfalfa* (0.1 million ha). Currently, the USA, Argentina, Brazil and Canada have the largest plantings of GRCs. Herbicide use patterns would indicate that over 50% of *glyphosate*-*resistant* (GR) maize hectares and 70% of GR cotton hectares receive alternative mode-of-action treatments... ..production system. Tillage

was likely used for multiple purposes ranging from seed-bed preparation to *weed* management. CONCLUSION: GRCs represent one of the more rapidly adopted *weed* management technologies in recent history. Current use patterns would indicate that GRCs will likely continue to be a popular *weed* management choice that may also include the use of other herbicides to complement glyphosate. Stacking...

□ 7/K,6/8 (Item 8 from file: 55) DIALOG(R) File 55:(c) 2008 The Thomson Corporation. All rights reserved. 18808410 BIOSIS NO.: 200600153805 *Glyphosate*-*resistant* crops: History, current status, and future*2004*

...ORGANISMS: *alfalfa* (Leguminosae MISCELLANEOUS TERMS: *weed* management...

□ 7/K,6/9 (Item 9 from file: 50) DIALOG(R) File 50:(c) 2008 CAB International. All rights reserved. 0009113458 CAB Accession Number: 20063199990

□ *Glyphosate*-*tolerant* *alfalfa* is compositionally equivalent to conventional *alfalfa* (*Medicago* sativa L.). Publication Year: 2006 *Glyphosate*-*tolerant* *alfalfa* (GTA) was developed to withstand

□ over-the-top applications of glyphosate, the active ingredient in...

□ ... United States during the 2001 and 2003 field seasons along with control and other conventional *alfalfa* varieties for compositional assessment. Field trials were conducted using a randomized complete block design with four replication blocks at each site. *Alfalfa* forage was harvested at the late bud to early bloom stage from each plot at...

... from GTA J101 x J163 is compositionally equivalent to forage from the control and conventional *alfalfa* varieties. IDENTIFIERS: *alfalfa*;
... *weedicides*; ... *weedkillers* ... *Medicago* sativa

□ 7/K,6/10 (Item 10 from file: 50) DIALOG(R) File 50:(c) 2008 CAB International. All rights reserved. 0007976368 CAB Accession Number: 20003004906

Roundup *Ready* *alfalfa*. Publication Year: 2000 Genetic engineering has been used to develop *Roundup* *Ready* SUP TM

□ (i.e. glyphosate herbicide tolerant) *alfalfa*. There is a significant interest in the use of RR *alfalfa* to improve options for effective, crop-safe *weed* control, both for establishment and for the control of tough perennial *weeds* in established stands. The project to develop *Roundup* *Ready* *alfalfa* is a collaboration between Monsanto, Montana State University and Forage Genetics International (FGI). Transformation,

event...

... application of Roundup Ultra. Applications at later reproductive stages reduced seed yield. The current RR *alfalfa* timeline predicts the commercial release of a wide range of RR *alfalfa* varieties in 2004. ORGANISM DESCRIPTORS: *Medicago* sativa... CABICODES: *Weeds* and Noxious Plants

□ 7/K,6/11 (Item 11 from file: 10) DIALOG(R) File 10:(c) format only 2008 Dialog. All rights reserved. 4660649 43931909 Holding Library: AGL

Is *Roundup* *Ready* *alfalfa* right for you
2007

URL: <http://cropwatch.unl.edu/>

DESCRIPTORS: *alfalfa*; *weed* control;

Section Headings: F120 PLANT PRODUCTION-FIELD CROPS; H000

PESTICIDES-GENERAL; F200 PLANT BREEDING; F900 *WEEDS*

7/K,6/12 (Item 12 from file: 10) DIALOG(R) File 10:(c) format only 2008 Dialog. All rights reserved.

□ 4442412 30961704 Holding Library: WYU; AGX *Roundup* *Ready*.reg. *alfalfa* a new technology for high plains hay

producers / Stephen D. Miller ... [et al.]*2006* URL:
<http://www.uwo.edu/CES/PUBS/B1173.pdf>DESCRIPTORS:
Alfalfa; *Weeds*;

□ 7/K,6/13 (Item 13 from file: 50)DIALOG(R)File 50:(c) 2008 CAB International. All rts.
reserv.0008500330 CAB Accession Number: 20033167182

□ Seed bank changes following the adoption of *glyphosate*-*tolerant*
□ crops.Publication Year: 2003 *Weed* seed banks in long-term tillage/rotation plots were sampled in the early spring of 1999 and 2002, before and after the adoption of *glyphosate*-*tolerant* soyabean (*Glycine max*) and maize (*Zea mays*),respectively. Canonical discriminant analysis was used to characterize.....first canonical function was strongly associated with crop rotation. Themaize-oat (*Avena sativa*)-lucerne (**Medicago* sativa*) rotation clustered separately from continuous maize and maize-soyabean rotations when visualized in a...05), suggesting that practices used in the varyingsystems selected for divergent communities. After employing *glyphosate**tolerant* maize and soyabean varieties for three growing seasons (1999-2001), differences incommunity composition between...use of a single, non-selective herbicideacross all treatments resulted in a more homogeneous *weed* seed bankcommunity.
...ORGANISM DESCRIPTORS: *Medicago*; ...

S9 9600 HERBICIDE? ?(TOLERAN? OR RESIST?)/2000:2008S3 121649 ALFALFA OR MEDICAGO S4 1796168 WEED? OR EVOLUTION S5 27 S2 AND S3 AND S4 S10 35 S9 AND S3 AND S4 NOT S5 S11 20 RD S10 (unique items)

□ 12/K,6/1 (Item 1 from file: 55)DIALOG(R)File 55:(c) 2008 The Thomson Corporation. All rts.
reserv.18075829 BIOSIS NO.: 200400443748 Development of 2,4-D-resistant transgenics in Indian oilseed mustard(*Brassica juncea*)*2004* ...ABSTRACT: monooxygenase, cloned downstream to the 35S promoter along with a leader sequence from RNA4 of *alfalfa* mosaic virus (AMV leader
□ sequence), for improved expression of the transgene in plant cells.Southern... ..available transgenic lines can be used for testing the potential of 2,4-D in *weed* control including the control of parasitic *weeds* (*Orobanche* spp) of mustard and for low-till cultivation of mustard.
ORGANISMS: *Alfalfa* mosaic virus (*Bromoviridae*...vegetable crop,

herbicide *resistant* transgenic line.....pest, *weed*

□ 12/K,6/2 (Item 2 from file: 50)DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.0008797522
CAB Accession Number: 20053050074

□ Efficacy of imidazolinone herbicides applied to imidazolinone-resistant maize and their carryover effect on rotational crops.Publication Year: 2005 ... a 31% petroleum hydrocarbon adjuvant at 125 and 250 mL ha SUP -1 ,
□ respectively. Overall *weed* control varied from 85%, up to 95%. *Weed*species controlled were *Setaria* sp., *Chenopodium album* , *Solanum* sp.,*Amaranthus retroflexus* and *Digitaria sanguinalis* , and... ..to low, was the following: *Beta vulgaris* > *Capsicum annum* > *Lycopersicumesculentum* > *Cucumis melo* > *Hordeum vulgare* > **Medicago** *sativa* > *Loliummultiflorum* > *Avena sativa* > *Pisum sativum* > *Allium cepa* > *Zea mays*DESCRIPTORS: *herbicide* *resistance*; *weed* control..... *weeds*...ORGANISM DESCRIPTORS: *Medicago*; ...

□ 12/K,6/3 (Item 3 from file: 50)DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.0009065754
CAB Accession Number: 20063137864

□ Influence of forage legume species, seeding rate and seed size on competitiveness with annual ryegrass (*Lolium rigidum*) seedlings.Publication Year: 2006 ... as short-term forage crops are an important non-chemical option for the control of *herbicide*-*resistant* annual ryegrass (*Lolium rigidum* L.). The relative ability of 5 annual forage legume species (*Trifoliumsubterraneum* L., *T. michelianum* Savi., *T. alexandrinum* L., **Medicago** *murex* Wild and *Vicia benghalensis* L.) to suppress annual ryegrassseedlings was examined in a.....DESCRIPTORS: *weed* control ...ORGANISM DESCRIPTORS: *Medicago* *murex*

□ 12/K,6/4 (Item 4 from file: 156)DIALOG(R)File 156:(c) format only 2008 Dialog. All rts. reserv.3840082
NLM Doc No: 12852606

Influence of *herbicide* *tolerant* soybean production systems on insectpest populations and pest-induced crop damage.Jun *2003*

Conventional soybean *weed* management and transgenic *herbicide*-*tolerant* management were examined to assess their effects on soybeaninsect pest populations in south Georgia..... leafhopper, Empoasca fabae (Harris), and grasshoppers Melanoplus spp.were more numerous on either conventional or *herbicide*-*tolerant* varieties on certain dates, although these differences were not consistentthroughout the season. Soybean looper, Pseudoplusia includens (Walker),threecornered *alfalfa* hopper, Spissistilus festinus (Say), and whitefringed beetles, Graphognathus spp , demonstrated no varietal preference in this study. Few *weed* treatment differences were observed,but if present on certain sampling dates, then pest numbers were higher inplots where *weeds* were reduced (either postemergence herbicides or preplant herbicide plus postemergence herbicide). The exception to this*weed* treatment effect was grasshoppers, which were more numerous in *weedy* plots when differences were present. In post emergence herbicideplots, there were no differences in...the conventional herbicides (e.g.,Classic, Select, Cobra, and Storm) compared with specific gene-inserted*herbicide*-*tolerant* materials (i.e., Roundup and Liberty).Defoliation, primarily by velvetbean caterpillar, was different betweensoybean..... We did not observe differences in seasonal abundance of arthropod pestsbetween conventional and transgenic *herbicide*-*tolerant* soybean.

□ 12/K,6/5 (Item 5 from file: 50)DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.0008298057
CAB Accession Number: 20023152152

Effect of herbicide treatment on the productivity of some annual pasturelegumes.

Book Title: 13th Australian *Weeds* Conference: *weeds* "threats now and forever?", Sheraton Perth Hotel, Perth, Western Australia, 8-13September 2002: papers and proceedings
Publication Year: 2002

... seed production of 11 pasture legume cultivars (Trifolium subterraneum cultivars Dalkeith and Urana, burr medic [*Medicago*polymorpha] cv. Santiago, French serradella [Ornithopus sativus] cv.Cadiz, yellow serradella [O. compressus] cv. Charano.....DESCRIPTORS: *herbicide* *resistance*;*weed* control.....*weeds*...ORGANISM DESCRIPTORS: *Medicago* polymorpha

□ 12/K,6/6 (Item 6 from file: 55)DIALOG(R)File 55:(c) 2008 The Thomson Corporation. All rts. reserv.18860532 BIOSIS NO.: 200600205927

Effects of Artemisia afra leaf extracts on seed germination of selected crop
and *weed* species
2005

ABSTRACT: *Herbicide* *resistance* in *weeds* is a phenomenon threateningsustainable cereal production in the winter rainfall region of SouthAfrica. Every possible *weed* control measure that may be used tocomplement chemical *weed* control measures should be investigated. Theeffect of aqueous leaf extracts of the aromatic shrub African wormwood(Artemisia afra) on germination of selected crop and *weed* species wereinvestigated. The selected plant species included wheat (Triticumaestivum L.), *herbicide* *resistant* and non-resistant ryegrass (Lolium,spp.), canola (Brassica napus) and lucerne (*Medicago* sativa). Various dilutions were investigated and the original extract was the most effective in inhibiting.....ORGANISMS: *Medicago* sativa (Leguminosae

□ 12/K,6/7 (Item 7 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0008298120 CAB Accession Number: 20023152089 *Evolution* of paraquat resistance in barley grass (Hordeum leporinumLink. and H. glaucum Steud.).Book Title: 13th Australian *Weeds* Conference: *weeds* "threats now and forever?", Sheraton Perth Hotel, Perth, Western Australia, 8-13September 2002: papers and proceedingsPublication Year: 2002

Herbicide *resistance* in *weed* species can eliminate the usefulnessof herbicides. In Australia, 25 *weed* species have been documented withresistance to one or more of nine herbicide groups. Two *weedy* barleygrass species, H. glaucum and H. leporinum [H. murinum subsp. leporinum],infest crops and...paraquat on these two

species, principally in lucerne and grain crops, has resulted in the *evolution* of paraquat resistance at a number of sites in southern Australia. The *evolution* of paraquat resistance occurs after a prolonged period of use, often up to 20 years... will lead to a better understanding of how resistance is spread as well as the *evolution* of paraquat resistance in field populations....DESCRIPTORS: *evolution*;*herbicide* *resistance*;*weeds* ...*Medicago* sativa...CABICODES: *Weeds* and Noxious Plants (FF500...

□ 12/K,6/8 (Item 8 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0008751520 CAB Accession Number: 20053008750 *Evolution* and spread of *herbicide* *resistant* barley grass (*Hordeum glaucum* Steud. and *H. leporinum* Link.) in South Australia. Book Title: *Weed* management: balancing people, planet, profit. 14th Australian *Weeds* Conference, Wagga Wagga, New South Wales, Australia, 6-9 September 2004: papers and proceedings Publication Year: 2004 The barley grasses (*H. glaucum* and *H. leporinum* (*H. murinum* subsp. *leporinum*)) are important *weeds* of crops and pastures in South Australia. Populations of both species have evolved resistance to paraquat, primarily following intensive use of paraquat for winter *weed* control in lucerne (*Medicago* sativa*) crops. In the past few years, agricultural consultants have been reporting an increase in.....This research was conducted to determine the relative importance of seed movement compared with independent *evolution* for paraquat resistance in

□ *Hordeum* spp. *H. glaucum* and *H. leporinum* seeds were collected from... by 7 km appeared to be the same genotype. These results suggest that both independent *evolution* and seed movement are important in the distribution of paraquat-resistant *Hordeum* spp. in South....DESCRIPTORS: *evolution*;*herbicide* *resistance*;*weeds* ...*Medicago* sativa...CABICODES: *Weeds* and Noxious Plants (FF500

□ 12/K,6/9 (Item 9 from file: 50)DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.0008324661
CAB Accession Number: 20023162508
Herbicides in *alfalfa* culture.
Original Title: Herbicidas na cultura da alfafa.
Publication Year: 2002
... the tolerance of lucerne cv. Crioula and the efficiency of

□ pre-emergent herbicides on broadleaved *weed* control, in 2 different soils having (a) 0.96% organic matter (OM) and pH of 5.4 and (b) 2.61% OM and pH of 6.1. The *weed* control efficiency of oxyfluorfen and mixture of diuron+paraquat was also evaluated one day after... 24 and 0.36 of oxyfluorfen. Two controls were added to all experiments,

□ i.e. *weeded* and unweeded. Pre-emergence herbicides were sprayed one day after planting in moistened soil. In...

□ ... plants. Oryzalin was selective to the crop, providing a better control of grasses and broadleaved *weeds* at the 2 highest doses, regardless of the amount of OM and soil pH. Acetochlor...

□ ... both contents of OM and soil pH, with excellent control of the broadleaved and grass *weeds*. Flumetsulam and imazaquin may be applied only at the lowest dose tested, regardless of OM content in the soil, providing good control of some broadleaved *weeds*, with spraying of fluazifop-P-butyl [fluazifop-P] needed in post-emergence. The herbicides showed, in average, 10% more control of the *weeds* in soil with 2.61% of OM and pH of 6.1, in comparison to the *weeds* in the soil with 0.96% of OM and pH of 5.4. Lucerne budding...

□ ... oxyfluorfen up to 12 days after application; this herbicide presented good potential for post-lasting *weed* control and excellent pre-emergence control. Mixture application in tank (diuron+paraquat) just after cutting
... ..DESCRIPTORS: *herbicide* *resistance*;*weed* control.....*weeds*...*Medicago* sativa

□ 12/K,6/10 (Item 10 from file: 50)DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.0009320611 CAB Accession Number: 20073193351

Herbicide-resistant crops as weeds in North America.

Publication Year: 2007

Growers have rapidly adopted transgenic herbicide-resistant (HR)

□ crops, such as canola (Brassica napus L.), soyabean [Glycine max (L.)

Merr.], maize (Zea...crops and subsequent potential for volunteerism of these crops are assessed. HR volunteers are common weeds and the relative weediness

□ depends on species, genotype, seed shatter prior to harvest and

disbursement of seed at harvest...limited if the crop volunteers are HR. There are generally no marked changes in volunteer weed problems associated with these crops, except in no-tillage systems when glyphosate (GLY) is used...

...DESCRIPTORS: Herbicide* resistance*; Weed* control..... Weeds*;

IDENTIFIERS: alfalfa*; weedicides*; weedkillers*

...ORGANISM DESCRIPTORS: Medicago* sativa

12/K,6/11 (Item 11 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0008751696 CAB Accession Number: 20053008458

How profitable are perennial pasture phases in Western Australian cropping systems?

Book Title: Weed* management: balancing people, planet, profit. 14th Australian Weeds* Conference, Wagga Wagga, New South Wales, Australia, 6-9 September 2004: papers and proceedings

Publication Year: 2004

... that, in most parts of Western Australia, it is not currently profitable to plant lucerne (Medicago* sativa) on the scale required for salinity abatement. However, these investigations have not incorporated the long-term benefits that accrue from the use of lucerne to enhance management of weeds* , especially for those growers facing the threat or actual presence of herbicide* resistance*. This work is an investigation of the economics of lucerne when these various benefits are considered simultaneously. An existing model for analysing herbicide* resistance* in annual ryegrass (Lolium rigidum) in Western Australia (Ryegrass Resistance and Integrated Management) is extended...

... pasture phase increase long-term profitability, relative to that of continuous cropping, because of improved weed* management, reduced chemical use and through increasing yields in subsequent cereal crops. The first two benefits help reduce the evolution* of herbicide* resistance*. In addition, the incorporation of lucerne in a rotation can significantly reduce recharge. These results.....

DESCRIPTORS: herbicide* resistance*;

..... herbicide* resistant*

weeds*; ...

... weed* control..... weeds* ... Medicago* sativa

□ 12/K,6/12 (Item 12 from file: 55)

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0019917724 BIOSIS NO.: 200700577465

New annual and short-lived perennial pasture legumes for Australian agriculture - 15 years of revolution

2007

ABSTRACT: Fifteen years ago subterranean clover (Trifolium subterraneum) and annual medics

(Medicago* spp.) dominated annual pasture legume sowings in southern Australia, while limited pasture legume options

existed...

... glanduliferum), arrowleaf (Trifolium vesiculosum), eastern star (Trifolium dasyrrhizum) and crimson (Trifolium incarnatum) clovers and sphere (Medicago* sphaerocarpos), button (Medicago* orbicularis) and hybrid disc (Medicago* tornata x Medicago* littoralis) medics have been commercialised. Improved cultivars have also been developed of subterranean (T. subterraneum), balansa (Trifolium michelianum), rose (Trifolium hirtum), Persian (Trifolium resupinatum) and purple (Trifolium purpureum) clovers, burr (Medicago* polymorpha), strand (M. littoralis), snail (Medicago* scutellata) and barrel (Medicago* truncatula) medics and yellow serradella (Ornithopus compressus). New tropical legumes for

pasture phases in subtropical...likely to increase due to the increasing cost

of inorganic nitrogen, the need to combat *herbicide*-*resistant* crop
weeds and improved livestock prices. Mixtures of these legumes allows for
more robust pastures buffered against...

12/K,6/13 (Item 13 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0008415606 CAB Accession Number: 20033074295

□ Preharvest glyphosate in *alfalfa* for seed production: control of
□ Canada thistle. Publication Year: 2003 Canada thistle (*Cirsium arvense*) is increasing in both frequency
and

density in Saskatchewan lucerne (**Medicago** sativa) seed fields. Application of preharvest glyphosate is an
effective means of controllingCanada thistle...

...DESCRIPTORS: *herbicide* *resistance*;*weed* control.....*weeds*...**Medicago** sativa

□ 12/K,6/14 (Item 14 from file: 10)DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.4818901
44029738 Holding Library: AGL

Role and value of including lucerne (**Medicago** sativa L.) phases in croprotations for the management of
herbicide-*resistant* *Lolium rigidum* inWestern Australia

2008 URL: <http://dx.doi.org/10.1016/j.cropro.2007.07.018>Use of lucerne (**Medicago** sativa L.) pastures in
crop rotations has been
proposed as a method to enhance *weed* management options for growersfacing *herbicide* *resistance* in
Western Australia. An existing model foranalysing *herbicide* *resistance* in the important crop *weed*
annualryegrass (*Lolium rigidum* Gaud.) is consequently extended to include lucerne, used for grazing by...options
are analysed, including variouscombinations of lucerne, annual pastures, and crops. Lucerne providesadditional
weed management benefits across the rotation, but in the region studied these benefits are only sufficient...

□ 12/K,6/15 (Item 15 from file: 50)DIALOG(R)File 50:(c) 2008 CAB International. All rts.
reserv.0008983866 CAB Accession Number: 20063055062

□ Sensitivity of selected crops to isoxaflutole in soil and irrigation
□ water. Publication Year: 2005 ... hectarage crops grown in Michigan, USA. The crops evaluated were:
□ adzuki bean (*Vigna angularis*), lucerne (**Medicago** sativa), carrot (*Daucus carota*), cucumber (*Cucumis sativus*), dry bean (navy and blackbeans; *Phaseolus vulgaris*...of the rates that resulted in injury were
substantially less than the rates used for *weed* control in maize.
Carryover from isoxaflutoleapplications in maize production may require plant back
restrictions.....DESCRIPTORS: *herbicide* *resistance*;...**Medicago** sativa

□ 12/K,6/17 (Item 17 from file: 55)DIALOG(R)File 55:(c) 2008 The Thomson Corporation. All rts.
reserv.17533797 BIOSIS NO.: 200300491454 Tolerance of annual forage legumes to herbicides in Alberta.*2003*
...ABSTRACT: under irrigation. Results indicate that recommended rates of
either ethalfluralin or imazethapyr have potential for *weed* control in

alfalfa, berseem clover, balansa clover, fenugreek, pea, and vetches.*alfalfa*
(*Leguminosae*...*herbicide* *tolerance*;*weed* controlpotential

□ 12/K,6/18 (Item 18 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

□ 0008566544 CAB Accession Number: 20043017840 *Weed* control in lucerne and pastures
2004.Publication Year: 2003 Information to aid the planning of *weed* control in lucerne and
pastures in Australia, is presented under the following headings:
identification of...

...establishing pasture legumes; poison warnings on herbicide labels; usingherbicides successfully; using
herbicides in pastures; *weed* glossary;time interval needed between herbicide application and rainfall;
*weed*control in seedling lucerne - grass *weeds*; *weed* control in seedlinglucerne - broadleaf *weeds*;
weed control in established lucerne stands(over one-year-old) -broadleaf *weeds*; *weed* control in
establishedlucerne stands (over one-year-old) -grass *weeds*; clover and medic pastures -grass *weeds* -for

presowing, seedling and establishment; clover and medic pastures - broadleaf *weeds* - for presowing, seedling and established pastures; *weed* control in grass pastures only - broadleaf *weeds*; *herbicide* *resistance* management; direct drill and surface sowing; perennial grass *weed* control; approximate retail prices of chemicals used on lucerne and pastures; herbicide volatility; winter crop.....DESCRIPTORS: *herbicide* *resistance*; *weed* control..... *weeds*
... *Medicago* sativa

12/K,6/19 (Item 19 from file: 50) DIALOG(R) File 50:(c) 2008 CAB International. All rts. reserv.

0008415608 CAB Accession Number: 20033074293 *Weed* management in irrigated fenugreek grown for forage in rotation with other annual crops. Publication Year: 2003 ... determine the tolerance of fenugreek (cv. Amber) to several herbicides and their efficacy on various *weeds* (*Avena fatua*, *Setaria viridis* and *Amaranthus retroflexus*) in 1997-99 in Alberta, Canada. Potentially, fenugreek... effect of herbicides, seeding method, and 11 previous crops on fenugreek yield. Without herbicide application, *weeds* contributed 37-86% to total dry matter production. When imazamox/imazethapyr, or combinations of imazamox/imazethapyr or imazethapyr with ethalfluralin was applied, *weed* contents were 5% of the total dry matter and the herbicides did not reduce fenugreek yield compared to the hand-*weeded* control. Total forage samples with a low *weed* content had lower fibre content and higher protein and digestible dry matter content than forages with a high *weed* content. When imazamox/imazethapyr was used for *weed* control, fenugreek yields and *weed* biomass were similar after direct seeding and after cultivation plus seeding. In addition, the effect...
... and the previous crop by seeding method interaction was not significant for fenugreek yield and *weed* biomass. Therefore, irrigated fenugreek can be successfully grown in conservation tillage systems in rotation with several crops provided an effective herbicide is used for *weed* control.

...DESCRIPTORS: *herbicide* *resistance*; *weed* control... *Medicago* sativa

□ 12/K,6/20 (Item 20 from file: 55)
DIALOG(R) File 55:(c) 2008 The Thomson Corporation. All rts. reserv.
0020265062 BIOSIS NO.: 200800312001
Winter annual *weed* control with herbicides in *alfalfa*-orchardgrass mixtures
2008

4.0 ABSTRACT: *Alfalfa*-orchardgrass hay is popular in the Western United States because of an expanding horse-hay market. However, *weed* control in mixed *alfalfa*-orchardgrass stands is problematic, as herbicides must be safe for both species. Most growers rely solely on the competitiveness of the crop for *weed* control, which is often insufficient, especially in older stands. Field experiments were established in northern California to determine the efficacy and crop safety of several herbicides for winter annual *weed* control in established *alfalfa*-orchardgrass. Metribuzin at 560 or 840 g/ha and hexazinone at 420 g/ha applied...
... Paraquat at 560 g/ha applied shortly after crop green-up gave 50 to 82% *weed* control and caused significant injury to orchardgrass, which was still noticeable at first cutting.... ORGANISMS: *Medicago* sativa { *alfalfa* } (Leguminosae) MISCELLANEOUS TERMS: *herbicide* *tolerance*

1.5 Supplemental Searches

www.scirus.com

Terms:

alfalfa AND glyphosate (40 titles evaluated)

www.scholar.google.com

Terms:

alfalfa AND glyphosate

www.yahoo.com

Terms:

Alfalfa hay
Alfalfa sprouts
Organic alfalfa sprouts
Alfalfa seeds
Alfalfa glyphosate
Feral alfalfa
Wild alfalfa
Alfalfa state extension guidance
Perennial bluegrass
Quackgrass
Red horned poppy
Sprangletop weed
Tall waterhemp
White cockle weed
Butyrac
Butoxone
Benefin
Balan herbicide
Bromoxynil herbicide

Clethodim herbicide
Prism herbicide
Select herbicide
Diuron herbicide
EPTC herbicide
Velpar herbicide
Raptor herbicide
Pursuit herbicide
Sencor herbicide
Solicam herbicide
Paraquat herbicide
Pronamide herbicide
Kerb herbicide
Poast herbicide
Terbacil herbicide
Sinbar herbicide
Trifluralin herbicide
Treflan/TR-10 herbicide

www.google.com

Terms:

alfalfa bloom
alfalfa crop rotation
alfalfa cultivation
alfalfa harvest
alfalfa quality definitions
alfalfa quality standards
alfalfa quality statistics
alfalfa sprouts
alfalfa weeds
dandelion off-taste milk
dairy cows
Eleusine indica
Burdock weed
Certified organic alfalfa seed
Common ragweed
Common ragweed weed problem
Gene flow simulation
GENESYS gene flow
Glyphosate
Glyphosate resistant weeds
Growing regions
Herbicide active ingredients

Horseweed
Lucerne Medicago
Meadow foxtail
Organic alfalfa acres
Organic alfalfa acres USDA
Organic alfalfa certified
Organic alfalfa seeds
Organic alfalfa statistics
Pigweed
Roundup ready label
Tansymustard
Tansyweed
Teuber gene flow alfalfa
Visual definition for alfalfa quality
Weed interference with rhizobium
Weeds off tasting milk
Weeds taste in milk
Horseweed Italian ryegrass
Italian ryegrass weed
Palmer amaranth
Buckhorn plantain
Goosegrass

Junglerice
Echinochloa junglerice
Burning nettle
Utica uren
Erodium filaree
Purslane weed
Large crabgrass in alfalfa
Bermudagrass weed alfalfa

Large crabgrass weed
Morning glory toxic livestock
Morning glory weed
Nutsedge
Nutsedge toxic livestock
alfalfa stand removal
volunteer alfalfa
alfalfa autotoxicity

Appendix G-3. Weeds in Alfalfa

Table G-9. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
African mustard	<i>Brassica tournefortii</i> Asian mustard wild turnip	Broadleaf	WA								X	Rogan and Fitzpatrick 2004
Barnyardgrass	<i>Echinochloa crus-galli</i> , cockspur grass, Japanese millet watergrass cockspur watergrass	Grass	SA	X	X			X	X	X	X	Rogan and Fitzpatrick 2004
Bermudagrass	<i>Cynodon spp.</i>	Grass	P			X		X			X	Rogan and Fitzpatrick 2004
Blessed milk thistle	<i>Silyburn marianum</i> blessed milkthistle milk thistle spotted thistle variegated thistle	Dicot	A								X	Canevari et al., 2007
Blue mustard	<i>Chorispora tenella</i> , beanpodded mustard chorispora crossflower purple mustard tenella mustard	Broadleaf	WA		X		X					Rogan and Fitzpatrick 2004
Bluegrass (annual)	<i>Poa annua</i> walkgrass, annual bluegrass	Grass	WA			X		X			X	Rogan and Fitzpatrick 2004
Bluegrass (perennial)	<i>Poa spp.</i> Perennial bluegrass	Broadleaf	P		X							Rogan and Fitzpatrick 2004
Bristly oxtongue*	<i>Picris echioides</i>	Dicot	WA								X	Canevari et al., 2007
Bromes	<i>Bromus spp.</i>	Grass	WA								X	Rogan and Fitzpatrick 2004
Buckhorn plantain	<i>Plantago lanceolata</i>	Broadleaf	P					X		X		Rogan and

²⁵ Source: <http://plants.usda.gov/java/invasiveOne>.

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
	English plantain buckhorn plantain lanceleaf plantain narrowleaf plantain ribgrass ribwort <i>Plantago major</i> broadleaf plantain buckhorn plantain common plantain rippleseed plantain											Fitzpatrick 2004
Buffalobur	<i>Solanum rostratum</i> Colorado bur Kansas thistle Mexican thistle Texas thistle Buffalobur nightshade	Broadleaf	SA					X				Rogan and Fitzpatrick 2004
Bulbous bluegrass	<i>Poa bulbosa</i>	Grass	P							X		Rogan and Fitzpatrick 2004
Bull thistle	<i>Cirsium lanceolatum</i>	Broadleaf	P							X		Rogan and Fitzpatrick 2004
Burcucumber	<i>Sicyos angulatus</i> Wall bur cucumber	Broadleaf	SA			X						Rogan and Fitzpatrick 2004
Burning nettle	<i>Urtica dioica</i> California nettle slender nettle stinging nettle tall nettle	Broadleaf	A								X	Canevari et al., 2004; Canevari et al., 2006b
Bushy wallflower	<i>Ersimum repandum</i> Treacle mustard	Broadleaf	WA					X				Rogan and Fitzpatrick 2004
California burclover	<i>Medicago polymorpha</i> burclover	Dicot	WA-P								X	Canevari et al., 2007
Canada thistle	<i>Cirsium arvense</i> Californian thistle creeping thistle	Broadleaf	P	X	X		X			X		Rogan and Fitzpatrick 2004

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
	field thistle <i>Cirsium thistle</i>											
Canarygrass	<i>Phalaris arundinacea</i> canary grass reed canarygrass <i>Phalaris canariensis</i> canary grass <i>Phalaris minor</i> canarygrass littleseed canarygrass	Grass	WA								X	Rogan and Fitzpatrick 2004
Carolina geranium	<i>Geranium carolinianum</i>	Broadleaf	WA			X						Rogan and Fitzpatrick 2004
Cheatgrass	<i>Bromus tectorum</i> downy brome early chess military grass thatch brome grass	Grass	WA	X	X		X	X	X	X	X	Rogan and Fitzpatrick 2004
Cheeseweed	<i>Malva neglecta</i> buttonweed cheeseplant little mallow common mallow	Broadleaf	WA-P							X	X	Rogan and Fitzpatrick 2004
Chickweed (common)	<i>Stellaria media</i>	Broadleaf	WA	X	X	X		X	X			Rogan and Fitzpatrick 2004
Chicory	<i>Cichorium intybus</i> blue sailors chicory coffeeweed succory	Broadleaf	P							X		Rogan and Fitzpatrick 2004
Coastal fiddleneck	<i>Amsinckia menziesii</i> var. <i>intermedia</i> coast buckthorn coast fiddleneck common fiddleneck fiddleneck	Broadleaf	WA							X		Rogan and Fitzpatrick 2004
Cocklebur (common)	<i>Xanthium strumarium</i> cocklebur common cocklebur rough cocklebur	Broadleaf	SA	X	X	X			X			Rogan and Fitzpatrick 2004
Cornflower	<i>Centaurea cyanus</i>	Broadleaf	WA			X						Rogan and

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
	bachelor's button garden cornflower											Fitzpatrick 2004
Crabgrass	<i>Digitaria bicornis</i> Asian crabgrass <i>Digitaria ciliaris</i> Henry's crabgrass fingergrass kukaepua'a saulangi smooth crabgrass tropical crabgrass <i>Digitaria ischaemum</i> small crabgrass smooth crabgrass <i>Digitaria Sanguinalis</i> hairy crabgrass large crabgrass purple crabgrass	Grass	SA	X	X	X		X				Rogan and Fitzpatrick 2004
Creeping swinecress	<i>Coronopus didymus</i> lesser swinecress <i>Coronopus squamatus</i> creeping wartcress swinecress	Dicot	WA								X	Canevari et al., 2007
Cupgrasses	<i>Eriochloa gracilis</i> southwestern cupgrass tapertip Cupgrass <i>Eriochloa contracta</i> prairie cupgrass <i>Eriochloa villosa</i> woolly cupgrass	Grass	SA					X			X	Rogan and Fitzpatrick 2004
Curly dock	<i>Rumex crispus</i> narrowleaf dock sour dock yellow dock Rumex dock	Broadleaf	P	X	X	X		X				Rogan and Fitzpatrick 2004
Cutleaf	<i>Oenothera</i>	Broadleaf	WA					X				Rogan

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
eveningprimrose	<i>laciniata</i> cut-leaved evening primrose	leaf										and Fitzpatrick 2004
Dallisgrass	<i>Paspalum dilatatum</i> dallies grass herbe de miel herbe sirop hiku nua palpalum dilate water grass	Grass	P								X	Canevari et al., 2007
Dandelion (common)	<i>Taraxacum officinale</i> blowball common dandelion faceclock	Broadleaf	P	X	X		X	X		X		Rogan and Fitzpatrick 2004
Dodder	<i>Cuscuta</i> 50 common names for species in the genus	Broadleaf	SA					X	X	X	X	Rogan and Fitzpatrick 2004
Fall panicum	<i>Panicum dichotomiforum</i> western witchgrass	Grass	SA	X		X						Rogan and Fitzpatrick 2004
Fescue	<i>Festuca</i> spp. 66 common names for species in the genus	Grass	P			X				X		Rogan and Fitzpatrick 2004
Fescue (tall)	<i>Festuca arundinacea</i> <i>Festuca pratensis</i> Alta fescue coarse fescue reed fescue tall fescue	Grass	SA							X		Rogan and Fitzpatrick 2004
Field bindweed	<i>Convolvulus arvensis</i> creeping jenny European bindweed morningglory perennial morningglory smallflowered morningglory	Broadleaf	P	X			X					Rogan and Fitzpatrick 2004
Field pepperweed	<i>Lepidium campestre</i>	Dicot	WA				X			X		Orloff et al., 1997
Flixweed	<i>Descurainia sophia</i>	Broadleaf	WA				X	X		X		Rogan and

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
	flixweed pinnate tansymustard											Fitzpatrick 2004
Foxtail (giant)	<i>Setaria faberi</i> Chinese foxtail Chinese millet giant bristlegrass giant foxtail nodding foxtail	Grass	SA	X	X	X		X	X			Rogan and Fitzpatrick 2004
Foxtail (green)	<i>Setaria viridis</i> bottle grass green bristlegrass green foxtail green millet pigeongrass wild millet	Grass	SA	X	X	X	X	X	X	X		Rogan and Fitzpatrick 2004
Foxtail (yellow)	<i>Setaria glauca</i> pearl millet pigeongrass wild millet yellow bristlegrass yellow foxtail	Grass	SA	X	X	X	X	X	X			Rogan and Fitzpatrick 2004
Foxtail barley	<i>Hordeum jubatum</i>	Grass	P				X			X		Rogan and Fitzpatrick 2004
Goosegrass	<i>Eleusine indica</i> crowsfoot grass Indian goosegrass manienie ali'l silver crabgrass wiregrass	Grass	SA			X		X				Rogan and Fitzpatrick 2004
Groundsel (common)	<i>Senecio vulgaris</i> ragwort old-man-in-the-Spring	Dicot	WA								X	Canevari et al., 2007
Hairy nightshade	<i>Solanum sarrachoides</i> hairy nightshade hoe nightshade	Broadleaf	SA							X		Rogan and Fitzpatrick 2004
Hare barley	<i>Hordeum leporinum</i> hare barley leporinum barley wild barley	Dicot	WA				X			X	X	Orloff et al., 1997
Henbit	<i>Lamium amplexicaule</i> deadnettle	Broadleaf	WA	X	X	X		X		X		Rogan and Fitzpatrick 2004

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Hoary alyssum	<i>Berteroa incana</i> hoary false alyssum hoary false madwort	Broadleaf	P		X							Rogan and Fitzpatrick 2004
Hoary alyssum	<i>Berteroa incana</i> hoary false alyssum hoary false madwort	Broadleaf	SA	X								Rogan and Fitzpatrick 2004
Horseweed	<i>Conyza canadensis</i> horseweed fleabane mares tail fleabane	Broadleaf	SA/WA					X				Rogan and Fitzpatrick 2004
Japanese brome	<i>Bromus japonicus</i> Japanese brome grass Japanese chess	Grass	WA					X				Rogan and Fitzpatrick 2004
Jimsonweed	<i>Datura stramonium</i> Jamestown weed mad apple moonflower stinkwort thorn apple	Broadleaf	SA	X		X						Rogan and Fitzpatrick 2004
Johnsongrass	<i>Sorghum halepense</i> aleppo milletgrass herbe de cuba sorgho d' Alep sorgo de alepo zacate johnson	Grass	P			X		X				Rogan and Fitzpatrick 2004
Jointed goatgrass	<i>Aegilops cylindrical</i> jointgrass	Grass	P					X				Rogan and Fitzpatrick 2004
Junglerice	<i>Echinochloa colona</i> junglerice watergrass	Grass	SA								X	Rogan and Fitzpatrick 2004
Kentucky bluegrass	<i>Poa pratensis</i>	Grass	P							X		Rogan and Fitzpatrick 2004
Knawel	<i>Sclerantus annuus</i> German knotgrass	Broadleaf	WA			X						Rogan and Fitzpatrick 2004
Knotweed	<i>Polygonum arenastrum</i>	Broadleaf	SA						X		X	Rogan and

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
	common knotweed doorweed matweed ovalleaf knotweed prostrate knotweed											Fitzpatrick 2004
Kochia	<i>Kochia scoparia</i> Mexican burningbush Mexican fireweed fireweed mock cypress summer cypress	Broadleaf	SA		X			X	X			Rogan and Fitzpatrick 2004
Lambsquarters (common)	<i>Chenopodium album</i> Lambsquarters White goosefoot	Broadleaf	SA	X	X	X	X	X	X	X	X	Rogan and Fitzpatrick 2004
Little barley	<i>Hordeum pusillum</i> little wildbarley	Grass	WA					X				Rogan and Fitzpatrick 2004
London rocket	<i>Sisymbrium irio</i>	Grass	WA								X	Rogan and Fitzpatrick 2004
Meadow foxtail*	<i>Alopecurus pratensis</i>	Grass	P							X		Rogan and Fitzpatrick 2004
Mexican sprangletop	<i>Leptochloa uninervia</i>	Grass	SA								X	Rogan and Fitzpatrick 2004
Mexican tea	<i>Chenopodium ambrosioides</i>	Dicot	P								X	Canevari et al., 2007
Miner's lettuce	<i>Claytonia perfoliata</i>	Dicot	WA-P								X	Canevari et al., 2007
Morningglory	<i>Ipomoea</i> spp.	Broadleaf	SA			X						Rogan and Fitzpatrick 2004
Muhly	<i>Muhlenbergia frondosa</i> wirestem muhly <i>Muhlenbergia racemosa</i> green muhly marsh muhly	Grass	P							X		Rogan and Fitzpatrick 2004
Musk thistle	<i>Caruus nutans</i>	Broadleaf	WA					X				Rogan

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
	Nodding plumeless thistle chardon penche nodding thistle plumeless thistle	eaf										and Fitzpatrick 2004
Mustards	<i>Brassica</i> spp.	Broadleaf	WA			X	X					Rogan and Fitzpatrick 2004
Mustards	<i>Brassica</i> spp.	Broadleaf	SA			X						Rogan and Fitzpatrick 2004
Nettleleaf goosefoot	<i>Chenopodium murale</i>	Broadleaf	SA								X	Rogan and Fitzpatrick 2004
Night-flowering catchfly	<i>Silene noctiflora</i> nightflowering silene sticky cockle	Broadleaf	WA		X							Rogan and Fitzpatrick 2004
Nightshade	<i>Solanum sarrachoides</i> hairy nightshade hoe nightshade	Broadleaf	SA			X			X			Rogan and Fitzpatrick 2004
Nightshade (E. black)	<i>Solanum ptychanthum</i> Eastern black nightshade black nightshade	Broadleaf	SA	X	X							Rogan and Fitzpatrick 2004
Nutsedge (yellow)	<i>Cyperus esculentus</i> yellow nutgrass yellow nutsedge	Grass	P	X								Rogan and Fitzpatrick 2004
Nutsedges	<i>Cyperus esculentus</i> yellow nutgrass yellow nutsedge <i>Cyperus rotundus</i> chaguan humatag cocograss kili'o'opu nutgrass pakopako purple nutsedge	Grass	P								X	Rogan and Fitzpatrick 2004
Palmer amaranth	<i>Amaranthus palmeri</i> carelessweed (type of pigweed)	Broadleaf	SA					X				Rogan and Fitzpatrick 2004
Pennycress	<i>Thlaspi arvense</i> Frenchweed	Broadleaf	WA	X	X				X			Rogan and

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
	Fanweed field pennycress pennycress stinkweed											Fitzpatrick 2004
Pepperweeds	<i>Lepidium densiflorum</i> common pepperweed greenflower pepperweed peppergrass	Broadleaf	WA					X		X		Rogan and Fitzpatrick 2004
Persian speedwell	<i>Veronica persica</i> birdeye speedwell winter speedwell	Broadleaf	WA							X		Rogan and Fitzpatrick 2004
Pigweed spp.	<i>Amaranthus</i> spp. redroot pigweed smooth pigweed Powell amaranth spiny amaranth tumble pigweed prostrate pigweed common waterhemp tall waterhemp Palmer amaranth	Broadleaf	SA	X	X	X	X	X	X	X	X	Rogan and Fitzpatrick 2004
Plains coreopsis	<i>Coreopsis tinctoria</i> golden tickseed	Broadleaf	WA					X				Rogan and Fitzpatrick 2004
Plantains	<i>Plantago major</i> common plantain broadleaf plantain buckhorn plantain rippleseed plantain	Broadleaf	P			X		X				Rogan and Fitzpatrick 2004
Poverty sumpweed	<i>Iva axillaris</i> Iva poverty weed Lesser marshelder mouseear povertyweed poverty sumpweed poverty weed smallflowered marshelder	Broadleaf	P							X		Rogan and Fitzpatrick 2004
Prickly lettuce	<i>Lactuca serriola</i> China lettuce	Broadleaf	WA					X	X	X		Rogan and

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
	wild lettuce											Fitzpatrick 2004
Purslane	<i>Portulaca oleracea</i> akulikuli-kula common purslane duckweed parsley pusley wild portulaca	Broadleaf	SA						X			Rogan and Fitzpatrick 2004
Quackgrass	<i>Elytrigia repens</i> couchgrass quackgrass quickgrass quitch scutch twitch <i>Elymus repens</i> couchgrass dog grass	Grass	P	X	X				X	X		Rogan and Fitzpatrick 2004
Rabbitsfoot grass	<i>Polypogon monspeliensis</i> rabbitfoot polypogon rabbitfootgrass	Grass	WA								X	Rogan and Fitzpatrick 2004
Ragweed (common)	<i>Ambrosia artemisiifolia</i> Roman wormwood annual ragweed common ragweed low ragweed short ragweed small ragweed	Broadleaf	SA	X	X	X		X				Rogan and Fitzpatrick 2004
Red horned poppy*	<i>Glaucium carniculatum</i>	Broadleaf	WA					X				Rogan and Fitzpatrick 2004
Red sprangletop*	<i>Leptochloa filiformis</i>	Grass	SA								X	Rogan and Fitzpatrick 2004
Redstem filaree	<i>Erodium cicutarium</i> redstem stork's bill alfilaree filaree stork's bill	Broadleaf	WA							X		Rogan and Fitzpatrick 2004
Rescuegrass	<i>Bromus catharticus</i> rescue brome	Grass	WA					X				Rogan and Fitzpatrick

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
												2004
Roughseed buttercup*	<i>Ranunculus muricatus</i>	Dicot	WA-P								X	Canevari et al., 2007
Russian thistle	<i>Salsola kali</i> tumbleweed <i>Salsola iberica</i> prickly Russian thistle tumbleweed tumbling thistle	Broadleaf	SA		X			X	X	X		Rogan and Fitzpatrick 2004
Ryegrass	<i>Lolium multiflorum</i> Italian ryegrass annual ryegrass	Grass	WA			X				X		Rogan and Fitzpatrick 2004
Ryegrass (perennial)	<i>Lolium perenne</i> Perennial ryegrass	Grass	WA							X		Rogan and Fitzpatrick 2004
Sandbur	<i>Cenchrus echinatus</i> burgrass common sandbur field sandbur konpeito-gusa se mbulabula vao tui tui	Grass	SA					X	X			Rogan and Fitzpatrick 2004
Shepardspurse	<i>Capsella bursa-pastoris</i> Shepardspurse	Broadleaf	WA	X	X	X	X	X	X	X	X	Rogan and Fitzpatrick 2004
Silversheath knotweed*	<i>Polygonum argyrocoleon</i>	Broadleaf	WA								X	Rogan and Fitzpatrick 2004
Smartweed	<i>Polygonum persicaria</i> lady's thumb ladysthumb smartweed	Broadleaf	SA	X	X	X						Rogan and Fitzpatrick 2004
Sowthistle	<i>Sonchus</i> spp. (5 species)	Broadleaf	P						X			Rogan and Fitzpatrick 2004
Spiny sowthistle	<i>Sonchus asper</i> perennial sowthistle prickly sowthistle	Broadleaf	WA					X				Rogan and Fitzpatrick 2004
Sprangletops	<i>Leptochloa fascicularis</i> bearded sprangletop	Grass	SA					X				Rogan and Fitzpatrick 2004

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
	Also other <i>leptochloa</i>											
Squirreltail*	<i>Sitanion hystrix</i>	Grass	P							X		Rogan and Fitzpatrick 2004
Stinkgrass	<i>Eragrostis cilianensis</i> candy grass lovegrass strongscented lovegrass	Grass	SA							X		Rogan and Fitzpatrick 2004
Sunflower (common)	<i>Helianthus annuus</i> annual sunflower common sunflower sunflower wild sunflower	Broadleaf	SA				X		X	X		Rogan and Fitzpatrick 2004
Swamp knotweed*	<i>Polygonum coccineum</i>	Broadleaf	P							X		Rogan and Fitzpatrick 2004
Tall waterhemp	<i>Amaranthus tuberculatus</i> roughfruit amaranth tall waterhemp	Broadleaf	SA		X			X				Rogan and Fitzpatrick 2004
Tansy mustard	<i>Descurainia pinnata</i> green tansymustard tansymustard	Broadleaf	SA		X			X	X	X		Rogan and Fitzpatrick 2004
Toad rush	<i>Juncus bufonius</i>	Grass	WA								X	Canevari et al., 2007
Tumble mustard	<i>Sisymbrium altissimum</i> Jim hill mustard tall mustard tumble mustard tumbleweed mustard	Broadleaf	SA						X	X	X	Rogan and Fitzpatrick 2004
Velvetleaf	<i>Abutilon theophrasti</i> Indian mallow butterprint buttonweed	Broadleaf	SA	X	X	X						Rogan and Fitzpatrick 2004
Virginia pepperweed	<i>Lepidium virginicum</i> Virginia Pepperweed Virginia	Broadleaf	WA			X						Rogan and Fitzpatrick 2004

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
	peppergrass poorman's pepper											
Volunteer grains		Grass	WA-SA	X		X		X	X	X		Rogan and Fitzpatrick 2004
White cockle	<i>Silene latifolia</i> bladder campion evening lychnis white campion	Broadleaf	P		X							Rogan and Fitzpatrick 2004
Wild celery*	<i>Apium graveolens</i>	Dicot	SA-P								X	Canevari et al., 2007
Wild mustard	<i>Brassica arvensis</i> wild mustard <i>Brassica kaber</i> canola charlock mustard kaber mustard rapeseed wild mustard	Broadleaf	SA	X	X				X			Rogan and Fitzpatrick 2004
Wild oats	<i>Avena fatua</i> flaxgrass oatgrass wheat oats	Grass	SA-WA		X				X	X	X	Rogan and Fitzpatrick 2004
Wild radish	<i>Raphanus raphanistrum</i>	Broadleaf	SA	X	X	X						Rogan and Fitzpatrick 2004
Windmillgrass	<i>Chloris verticillata</i> tumble windmill grass windmillgrass	Grass	P					X				Rogan and Fitzpatrick 2004
Witchgrass	<i>Panicum capillare</i> panicgrass ticklegrass tumble panic tumbleweed grass witches hair	Grass	SA	X						X		Rogan and Fitzpatrick 2004
Yellow rocket	<i>Barbarea vulgaris</i> garden yellow rocket winter cress	Broadleaf	P	X	X							Rogan and Fitzpatrick 2004
Yellow starthistle	<i>Centaurea solstitialis</i>	Dicot	WA				X			X		Canevari et al., 2007

Common Name	Scientific Name and Synonyms ²⁵	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter- mountain	Southwest	Source
Yellowflower pepperweed	<i>Lepidium perfoliatum</i> clasping pepperweed	Dicot	WA				X			X		Orloff et al., 1997

Appendix H. Effects of Glyphosate-Resistant Weeds in Non-Agricultural Ecosystems

Effects of Glyphosate-Resistant Weeds in Non-Agricultural Ecosystems

Executive Summary

The subject of this report is whether glyphosate-tolerant (GT) alfalfa or glyphosate resistant weeds that might increase in prevalence due to use of GT alfalfa are likely to present weedy problems in non-agricultural ecosystems.

Medicago sativa (alfalfa) is native to the Middle East and Central Asia and was introduced to North America over 200 years ago. *Medicago sativa* spp. *sativa* (purple-flowered alfalfa) has naturalized populations in the U.S. and occurs in all 50 states. In a survey of 940 roadside sites in 47 counties in six northwestern states, Washington had the lowest percentage of sites with feral alfalfa occurring in 10 percent of the pre-selected sites and South Dakota had the highest with feral alfalfa occurring in 63 percent of the pre-selected sites. In sites where alfalfa was present, the ground cover of alfalfa was 1.2 to 5.4 percent. At approximately 22 percent of the sites, feral populations were located 2000 meters from cultivated alfalfa.

Medicago sativa spp. *falcata*, (yellow-flowered or Siberian alfalfa) is naturalized in the more northern and western states. It is being promoted as a rangeland enhancer for grazing. A naturalized population of *falcata* that was seeded on rangeland in South Dakota in 1915 is still in existence. Hybridization between *falcata* and cultivated alfalfa would result in hybrids that would be less adapted to northern plains rangeland than the *falcata* parent, but possibly better adapted than the cultivated alfalfa parent.

Alfalfa is used for a variety of non-agricultural purposes. These uses include: rehabilitation of overgrazed rangelands, erosion-control projects in interior forests, treatment of compacted soils, re-vegetation of areas damaged by wildfire, and erosion reduction in mined soils.

Twenty four weed species are known that either have newly evolved glyphosate resistant biotypes or have historically natural resistance to glyphosate. All 24 of these have naturalized or native populations in the U.S. (although one, Chinese foldwig, is found only in Hawaii). Thirteen of the 24 glyphosate resistant weed species are on at least one noxious weed list. Nine of the 14 newly evolved glyphosate resistant weeds have documented glyphosate resistant biotypes in the U.S. The remaining 5 have sensitive biotypes in the U.S, but glyphosate resistant biotypes have not yet been documented in the U.S. An increase in the prevalence of these glyphosate resistant weeds would likely be combated with alternative herbicides, mechanical removal, and spot burning.

There is very little evidence to suggest that alfalfa is considered a weed, other than as a volunteer in agricultural settings. Out of 12 weed lists from the USDA PLANTS Database, *Medicago sativa* is only listed on one, the Southern Weed Science Society, and this listing may be due to volunteer alfalfa in cropland. Thirteen surveyed weed control experts only identified one setting, irrigation ditches in California, where GT alfalfa could not be controlled by alternative

herbicides. In this case only glyphosate is approved for irrigation ditches, so mechanical removal or spot burning would be the alternative control measures.

The USDA Forest Service uses glyphosate to manage forests. Their usage is 0.275 percent of the quantity used on agricultural lands. The Roundup® herbicide label has 41 other non-crop setting listed. Many of these setting overlap with areas where feral alfalfa is found. There is a possibility that feral GT alfalfa could be found in non-crop areas. In cases where control is desired alternative control methods are available.

1.0 Introduction

This technical report discusses the distribution and possible effects of glyphosate resistant weeds and escaped glyphosate-tolerant (GT) alfalfa in non-agricultural ecosystems. Alfalfa that is intentionally grown in agricultural fields and volunteer alfalfa in agricultural fields is not discussed in this report.

1.1 Non-Agricultural Alfalfa in the United States

Medicago sativa (alfalfa) was introduced to the United States at least 200 years ago (Putnam et al., 2001). It is native to the Middle East and Central Asia, and has adapted to many growing conditions as it has been cultivated and distributed by humans (Xu et al., 2004). Since its introduction to the U.S., alfalfa has escaped agricultural fields and become naturalized, or feral. Different settings where feral alfalfa may be found include air fields, canals, cemeteries, ditch banks, fence rows, highways, irrigation ditches, pipelines, railroads, rangeland, rights-of-way, roadsides, wasteland (Rogan and Fitzpatrick 2004). Alfalfa in non-agricultural ecosystems may be either intentionally seeded or escaped from agricultural settings. Regardless, alfalfa plants outside of cropping systems generally do not have regular external inputs like irrigation, herbicides, insecticides, and fertilizers. Sometimes the definition of feral alfalfa includes volunteer alfalfa in crop land (Bagavathiannan and Van Acker 2008). For this report, volunteer alfalfa growing out of rotation in an agricultural field with another crop (e.g., corn) is not discussed, but escaped volunteers are included. Escaped volunteers are alfalfa plants from seed that escaped from an agricultural field, creating the first generation of a possible feral population. Escaped volunteers may not persist past a generation or two, depending on environmental conditions.

There is considerable literature on wild alfalfa in regions where it is native and wild relatives exist (Appendix 1 to this technical report). In other countries, such as Spain, gene flow between wild and cultivated alfalfa has been more extensively studied than in the U.S. (Jenczewski et al., 1999). This report does not review the global body of literature on wild alfalfa; it focuses on only naturalized populations in the U.S.

One concern in the U.S. is that naturalized alfalfa could act as a reservoir for the GT trait and be a source for the trait to be present in non GT alfalfa fields (Bagavathiannan et al., 2006). Gene flow to and from naturalized alfalfa is discussed in Appendix 2 of the technical report *Economic and Social Impacts to Organic Farmers of Deregulation of Roundup Ready Alfalfa* (Appendix T). The subject for this report is whether GT-alfalfa or glyphosate resistant weeds that might increase in prevalence due to use of GT alfalfa are likely to present weedy problems in non-agricultural ecosystems.

1.2 Feral Attributes

Survival without management inputs requires that feral plants have traits that may be different from cultivated plants. Bagavathiannan and Van Acker (2008) list the following traits that are common among most successful feral species:

- Variety of pollinators
- Continuous seed production
- Considerable seed output
- Seeds produced in several habitats
- Seed dispersal over short and long distances
- Seed dormancy (ability to form a seedbank)
- Broad germination requirements
- Discontinuous germination
- Rapid vegetative growth
- Can withstand competition
- Tolerance to unfavorable biotic and abiotic conditions
- Rapid flowering

Alfalfa has many of the above attributes and competes well with other native and introduced plants in a variety of settings. Some of the intentional uses of alfalfa on non-agricultural lands are discussed in this technical report, such as habitat rehabilitation, erosion control, and rangeland rehabilitation or enhancement.

1.3 Methodology

A literature search was designed to identify peer reviewed articles and grey literature (e.g., government reports, State Agricultural Extension Office publications) on feral alfalfa (Appendix 1 of this technical report). Several DIALOG databases were searched. Google, Yahoo, and Scirus search engines supplemented the DIALOG search. Calculations for percentages of harvest were done with Microsoft Excel. Alfalfa harvest statistics were obtained from USDA's National Agricultural Statistics Service.²⁶ USDA's Agricultural Marketing Service also provided information on harvests.²⁷ The common and scientific names for weeds were found in the USDA PLANTS database (Appendix 3 of this technical report).²⁸

2.0 Alfalfa Populations

2.1 Distribution of Naturalized Alfalfa in the United States

USDA, Natural Resources Conservation Service (NRCS), National Plant Data Center, PLANTS Database provides habitat ranges and other standardized information for over 43,000 U.S. plant species.²⁹ Appendix 2 of this technical report includes U.S. distribution maps for *Medicago sativa* (purple alfalfa) and *Medicago sativa* spp. *falcate* (yellow alfalfa). For some states, county specific data are available. The PLANTS Database indicates that "county data are based primarily on the literature, herbarium specimens, and confirmed observations. Not all populations have been documented, however, and significant gaps in the distribution shown may not be real... Remember that only native and naturalized populations are mapped!" Agricultural

²⁶ <http://www.nass.usda.gov/index.asp>

²⁷ <http://www.ams.usda.gov>

²⁸ <http://plants.usda.gov/java/invasiveOne>.

²⁹ http://npdc.usda.gov/pdf/0105_npdc_brochure.pdf

distribution is not included in the PLANTS Database and the size of the naturalized population in a given area is not indicated.

Scientists at Forage Genetics and Monsanto Company conducted a six state survey of alfalfa populations in 2001 and 2002 (Kendrick et al., 2005; Rogan and Fitzpatrick 2004). Data were collected at 1040 survey sites (20 sites per county, 500m² per site). Three survey strategies were adopted. “Pre-selected” survey sites without knowledge of terrain or vegetation were selected to avoid sampling bias. “Satellite” sites were selected at or near 3 miles from each pre-selected site and were intentionally scouted for feral alfalfa. The third strategy recorded the frequency of feral alfalfa populations observed along an entire travel route. Rogan and Fitzpatrick (2004) summarized the results. Their narrative summary was converted to table H-1. In a meeting abstract Kendrick et al (2005) summarize that 940 roadside sites were surveyed in 47 counties in six states. At approximately 22 percent of the sites, feral populations were located 2000 meters from cultivated alfalfa. On average, feral populations occupied less than 3 percent of the area surveyed.

Table H-1 Summary of Six State Feral Survey (adapted from Rogan and Fitzpatrick 2004)

State (# of counties surveyed)	Feral alfalfa occurred within or near X% of pre-selected sites	Feral alfalfa occurred within or near X% of satellite sites	Cultivated alfalfa occurred near X% of pre-selected sites	Cultivated alfalfa occurred near X % of satellite sites	Average mean coverage in sites where feral alfalfa occurred	Travel route – distance between feral populations
Idaho (11)	17%	41%	44%	43%	1.7%	>12 miles
Pennsylvania (10)	ND	57%	Feral and cultivated occurred together in 10% of sites	Feral and cultivated occurred together in 21% of sites	1.2%	6-12 miles (Centre and Franklin Counties 1-3 miles)
Wisconsin (10)	ND	47% (70-80% in Dane, Grant, Shawno and Vernon counties)	Feral and cultivated occurred together in 9% of sites	Feral and cultivated occurred together in 31% of sites	1.7%	ND
California (10)	27%	67%	38%	52%	4.2%	3-6 miles
South Dakota (6)	63%	82%	ND	Feral and cultivated occurred together in 40% of sites	5.4%	3-6 miles (Hand, Harding, Tripp counties 1-3 miles)
Washington (10)	10%	ND	Feral and cultivated occurred together in 2% of sites	ND	ND	>12 miles

ND = no data provided by Rogan and Fitzpatrick 2004 summary

The distance between feral and cultivated populations also varied. In Idaho, feral and cultivated populations occurred within 2000 meters of each other in approximately three sites per county. In approximately half of those sites, the average distance was less than 20 meters. In Wisconsin, three-fourths of the sites where feral and cultivated populations occurred together had an average distance of less than 20 meters. In California, feral and cultivated populations occurred within 2000 meters of each other in approximately six sites per county. In approximately half of those sites, the average distance was less than 20 meters. The relevance of feral populations' distance from cultivated alfalfa fields is discussed in Appendix 2 of the technical report *Economic and Social Impacts to Organic Farmers of Deregulation of Roundup Ready Alfalfa* (Appendix T).

2.2 Seeding into Non-Agricultural Lands

2.2.1 Rangeland

Medicago sativa spp. *sativa* (purple-flowered alfalfa used in cultivation) only rarely becomes naturalized in North American rangelands (Xu et al., 2004). However, *Medicago sativa* spp. *falcata*, (yellow-flowered or Siberian alfalfa) is naturalized in the more northern and western states (Appendix 2 of this technical report). *Falcata* was introduced to North Dakota in the late 1800s by Dr. N.E. Hansen, who was a professor at what is now South Dakota State University at Brookings. He traveled to Europe and Asia to collect plants for the Northern Great Plains (Smith 1997). Interest in *falcata* as a rangeland plant to benefit livestock grazing has increased in the past decade partially because of a notable ranch. *Falcata* was seeded in rangeland (near Lodgepole, SD) in 1915 with a small packet of seeds from Dr. Hansen. In the 1950's, Norman "Bud" Smith, began nurturing seed to harvest and periodically reseeded the rangeland. Those *falcata* populations reproduce and survive without help (Smith 1997; Bliss 2003). In fact about 150 acres trace back to the original 1915 seeding (Smith 1997). USDA Agricultural Research Service (ARS) scientists have determined that on the Smith farm, soil organic carbon was increased by 4 percent in the 1998 seeding, 8 percent in the 1987 seeding and 17 percent in the 1965 seeding. Soil inorganic nitrogen increased from 8 to 51 percent on the interseeded pastures, which corresponded to an increased plant nitrogen content of 8 to 33 percent in the native species (Schuman and Mortenson 2003; Hess et al., 2004). Researchers are recruiting more ranchers to seed *falcata* on native rangelands (Waggener 2007; High Plains Midwest Ag Journal 2008) and are conducting rangeland seeding projects with different varieties of alfalfa (Manske 2004). Projects are ongoing in South Dakota, North Dakota, and Utah (Boe et al., 2006).

Xu et al (2004) studied the effects of naturalized *falcata* in northwestern South Dakota on native species in the Grand River National Grassland (GRNG). The GRNG is adjacent to the Smith ranch discussed above, and *falcata* has become naturalized on over 600 acres in the GRNG. As the percentage cover of *falcata* increases, the number of other plant species decreases, so plant biodiversity is less as *falcata* increases. The authors conclude that although naturalized *falcata* increases the total biomass production on semiarid rangeland, it is at the expense of species richness and native species production. At the GRNG, the highest alfalfa seed density was more than 39,000 seeds per square meter (790 kg/ha) and 99 percent of the alfalfa seeds collected from the soil seed bank were hard and viable (Xu et al., 2007).

Researchers and rangeland managers have been trying since the 1930s to find or adapt a variety of alfalfa to enhance rangeland (Berdahl et al., 1986; Berdahl et al., 1989; Lorenz 1982; Rumbaugh 1982; Sneva et al., 1964). It is unclear how widely falcata might be adopted as interseed for rangeland because USDA ARS has only begun recruiting test ranches in the last few years. Researchers have also put forth the idea that the practice of interseeding adaptable cultivars of alfalfa into native rangelands may help in the mitigation of elevated atmospheric carbon dioxide and enhance the long-term sustainability of the ecosystem (Mortenson et al., 2004).

Future widespread adoption of falcata for rangeland could influence the overall feral alfalfa populations.

The traits that are likely to contribute to falcata's survival on rangeland include (Berdahl et al., 1989):

- Root proliferation – new shoots from horizontal roots (creeping root trait)
- Broad crown development – protection from trampling and winter injury
- Dormancy during midsummer in drought – low forage production in dry years with regrowth and blossom after late rain
- Slow regrowth compared to cultivated alfalfa (slow decumbent regrowth – lying or growing on the ground but with erect or rising tips) – possibly a grazing survival mechanism
- Hard seed that remains viable over extended periods of drought

These traits may enhance alfalfa in semiarid rangeland, but may have no utility in more humid environments where maximum forage yields from multiple harvests are desired (Berdahl et al., 1989). Expression of traits that are important for feral survival in semiarid rangeland can be masked in performance tests, because performance tests are seeded in narrow rows with high plant densities, in monoculture, are often irrigated, and are usually maintained for short periods (2 to 5 years) (Berdahl, et al., 1989).

A few examples of alfalfa cultivars that have falcata germplasm in their parentage include: Drylander, Roamer, Swift Current S3703L, Travois, South Dakota T25SYN2, Spredor 2, Alaska Synthetic A, Mandan MAL34, Alaska Synthetic B, Alaska Falcata Strain, Colorado C-3, and Mandan MAL 33 (Berdahl et al., 1989). Gimm and Ranger are also known to have falcata in their parentage (Rumbaugh, 1982). Alfalfa cultivars and experimental strains with a high proportion of falcata parentage are better adapted to interseeding into rangeland in the Northern Great Plains than traditional hay-type cultivars which have a high proportion of sativa parentage (Berdahl et al., 1989).

It is reasonable to predict that hybridization between rangeland falcata and GT alfalfa varieties with mostly sativa parentage, would result in hybrids with more rangeland hardiness than the original GT alfalfa but less rangeland hardiness than the falcata parent. It is possible that a falcata hybrid with the GT trait could establish in rangeland habitats and serve as a reservoir for the GT trait.

2.2.2 Rehabilitation and Erosion Control

Sullivan (1992) reviewed alfalfa use for rehabilitation and disturbed sites. Some of the uses that lead to feral alfalfa populations include:

- Rehabilitation of overgrazed rangelands for improvement of both wildlife habitat and livestock
- Erosion-control projects in interior forests
- Beneficial for compacted soils (alfalfa has deep roots that will grow vigorously in compacted soils)
- Re-vegetation of areas damaged by wildfire (Oregon DFW 2008)
- Erosion reduction in mined soils (also increased forage value, and as a soil conditioner in mined soils)(Sullivan (1992) cites examples in Montana, Illinois, Arizona; also Yukon mine sites (Withers 2002))

Alfalfa was found to survive and increase on rangeland in Utah for more than 10 years and can reseed on sites with as little as 11 inches (28 cm) of precipitation a year (Sullivan 1992).

When the Bureau of Land Management (BLM) toured sites in eastern Oregon that had undergone seeding treatment 35 to 40 years prior to the tour, they noted that Nomad alfalfa cultivar, which had been seeded in 1966 (36 years before 2002), was still scattered sparingly at each site (Kindschy et al., 2002).

As an example of what one state recommends for rehabilitation after wildfires, the Oregon Department of Fish and Wildlife recommends alfalfa as one component of seeding mixtures, which can sometimes contain over 20 different plant species. Recommended alfalfa quantities (only) are as follows (Oregon DFW 2008):

- Southwest Oregon Elk Mix – 7% alfalfa
- North Central Oregon Precipitation Zones, 12-20 inches and 18-30 inches - Ranger and Ladak alfalfa, 1 lb/acre each
- Central Oregon, greater than 12 inches precipitation - Ranger or Ladak alfalfa, 2 lbs/acre each (if appropriate)
- Central Oregon, less than 12 inches precipitation - Ranger or Ladak alfalfa, 1-2 lbs/acre each (if appropriate)
- Northeast Oregon, dry south-facing slopes with little soil - Ladak alfalfa, 1 lb/acre
- Northeast Oregon, north slopes or flat areas with soil and some broken shade quality (charred sticks count) - Ladak alfalfa, 2 lb/acre
- Northeast Oregon, north slopes/flat areas with soil, some broken shade quality only with rocks or little soil - Ladak alfalfa, 1 lb/acre
- Wallowa County - If grazed, Rhizoma or Spreader, 2 lbs/acre, if not grazed, Ladak, 2 lbs/acre
- Baker County Range Mix - Nomad Alfalfa, 1-2 lbs. in mix
- South Central and Southeast Oregon seed mixes, for sagebrush steppe and upland environments with 9-12 inches precipitation (Common Mix), seed mixes for saline or alkali soils and areas of poor drainage, seed mixes for rangelands with 9-12 inches precipitation (Common Mix), Seed mixes for rangelands with less than 9" precipitation. – alfalfa listed, but unspecified quantity

- South Central and Southeast Oregon Sandy or Loam Soils – alfalfa, 2 lbs/acre

To put the above seeding rates in context, irrigated agricultural alfalfa is seeded at 12 to 15 pounds per acre under ideal conditions, 15 to 20 pounds per acre when drilling, and 20 to 25 pounds per acre when broadcasting. Typically only 60 percent of the seeds germinate and 60 percent of the emerged seedlings may die during the first year. Four pounds per acre equals 20 seeds per square foot (Orloff et al., 1997). Therefore, two pounds per acre equals 10 seeds per square foot, six of which may germinate. Seedling survival would depend on the competing species. Alfalfa is included in almost all of the wildfire rehabilitation mixes. Even though the seeding rate is low, populations from rehabilitated lands could contribute to the feral population of alfalfa. As mentioned previously, to what degree feral alfalfa would serve as a reservoir for transgenes is discussed in Appendix 2 of the technical report *Economic and Social Impacts to Organic Farmers of Deregulation of Roundup Ready Alfalfa* (Appendix T).

2.3 Summary of Findings

Medicago sativa spp. *sativa* has naturalized populations in the U.S. and occurs in all 50 states. In a survey of 940 roadside sites in 47 counties in six states, Washington had the lowest percentage of sites with feral alfalfa occurring in 10 percent of the pre-selected sites and South Dakota had the highest, with feral alfalfa occurring in 63 percent of the pre-selected sites. In sites where alfalfa was present, the ground cover of alfalfa was 1.2 to 5.4 percent. At approximately 22 percent of the sites, feral populations were located 2000 meters from cultivated alfalfa.

Medicago sativa spp. *falcata*, (yellow-flowered or Siberian alfalfa) is naturalized in the more northern and western states. It is being promoted as a rangeland enhancer for grazing. A naturalized population of *falcata* that was seeded on rangeland in South Dakota in 1915 is still in existence. Hybridization between *falcata* and cultivated alfalfa would result in hybrids that would be less adapted to northern plains rangeland than the *falcata* parent, but possibly better adapted than the cultivated alfalfa parent.

Alfalfa is used for a variety of non-agricultural purposes. These uses include; rehabilitation of overgrazed rangelands, erosion-control projects in interior forests, treatment of compacted soils, re-vegetation of areas damaged by wildfire, and erosion reduction in mined soils.

3.0 Glyphosate-Resistant Weeds

3.1 Potential Glyphosate-Resistant Weeds in Non-Agricultural Ecosystems

The use of GT-alfalfa could conceivably increase the occurrence of glyphosate resistant weeds, which may impact non-agricultural lands. However, as discussed in the technical report *Effects of Glyphosate-Tolerant Weeds in Agricultural Systems* (Appendix G), alfalfa farming practices limit the likelihood of weed occurrence because alfalfa grown for hay is mowed, which reduces the likelihood that weeds reach their reproductive stage, and alfalfa is grown in rotation with annual crops (because of the nitrogen benefits it provides and autotoxicity limiting continuous alfalfa), which also limits both perennial and annual weed presence.

Appendix 3 of this technical report presents 24 glyphosate resistant weeds and their range and noxious status. Whether or not they are mentioned on the Roundup® herbicide label is also included. Two categories of glyphosate resistant weeds are shown: newly evolved or selected biotypes and species with known historical resistance to glyphosate. U.S. distribution maps for all 24 weeds are also presented. As mentioned for the Appendix 2 *Medicago* maps, the PLANTS database indicates that “not all populations have been documented, however, and significant gaps in the distribution shown may not be real... Remember that only native and naturalized populations are mapped.” Also, the distribution maps in Appendix 3 of this technical report do not represent glyphosate resistant biotypes. The maps are presented to give a general sense of where the plant species currently grow, which are potentially states to which glyphosate resistant biotypes could spread if conditions promoted their spread. For example, glyphosate resistant buckhorn plantain, goosegrass, junglerice, sourgrass, and wild poinsettia, have been reported in other countries, but not in North America. However, since these weeds have susceptible populations in North America, the growing conditions in North America presumably would also support glyphosate resistant biotypes. It is possible that glyphosate resistant biotypes could independently evolve from the North American populations, or foreign biotypes could be introduced to North America through human error or other unintentional routes.³⁰

The Federal Noxious Weed Act (1975) gave USDA the authority to designate plants as noxious weeds. The movement of noxious weeds in interstate or foreign commerce is prohibited except under permit. USDA can inspect, seize and destroy products, and quarantine areas, if necessary to prevent the spread of noxious weeds. Only tropical spiderwort (Benghal dayflower) is both glyphosate resistant and on the Federal noxious weed list. Several of the glyphosate resistant weeds are on at least one state’s noxious weed list. These include:

- Common ragweed
- Giant ragweed
- Johnsongrass
- Buckhorn plantain
- Bermudagrass
- Field bindweed
- Filaree
- Hemp sesbania

³⁰ Intentional introduction of noxious or herbicide resistant weeds is possible, but discussion of intentional environmental and agricultural sabotage is beyond the scope of this report.

- Morning glory
- Nutsedge
- Purslane
- Topical spiderwort (Benghal dayflower)
- Velvet leaf

Because control programs actively seek to eradicate noxious weeds, their susceptibility to herbicides and their distribution is important information for control managers. It is important to note that noxious weeds are not just weeds in agricultural systems. They are considered weeds regardless of their habitat, once they have been declared noxious in that state, county, or area. Alternative herbicides, mechanical removal, and spot burning are possible alternative control strategies for glyphosate resistant weeds.

3.1.1 *Is Alfalfa Considered a Weed?*

There is very little evidence to suggest that alfalfa is considered a weed, other than as a volunteer in agricultural settings (see USDA APHIS 2009). Monsanto corresponded with 13 weed control experts in Arizona, California, Idaho, Pennsylvania, Oregon, South Dakota, Washington, and Wisconsin (Rogan and Fitzpatrick 2004). None of the respondents considered alfalfa a weed. In South Dakota and Wisconsin it is encouraged to grow along roadsides. Alfalfa is one of the species that is controlled where bare ground is desired. Glyphosate as well as other herbicides were cited as tools for weed control in non-agricultural settings. Rogan and Fitzpatrick (2004) conclude that GT alfalfa would not be a problem weed in non-agricultural setting. There were also two situations where GT alfalfa would require extra control strategies. One is in irrigation ditches with running water in regions of California where the only approved herbicide for that location is glyphosate. In these situations mechanical weed removal or spot burning was recommended. Another situation that is more related to volunteer alfalfa, is alfalfa on land rotated to fruit trees. In this situation, Rogan and Fitzpatrick (2004) suggest that aggressive alfalfa stand termination practices be adopted for land that is rotated to fruit trees or other crops where herbicide use is limited and GT alfalfa has been grown previously. However, this strategy is prevention-based and does not address mitigation once a problem occurs.

Out of the 12 weed lists from the USDA PLANTS Database, *Medicago sativa* is only listed on one, the Southern Weed Science Society.

- Plant Protection and Quarantine. 2006. *Federal noxious weed list* (24 May 2006). USDA Animal and Plant Health Inspection Service. Washington, DC. 2pp. (104 entries)
- Assorted authors. *State noxious weed lists for 46 states*. State agriculture or natural resource departments. (661 entries)
- California Invasive Plant Council. 2006. *California Invasive Plant Inventory*. Cal-IPC Publication 2006-02 (February 2007). California Invasive Plant Council. Berkeley, California. (107 entries)
- Florida Exotic Pest Plant Council. 1999. *Invasive plant list* (19 October 1999). Florida Exotic Pest Plant Council. Florida. (134 entries)

- USDI, Geological Survey. 1999. *Information index for selected alien plants in Hawaii* (20 October 2003). Hawaiian Ecosystems at Risk Project, Biological Resources Division, Haleakala Field Station. Makawao, Hawaii. (197 entries)
- Haragan, P.D. 1991. *Weeds of Kentucky and adjacent states: a field guide*. The University Press of Kentucky. Lexington, Kentucky. 278pp. (141 entries)
- Uva, R.H., J.C. Neal, & J.M. DiTomaso. 1997. *Weeds of the Northeast*. Cornell University Press. Ithaca, New York. 397pp. (237 entries)
- Stubbendieck, J., G.Y. Friisoe, & M.R. Bolick. 1994. *Weeds of Nebraska and the Great Plains*. Nebraska Department of Agriculture, Bureau of Plant Industry. Lincoln, Nebraska. 589pp. (287 entries)
- Southeast Exotic Pest Plant Council. 1996. *Invasive exotic pest plants in Tennessee* (19 October 1999). Research Committee of the Tennessee Exotic Pest Plant Council. Tennessee. (140 entries)
- Southern Weed Science Society. 1998. *Weeds of the United States and Canada*. CD-ROM. Southern Weed Science Society. Champaign, Illinois. (411 entries)
- Hoffman, R. & K. Kearns (eds.). 1997. *Wisconsin manual of control recommendations for ecologically invasive plants*. Wisconsin Dept. Natural Resources. Madison, Wisconsin. 102pp. (75 entries)
- Whitson, T.D. (ed.) et al. 1996. *Weeds of the West*. Western Society of Weed Science in cooperation with Cooperative Extension Services, University of Wyoming. Laramie, Wyoming. 630pp. (344 entries)

The updated Southern Weed Science Society (SWSS), in collaboration with the North Central Weed Science Society, Interactive Encyclopedia of North American Weeds Version 3.0 (447 entries), includes alfalfa (NCWSS 2005). This is an updated version of the 1998 version cited above. The documentation provided by this list does not indicate why alfalfa is considered a weed. It is possible that it is included because it can be an unwanted volunteer in agricultural settings.

The author of the alfalfa segment of the SWSS Weed Identification guide has stated that alfalfa is not “an invasive weed” nor does it “displace native species,” but alfalfa does colonize disturbed areas (Brett Serviss, Docket No. 04-085-1 #480).

3.2 Use of Glyphosate in Non-Agricultural Settings

3.2.1 USDA Forest Service

The Forest Service uses glyphosate primarily in conifer release (58.2%), noxious weed control (15.5%), and site preparation (16.4%). Other minor uses (10.3%) include hardwood release, facilities maintenance, recreation improvement, right-of-way maintenance, seed orchard protection, wildlife habitat improvement, and other weed control (agricultural, aquatic, or nursery). The application rates are approximately 3.31 lb/acre for conifer release, 1.06 lb/acre for noxious weed control, and 3.34 lb/acre for site preparation. Thirty five commercial formulations of glyphosate are registered for forestry applications. In 2001, the total annual use of glyphosate by the Forest Service was approximately 44,700 pounds applied to approximately 19,000 acres, which corresponds to about 0.275 percent of the agricultural use (USDA FS 2003).

The Forest Service tracks usage by Region. The usage rates for the Regions are shown in table 3.1.³¹

Table H-2 USDA Forest Service use of Glyphosate 2001 (USDA FS 2003)

Region	Forest Area	Pounds	Pounds per Acre	Percentage of FS Use by Pounds
1	Northern	264	1.99	0.6
2	Rocky Mountain	182	0.69	0.4
3	Southwestern	3	1.00	--
4	Intermountain	261	0.64	0.6
5	Pacific Southwest	34,740	4.14	78
6	Pacific Northwest	1,706	1.70	3.8
8	Southern	3,419	0.88	7.6
9	Eastern	4,146	0.84	9.3
Total		44,721	2.35	100%

Glyphosate can be applied by directed foliar, broadcast foliar, or aerial methods. Backpack-applied directed foliar sprays are the most common method of application in Forest Service programs. In these applications, the sprayer is carried by backpack, and the glyphosate is sprayed on selected plant species. Glyphosate may also be applied by “hack and squirt” operations, in which a hatchet is used to cut open a tree exposing the cambium, and then the herbicide is applied to the tree using a squirt bottle. Hack and squirt applications are used to eliminate large trees during site preparation, rights-of-way maintenance, or conifer release procedures.

A less often used method of glyphosate application is broadcast foliar ground applications. This method involves mounting a two to six nozzle boom to a tractor or heavy-duty vehicle and applying the herbicide while driving through the selected vegetation.

Some additional methods are also occasionally used by the Forest Service. One is a cut stem application that is used to treat noxious weeds. The weed stem is cut and the herbicide is sprayed onto the cut stem. Another method is an aquatic application, in which the herbicide is sprayed onto aquatic noxious weeds. Aerial applications may be used for brown-and-burn operations.

In situations where bare ground is desired, glyphosate resistant weeds may persist after glyphosate application. However, since burning follows herbicide treatment, the resistant weeds would likely be controlled.

3.2.2 Other Glyphosate Users

As mentioned previously, 13 weed control experts did not consider glyphosate to be the only herbicide for roadside and other weed management, but it is considered among the tools that could be used. It was also mentioned that glyphosate is not particularly good at controlling non-GT alfalfa (Rogan and Fitzpatrick 2004).

³¹ FS regions do not correspond to EPA Regions or to the USDA Plant Variety Protection Office alfalfa growing regions. Also there is no Region 7 in the FS system.

The Roundup® herbicide (glyphosate) label³² includes numerous non-crop uses such as: airports, apartment complexes, Christmas tree farms, Conservation Reserve Program (CRP) areas, ditch banks, driveways, dry ditches, dry canals, fencerows, golf courses, greenhouses, industrial sites, landscape areas, lumber yards, manufacturing sites, municipal sites, natural areas, office complexes, ornamentals, parks, parking areas, pastures, petroleum tank farms and plumbing stations, plant nurseries, public areas, railroads, rangelands, recreation areas, rights-of-way, roadsides, schools, shadehouses, sod or turf seed farms, sports complexes, storage areas, substations, turfgrass areas, utility sites, warehouse areas and wildlife management sites.

Feral alfalfa is known to grow in many of the above settings, therefore it is possible that feral GT alfalfa could also survive in some of these non-crop locations. In these situations, alternative control measures would need to be adopted.

3.3 Summary of Findings

Twenty four weed species are known that either have newly evolved glyphosate resistant biotypes or have historically natural resistance to glyphosate. All 24 of these have naturalized or native populations in the U.S. (although one, Chinese foldwig, is found only in Hawaii). Thirteen of the 24 glyphosate resistant weed species are on at least one noxious weed list. Nine of the 14 newly evolved glyphosate resistant weeds have documented glyphosate resistant biotypes in the U.S. The remaining 5 have sensitive biotypes in the U.S, but glyphosate resistant biotypes have not yet been documented in the U.S.

There is very little evidence to suggest that alfalfa is considered a weed, other than as a volunteer in agricultural settings. Out of the 12 weed lists from the USDA PLANTS Database, *Medicago sativa* is only listed on one, the Southern Weed Science Society, and this listing may be due to volunteer alfalfa in cropland. Thirteen surveyed weed control experts only identified one setting, irrigation ditches in California, where GT alfalfa could not be controlled by alternative herbicides. In this case only glyphosate is approved for irrigation ditches, so mechanical removal or spot burning would be the alternative control measures.

The USDA Forest Service uses glyphosate to manage forests. Their usage is 0.275 percent of the quantity used on agricultural lands. The Roundup® herbicide label has 41 other non-crop setting listed. Many of these setting overlap with areas where feral alfalfa is found. There is a possibility that feral GT alfalfa could be found in non-crop areas. In cases where control is desired alternative control methods are available.

³² http://www.monsanto.com/monsanto/ag_products/pdf/labels_msds/roundup_orig_max_label.pdf

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Appendix H-2. Literature Search

1.0 Literature Search Strategy

1.1 Purpose

The purpose of this literature search is to locate references about the potential impacts of glyphosate-tolerant weeds in non-agricultural ecosystems.

In addition, the titles retrieved for the literature search for the technical report *Effects of Glyphosate-Tolerant Weeds in Agricultural Systems* were also reviewed for applicability to non-agricultural eco-systems.

1.2 Retrieval criteria

Titles were used to indicate the subject of the paper. If the paper was not in English or indicated a geographic region outside of the U.S., it was not retrieved. Titles that seemed to focus on insect pests were not retrieved. Titles that seemed to indicate an agricultural focus were not retrieved. All titles that seemed applicable to the scope of the paper were searched for online by a professional librarian. Titles that were obtained for free and were cited include the URL in the citation. Titles that were not free access were obtained through online purchase or the use of a copy vendor, who regularly visits National Institutes of Health and National Agricultural Library to obtain references.

1.3 Databases

File 10:AGRICOLA 70-2008/Jun
(c) format only 2008 Dialog
File 203:AGRIS 1974-2008/Feb
Dist by NAL, Intl Copr. All rights reserved
File 266:FEDRIP 2008/Apr
Comp & dist by NTIS, Intl Copyright All Rights Res
File 5:Biosis Previews(R) 1926-2008/Jul W1
(c) 2008 The Thomson Corporation
File 6:NTIS 1964-2008/Jul W3
(c) 2008 NTIS, Intl Cpyrght All Rights Res
File 41:Pollution Abstracts 1966-2008/Aug
(c) 2008 CSA.
File 40:Enviroline(R) 1975-2008/Apr
(c) 2008 Congressional Information Service
File 76:Environmental Sciences 1966-2008/Jul
(c) 2008 CSA.
File 24:CSA Life Sciences Abstracts 1966-2008/Mar
(c) 2008 CSA.
File 117:Water Resources Abstracts 1966-2008/Mar
(c) 2008 CSA.

File 144:Pascal 1973-2008/Jul W1
 (c) 2008 INIST/CNRS
 File 50:CAB Abstracts 1972-2008/Jun W5
 (c) 2008 CAB International
 File 44:Aquatic Science & Fisheries Abstracts 1966-2008/Mar
 (c) 2008 CSA.
 File 71:ELSEVIER BIOBASE 1994-2008/Jun W5
 (c) 2008 Elsevier B.V.
 File 143:Biol. & Agric. Index 1983-2008/Apr
 (c) 2008 The HW Wilson Co

Descriptions of these files are available at <http://library.dialog.com/bluesheets/>.

1.4 Scope of Search

The search focused on any published references between 1980 and the present. A list of titles (below) was screened followed by screening of abstracts for relevant titles. There were no limits on language for titles but only English language publications were retrieved for evaluation. In addition, only papers relevant to the U.S. were retrieved. All titles are provided below, to demonstrate the wide range of literature available for other countries where Medicago species are naturally occurring.

1.5 Keywords

alfalfa (Medicago and Lucerne are synonyms for alfalfa) combined with the terms below

Feral
 Wild
 Forest*
 Meadow*
 Roadside*
 Ditch*
 Canal*
 Railroad*
 Wasteland*
 Cemetery* (for cemeteries and cemetery)
 Highway*
 Pipeline*
 Fence*

1.6 Results

```

S1  163012  ALFALFA OR MEDICAGO OR LUCERNE OR M( )SATIVA
S2  936526  WILD OR FERAL
S3  1819113 FOREST? OR MEADOW? OR ROADSIDE? ? OR WASTELAND? ?
S4  265626  DITCH OR DITCHES OR CANAL OR CANALS
S5  199278  RAILROAD? ? OR CEMETER? OR HIGHWAY? ? OR PIPELINE? ? OR
      FENCE OR FENCES OR NATURAL( )(AREA OR AREAS OR HABITAT? ?)
S6  120548  S1 NOT PY=1900:1979
  
```


S7 2240 S6 (S) (S3 OR S4 OR S5)

10/K,6/3 (Item 3 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0007280290 CAB Accession Number: 19960710684
The avifauna of remnant tallgrass prairie near Boulder, Colorado.
Publication Year: 1995

... virgatum and Sorghastrum nutans , and the agricultural grasslands in the Boulder valley include mixtures of *Medicago* sativa , Carex sp. and various non-native pasture grasses such as Bromus inermis , Festuca pratensis...

... grasses and herbs, and Yucca glauca and Opuntia spp. are common. The relative abundances of *wild* birds on tallgrass prairie plots were compared with those of the 2 adjacent grassland habitats...

...the Great Plains, USA. Nesting songbird species were abundant in Boulder tallgrass and included western *meadowlark* (Sturnella neglecta), red-winged blackbird (Agelaius phoeniceus) and grasshopper sparrow (Ammodramus savannarum), with smaller numbers...

10/K,6/9 (Item 9 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0005385072 CAB Accession Number: 19840507892

Diet of the adult of Tytthaspis sedecimpunctata (L.) (Coleoptera Coccinellidae) in an environment with primary human influence: a meadow containing multiple plant species.

Original Title: Regime alimentare dell'adulto di Tytthaspis sedecimpunctata (L.) (Coleoptera Coccinellidae) in ambiente a influenza antropica primaria: prato polifita.

Atti XIII Congresso Nazionale Italiano di Entomologia.

Publication Year: 1983

... 1978-79 by examination of the gut contents of insects sampled by aspirator from a *meadow* used for agricultural purposes; it contained a wide variety of plants including *lucerne*, red clover, various grasses and *wild* carrot. The diet of the coccinellids as indicated by the gut contents consisted largely of...diet varied in relation to the time of year and to the mowing of the *meadow* for hay, but in general pollen was the preferred food and fungi were taken in...

10/K,6/11 (Item 11 from file: 203)
DIALOG(R)File 203:Dist by NAL, Intl Copr. All rights reserved. All rts. reserv.

02391566

Ecogeography and distribution of wild legumes in Turkey

1998

Proceedings of International Symposium on In Situ Conservation of Plant Genetic Diversity

Since Turkey is one of the center of diversity for legumes, most of the *wild* relatives of economically important food and forage legume species consisting of Cicer, Lens, Pisum, Vicia, Lathyrus, Trifolium, *Medicago*

exist in flora. The ecogeography and distribution of *wild* legumes differ from species to species for each genus, starting from coastal habitats up to the highlands including *forests*. Within the framework of National Plant Genetic Resources Program ecogeography and distribution of *wild* legumes have been determined with systematic annual expeditions.

10/K,6/15 (Item 15 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0007088386 CAB Accession Number: 19950710609

Phenological development of different wild flower meadow mixtures during the course of a growing season.

Original Title: Phanologische Entwicklung verschiedener Blumenwiesenmischungen im Verlauf einer Vegetationsperiode.

Publication Year: 1994

The development of *wild* flower *meadows* from 4 seed mixtures was observed between 14 May and 9 Oct. 1992. The plots...
... desirable. A mixture with a high proportion of legumes was dominated by Lotus corniculatus and *Medicago* sativa . Except for Anthoxanthum odoratum and Trisetum flavescens , the flowering grasses were mostly inconspicuous. The...

10/K,6/20 (Item 20 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0008321578 CAB Accession Number: 20023088265

Genetic resources of forage-turf grasses and legumes in Lithuania: collecting activity, evaluation/characterization, genetical collection.

Publication Year: 2001

... locations of 16 Lithuanian administrative districts. The work was started by making inventories of natural *meadows* in each district. 624 seed accessions of forage-turf grasses and legumes were collected in...
... programmes. Initial evaluation has shown that there are real grounds to accumulate genetic resources of *wild* ecotypes of perennial grasses and legumes, as the genotypes collected in Silute, Kaisiadoriai, Trakai, Klaipeda...
... morphological traits and agronomic properties within the species. The new varieties "Arka" and "Gaja" of *Medicago* lupulina L. and Poa pratensis L. species created from *wild* ecotypes collected in the Klaipeda district will be tested in the official variety trials over...
... collection of forage-turf grasses and legumes currently consists of 548 seed samples, including 265 *wild* or semi-natural ecotypes, 229 breeder's lines, 54 advanced cultivars.

10/K,6/26 (Item 26 from file: 5)

DIALOG(R)File 5:(c) 2008 The Thomson Corporation. All rts. reserv.

06664738 BIOSIS NO.: 198274081161

THE LEGUMES OF VAISHALI DISTRICT BIHAR INDIA

1982

ABSTRACT: A systematic survey of *wild* and naturalized (46 spp.) and cultivated (47 spp.) leguminous plants of the Vaishali district is...
...important synonyms, diagnostic features, local names, economic uses, locality records, ecological amplitude and phenology. The *wild* and naturalized taxa are mostly found in pastures, *wastelands*, orchards, etc. Alysicarpus longifolius Wight et Arn., Astragalus graveolens Buch.-Ham. ex Benth. and *Medicago* laciniata var. brachycantha Bioss. are new records for the state. Astragalus graveolens Buch.-Ham. ex...
...appears to have extended its geographical range from the western hills to the eastern plains. *Medicago* falcata L., Psophocarpus tetragonolobus DC. and Trifolium alexandrinum L. were introduced under cultivation for food...

10/K,6/27 (Item 27 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0007913654 CAB Accession Number: 20001612632

The mielgas: wild Spanish populations of alfalfa. Results of ten years of researches.

Lucerne and medics for the XXI Century. Proceedings XIII Eucarpia Medicago spp. Group Meeting, Perugia, Italy, 13-16 September 1999.

Publication Year: 2000

Some 104 natural populations of *Medicago* sativa were collected in Spain, from September 1985 to July 1987. They were mainly from *roadsides* , non-irrigated and often grazed rangelands or even orchards. This germplasm has been evaluated at...

... of the total annual dry matter production for the first cut), a greater persistence than *alfalfa* [*lucerne*] cultivars and a good vegetative spring yield and seed production level for non-selected populations...

...distinguished from the others. The maintenance of original morphological features in most natural populations of *Medicago* sativa in Spain questions the relative extent of crop-to-weed gene flow versus selection

...

... pattern of population differentiation were measured in a subset of populations, within and among the *wild* and cultivated gene pools with respect to both allozymes, RAPD and quantitative traits. Combining these

...

... in some locations is likely to oppose gene flow to establish cultivated traits into the *wild* populations. Third, some other populations were different from all the cultivated landraces with respect to...

10/K,6/28 (Item 28 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0007693735 CAB Accession Number: 19991102584

Monitoring for impact of the introduced leafcutting bee, *Megachile rotundata* (F.) (Hymenoptera: Megachilidae), near release sites in South Australia.

Publication Year: 1996

Native plants from remnant strip vegetation at *roadside* sites near Keith, South Australia, were monitored during the period when *M. rotundata* were managed on nearby *lucerne* crops. The predominant native plants flowering at sampling sites during the November to March period...

... 12 microdomiciles placed in a nearby Conservation Park. The results of the monitoring programme suggested *feral* leafcutting bee populations were unlikely to have established in significant numbers and the impact on

...

10/K,6/29 (Item 29 from file: 5)

DIALOG(R)File 5:(c) 2008 The Thomson Corporation. All rts. reserv.

19070960 BIOSIS NO.: 200600416355

Morphologic and agronomic diversity of wild genetic resources of *Medicago sativa* L. collected in Spain

2006

ABSTRACT: One hundred and three natural populations of *Medicago* L. were collected in Spain, mainly from *roadsides*, non-irrigated or grazed lands. This germplasm was evaluated at Montpellier (France) with control cultivars...

...Differences between natural populations and cultivated controls are highly significant, but gene flow occurs between *wild* and cultivated compartment and hybrid populations were identified. On the basis of multivariable analysis, the...

...their disappearance even when they disappeared from the other regions of the western Mediterranean. Spanish *wild* pool of *alfalfa*, also called 'Mielga', appears of great interest for the breeding of *alfalfa* because it contains a large diversity of characteristics (prostrate habit, rhizomes) linked to tolerance to...

...of natural habitats and the necessity for rehabilitation of degraded ecosystems, the importance of this *wild* pool is really inestimable.

10/K,6/30 (Item 30 from file: 5)
DIALOG(R)File 5:(c) 2008 The Thomson Corporation. All rts. reserv.
14952858 BIOSIS NO.: 199900212518
Morphometric analysis of main wild food plants of South Ural region
1998

ABSTRACT: The morphometric and phenotypic analysis of variability of 16 natural populations of eight *wild* food species have been carried out in the central mountain-*forest* part of the South Urals and in north-eastern *forest*-steppe Bashkir Cis-Urals. As a result, 11 populations with high plant morphometric values and...
...are selected within the following species: *Alopecurus pratensis* L., *Dactylis glomerata* L., *Phleum pratense* L., **Medicago** *falcata* L., *Trifolium medium* L., *T. hybridum* L. Populations with morphometric parameters of plants are...

10/K,6/43 (Item 43 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0009355551 CAB Accession Number: 20073193255
Steppe field shelterbelts: a new factor in ecological stabilization and sustainable development of agrolandscapes.
Publication Year: 2007

... erosion, which pertains to phytoamelioration, was examined. The steppe shelterbelts were laid out between existing *forest* belts across slopes, along horizontals, with a width of 7-10 m, and on a...
...7%; and the dominant association is fescue and grass (*Festuca valesiana* + *Koeleria cristata* [*K. macrantha*] + **Medicago** *romanica*). The most important characteristics of the steppe shelterbelts, these quasi-natural plant communities, are unlimited longevity, self-reproduction of rich flora, annual regeneration after a fire, optimum environment for *wild* fauna and 95-97% reduction of runoff processes.

10/K,6/44 (Item 44 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0007473718 CAB Accession Number: 19980200036
Structure and density of lucerne pollinating wild bee populations as affected by changing agriculture.
Proceedings of the 7th International Symposium on Pollination, Lethbridge, Alberta, Canada, 23-28 June 1996.
Publication Year: 1997

Intensive surveys on populations of *wild* bees (Apoidea) which pollinate *lucerne* were made in Hungary in the mid-fifties, late sixties and early seventies. Comparing these surveys, a dramatic change in the structure of *wild* bee populations occurred between the fifties and the sixties. The populations of some bee species have fallen, other species have remained unchanged, while the population of **Medicago** *oligoleges* has increased. The changes may be explained by changes in agricultural land usage since...increase in field size as well as an increased use of mechanical weed

control along *roadsides*, and by an increased use of herbicides on arable land. The effects are discussed in terms of seasonal occurrence for different groups of *wild* bees. It is concluded that the changes in agriculture have been favourable for some bee...

10/K,6/45 (Item 45 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0008974830 CAB Accession Number: 20053170218

Strip undersowing of perennial fodders in natural degraded pastures of the forest steppe of the River Ob region.

Publication Year: 2005

... work carried out in 1999-2004, the botanical composition of degraded pastures in the northern *forest* steppe of Novosibirsk province in Siberia around the River Ob (Priob'e region) was determined...

... yielding perennial fodder species was investigated. The pastures were mainly mixed grass and narrow-leaved *meadow* grass [*Poa angustifolia*] grasslands on *meadow* chernozem soil, in which the dominant plant species were dandelion [*Taraxacum officinale*], dropwort [*Filipendula vulgaris*], *wild* strawberry [*Fragaria vesca*] and tufted vetch [*Vicia cracca*]. Pasture plots were undersown with either cocksfoot [*Dactylis glomerata*] or yellow *lucerne* [*Medicago falcata*]. Best results in terms of dry matter (DM) yield (3-4 t/ha) were...

... 340 to 480 g/m SUP 2 . One drawback was poor seedling drought resistance. For *lucerne* , which was also relatively competitive, after 3-6 years it occupied 60-70% of the...

16/K,6/3 (Item 3 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0007903234 CAB Accession Number: 20001911501

The influence of sewage water on the growth of wild plants, north of Sana'a, Republic of Yemen.

Publication Year: 2000

...to 70% in areas fed by sewage and rain water, and 5 to 10% in *natural* *areas* , fed by rainfall only. On the basis of their life form plants were classified as short-lived annual, long-lived annuals, long-lived annuals or biennials, and perennials. Barley, *alfalfa* (*Medicago sativa*) and maize were successfully planted for animal and human consumption along the banks of...

21/K,6/1 (Item 1 from file: 71)

DIALOG(R)File 71:(c) 2008 Elsevier B.V. All rts. reserv.

03691993 2007114099

Acacia nilotica and **Medicago sativa*, suitable plants for agro-*forestry* in southern coasts of Iran

PUBLICATION DATE: May 15, 2007

...leaf and fruit of *Acacia* were determined and compared with those of in foliage of **Medicago sativa* being managed under an agro-*forestry* system.

By analyzing data it was revealed that the biggest trees were found in Dashteyari...

...the Oman Sea coast). Values in most of nutritional elements were higher in foliage of **Medicago** than in leaf and fruit of *Acacia*, respectively. From this investigation it is concluded that in south of Iran where the site is favorable for *Acacia* plantation, cultivation of **Medicago** or other adaptable crops together with *Acacia* can be developed as agroforestry systems (such as...

21/K,6/2 (Item 2 from file: 10)

DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.

2135393 83040751 Holding Library: AGL

Aggregation patterns of *meadow* spittlebugs, *Philaenus spumarius* L. (Homoptera: Cercopidae), on old-field *alfalfa* plants

1983

21/K,6/5 (Item 5 from file: 10)
 DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.
 2455244 85032562 Holding Library: AGL
 Alfalfa in the *forest*-steppe zone of the Ukrainian SSR
 1984 Nov

21/K,6/6 (Item 6 from file: 10)
 DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.
 1871930 81061129 Holding Library: AGL
 Alfalfa pests and measures of their control in the central
 foreststeppe of the Ukranian SSR.
 1980

21/K,6/8 (Item 8 from file: 76)
 DIALOG(R)File 76:(c) 2008 CSA. All rts. reserv.
 0002018019 IP ACCESSION NO: 7669446
 Alternative methods for sustainably managing coastal *forests* as silvo-
 pastoral systems
 PUBLICATION DATE: 2006
 ABSTRACT: Integration of shelter *forest* and herbage into a silvo-pastoral
 system
 with sustainable management can improve the ecological and economic
 sustainability of shelter *forest* in coastal China. Sustainable management
 of tree density and forage grasses planting was studied by establishing
 five experimental treatments through selective logging of the *forest*. The
 tree density at the five treatments was 5.00, 2.50, 1.67, 1...
 ...100m2 (Treatment 4) is the best for introduced forage plants (*Sorghum*
sudanense, *Lolium multiflorum*, and **Medicago** *sativa*) and mature *Populus* to
 integrate into a silvo-pastoral system, while the density of...

21/K,6/10 (Item 10 from file: 50)
 DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
 0009070567 CAB Accession Number: 20063118697
 Applications of bioengineering for *highway* development in southwestern
 China.
 Book Title: Ground and water bioengineering for erosion control and
 slope stabilization
 Publication Year: 2004
 A surge of high-grade *highway* infrastructure construction is expected
 in China (includes Yunnan, Guizhou and Sichuan) by 2020 within the
 framework of the National Trunk *Highway* Networks. The southwestern part
 of China, where over 170 million people live, is characterized by...
 ...rainfalls and high seismic activity. Due to the complex nature of this
 environment, construction of *highways* is a highly challenging task.
 Bioengineering techniques have been utilized since 1992 in an attempt to
 reduce the ecological impacts of *highway* construction and improve the
 aesthetics of *highway* environment. Plants are used to reduce the flow of
 water, provide protection against raindrop impact...
 ...subtropical montane areas and include: *Agropyron cristatum*, *Cynodon*
dactylon, *Eragrostis ferruginea*, *Festuca arundinacea*, *Lolium perenne*,
 Medicago *sativa*, *Paspalurn notatum*, *Poa pratensis*, *Trifolium pratense*,
T. repens, and *Zoysia japonica*. Grasses and shrubs...
 ...Evidence clearly shows that bioengineering techniques are part of the
 sustainable development of high-grade *highway* construction projects by
 creating beautiful scenery, ensuring the security of transportation, and
 improving environmental protection.

21/K,6/12 (Item 12 from file: 50)
 DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
 0006615591 CAB Accession Number: 19920758889
 Applying chemical treatments to hay *meadows*.
 Publication Year: 1992
 A weed-infected natural hay *meadow* on a S.-facing 15(deg) slope in the Krasnodarsk district was sprayed with 2...
 ... was sown with a mixture of Bromus inermis, Festuca pratensis, Dactylis glomerata, Trifolium pratense and *Medicago* falcata after preliminary loosening to 6-8 cm depth. The herbicide and fertilizer treatments were...

21/K,6/13 (Item 13 from file: 50)
 DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
 0009056221 CAB Accession Number: 20063096543
 Application of thick substrate spraying technique to high edge slopes in Chengdu-Nanchong *highway*.
 Publication Year: 2004
 ... tested during 2001-02 for controlling the collapse of high edge slopes of Chengdu-Nanchong *Highway* in Sichuan, China. It was developed by the Sichuan Sihai Brilliant Ecological Environment Engineering Co...
 ...to sow plant seeds to the substrates. The sown plants were Festuca elata, Cynodon dactylon, *lucerne* [*Medicago* sativa], Lespedeza bicolor and Ficus tikoua. Observations on their growth showed that C. dactylon, F. elata and *lucerne* had a plant height and density 29 and 2089, 15 and 209, and 8 cm...

21/K,6/16 (Item 16 from file: 50)
 DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
 0006490254 CAB Accession Number: 19920750531
 Studies of the biology and its application in the cropping system of upland red soil in southeastern China. II. A study of the microflora and crop yield potential of sloping *wasteland* planted with grass.
 Publication Year: 1990
 ... in southeastern China. II. A study of the microflora and crop yield potential of sloping *wasteland* planted with grass.
 ... autumn 1986 and 1987 mixtures of Festuca arundinacea or Lolium perenne with Trifolium repens and *Medicago* sativa were sown on sloping *wasteland* at Nanchang and Qingjiang in Jiangxi. The total number of microorganisms in soil increased each...

21/K,6/17 (Item 17 from file: 203)
 DIALOG(R)File 203:Dist by NAL, Intl Copr. All rights reserved. All rts. reserv.
 01046132
 1984
 Bromus willdenowii, Dactylis glomerata, Festuca arundinacea, *Medicago* sativa: 4 species for the rotating *meadows* of the plain (Bromus willdenowii, Dactylis glomerata, Festuca arundinacea, Medicago sativa: 4 specie per i prati avvicendati di pianura)

21/K,6/19 (Item 19 from file: 50)
 DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
 0008548930 CAB Accession Number: 20033206628
 Botanical and chemical composition of *meadow* hay from different grassland regions of Macedonia.
 Original Title: Botanicki i kemijski sastav livadnog sijena s

razlicitih pasnjackih podrucja r. Makedonije.

Publication Year: 2003

In order to determine the botanical and chemical composition of *meadow* hay, share of grasses, legumes and other plants as well as the basic nutrients, 10...

... and *Dactylis glomerata*, from the family of legumes Fabaceae are *Trifolium repens*, *Trifolium pratense* and **Medicago** *lupulina* and representatives of other plant families are *Plantago lanceolata*, *Achillea millefolium* and *Silene vulgaris*...low or medium quality and those from the Males region as good and medium quality *meadow* hay.

21/K,6/27 (Item 27 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0005653396 CAB Accession Number: 19851645170

The concept of *meadow* structure and its importance in the definition of the *lucerne* ideotype.

Development, construction and multiplication of fodder crop varieties. Meeting of the Fodder Crops Section of Eucarpia, 17-20 September 1984, Freising-Weihestephana, German Federal Republic.

Publication Year: 1985

21/K,6/33 (Item 33 from file: 6)

DIALOG(R)File 6:(c) 2008 NTIS, Intl Copyright All Rights Res. All rts. reserv.

1946278 NTIS Accession Number: MIC-96-02326

Cover crops for *forest* vegetation management: A literature review

(Technical report no. no. 93, and VMAP technical report no. 95-01)

c1995

With increasing social pressures to reduce the amount of herbicides used in *forestry*, cover crops are being evaluated for their use as a *forest* management tool. This publication summarizes current available information on the use of cover crops to control competing vegetation in *forest* management. The publication begins with a review of research on cover crops for weed suppression...species and describes some cover crop plants suitable for use in northern Ontario. These include *alfalfa*, timothy grass, clover, bird's-foot trefoil, and orchard grass.

21/K,6/38 (Item 38 from file: 144)

DIALOG(R)File 144:(c) 2008 INIST/CNRS. All rts. reserv.

10958470 PASCAL No.: 93-0467834

Dynamics of mown *meadows* in the hinterland of the Province of Macerata (Central Italy)

1993

A study has been made of the dynamics of the Pian di Pieca mown *meadows* in the Sarnano area (Province of Macerata). These are subjected to rotation and alternate every five years with wheat and oat crops. The *meadow* regrowth prevalently occurs through the seed bank in the soil and through the dispersion of seed from the more mature plots of the surrounding *meadowlands*, with the addition by man of **Medicago** *sativa* and *Lolium multiflorum* seed in the first year. The floristic, phytosociological and ecological analyses of the *meadowlands* belonging to five different age classes, each of which corresponds to a vegetative period, has...

... in the presence of *Molinio-Arrhenatheretea* class species concurrently with the age of the individual *meadow* plots (...)

21/K,6/40 (Item 40 from file: 5)

DIALOG(R)File 5:(c) 2008 The Thomson Corporation. All rts. reserv.
16997589 BIOSIS NO.: 200200591100
[Dissertationes Botanicae. The plant communities on way- and *roadsides* in the area of Hannover and the relations of these communities to rock and soil.]

ORIGINAL LANGUAGE TITLE: Dissertationes Botanicae. Die Pflanzengesellschaften der Weg- und der Strassenraender in der Region Hannover und die Beziehungen dieser Gesellschaften zu Gestein und Boden
2002

...ABSTRACT: page book is part of the Dissertationes Botanicae series. This band describes vegetation composition along *roadsides* in Hannover, Germany and their relation to rock and soil type. Seventy-six vegetation units are grouped into five fundamental communities that include *Agrostis capillaris*, **Medicago lupulina*, *Chaerophyllum bulbosum*, *Lolium perenne*, and one community free of differential species. In addition to...

21/K,6/49 (Item 49 from file: 10)
DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.
1858511 81049724 Holding Library: AGL
The influence of formalin addition on the quality of silages made of *meadow* grass, *alfalfa* or red clover
1980

21/K,6/50 (Item 50 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0005562142 CAB Accession Number: 19850772947
The effect of fertilizer application and duration of exploitation on the composition of the vegetative cover of temporary *meadows*.
Original Title: Dinamica structurii covorului vegetal al pajistilor temporare sub influenta fertilizarii si a duratei de exploatare.
Publication Year: 1982
... fertilizer application and duration of exploitation on the composition of the vegetative cover of temporary *meadows*.
A temporary *meadow* composed initially of a 1:1 mixture of *lucerne* and cocksfoot studied during 1979-83 was treated with 0, 100, 140 or 180 kg...
... doses of sheep dung had little effect on pasture composition, but favoured the maintenance of *lucerne* cover when applied with P. Increasing the length of pasture production increased the proportion of...

21/K,6/51 (Item 51 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0005164770 CAB Accession Number: 19810729014
Effect of potassium and molybdenum on *lucerne* yield on dark grey *forest* soils.
Publication Year: 1980
Application of 100-200 kg K₂O/ha to *lucerne* grown on dark grey *forest* soil increased plant resistance to cold, drought and lodging, but had no effect on DM...

21/K,6/57 (Item 57 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0006419738 CAB Accession Number: 19910746119
Effect of nitrogen and lime application at sowing on soil properties, weed development, dry matter yield and nutritive value in *alfalfa* *meadow*.
Publication Year: 1990

... lime/ha on soil properties, weed growth and DM yield and nutritive value in a *Medicago* sativa *meadow* were studied. Soil pH, P, K and Ca contents increased 6 months after lime application...

21/K,6/60 (Item 60 from file: 10)
DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.
1893847 81079873 Holding Library: AGL
Effect of application of potassium and molybdenum fertilizer on *alfalfa* yield on dark Gray *forest* soils.
1980

21/K,6/65 (Item 65 from file: 5)
DIALOG(R)File 5:(c) 2008 The Thomson Corporation. All rts. reserv.
10100547 BIOSIS NO.: 199089018438
EFFECT OF RIPE BRACKEN LEAF WATER EXTRACT ON THE GROWTH OF SOME PERENNIAL CEREAL AND LEGUMINOUS GRASSES SOWN ON *MEADOW* SOIL
1989
...ABSTRACT: of ripe bracken leaf water extract on the seeds of some grass species sown on *meadow* soil. Watering soil with this extract inhibited seed emergence and plant stem and root growth...
...more toxic for burr reed, red clover, trefoil and agropyrum and less toxic for pasture *alfalfa*, cane like foescue, red fescue and timothy.

21/K,6/68 (Item 68 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0008583702 CAB Accession Number: 20043020622
The environmental weed risk of revegetation and *forestry* plants.
Publication Year: 2003
... and grasses which have been planted for use in broad scale rural revegetation and farm *forestry* in South Australia. The result of a weed risk assessment of 20 plant species in...
... also the minimal weed risk of others (including Eucalyptus globulus, E. grandis, E. platypus and *lucerne*). Suggestions are given on how the weed risk of various species can be managed more...

21/K,6/73 (Item 73 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0008821638 CAB Accession Number: 20053069255
Evaluation on the synthetic benefits of the agro-*forest* compound ecosystem in the loess hilly-ravine region in the central part of Gansu Province.
Publication Year: 2004
... in the study area includes the management modes of Hippophae rhamnoides-Armeniaca vulgaris [Prunus armeniaca]- *Medicago* sativa, Platycladus orientalis [Thuja orientalis]- Tamarix austromongolica-*M*. *sativa* , Tamarix austromongolica -crops, courtyard industrial crops irrigated with converged rainwater, enclosure-grazing animal husbandry, etc...
... project of withdrawing from farming to afforesting and grass planting, achieving the sustainable development of *forestry* and agriculture, and promoting the rural social and economic development in the loess hilly-ravine...

21/K,6/74 (Item 74 from file: 10)
DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.
3429849 20448256 Holding Library: AGL
Evaluation of sulfur mineralization potential of *meadow* soils and

availability to *alfalfa*
1994 Aug

21/K,6/75 (Item 75 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0008914574 CAB Accession Number: 20053149967

The evolution of the *forestry* vegetation on degraded areas in Ariesul Valley basin.

Publication Year: 2004

Results are presented of a study, conducted in Campeni *forest* districts in Romania, which aimed to: provide a better information referring to the degraded areas stational conditions; specify the ecological features of the *forestry* species used for afforestation of degraded areas in Ariesul Valley basin, following the evolution of different species and types of *forestry* cultures in various conditions of degraded areas for cultures and for recently installed experimental areas...

... the degraded lands for previously installed experimental areas. Four experimental blocks were set up where *forestry* species and working technologies were tested for the rehabilitation of degraded areas: Turda experimental block...excelsior, E. angustifolia and F. ornus); Turda experimental block (R. typhina + Lolium sp., R. typhina + *Medicago* sativa , R. typhina + Lolium sp. and control area (bare ground)); and Baia de Aries experimental...

21/K,6/77 (Item 77 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0005693401 CAB Accession Number: 19860786105

Establishment of forage species in *forests* on calcareous soils with a cold semiarid climate.

Original Title: Implantacion de especies pascicolas en montes calizos con clima semiarido frio.

Publication Year: 1984

... 1982, plants of (a) Astragalus cicer cv. Lutana, (b) Colutea arborescens, (c) Coronilla minima, (d) *Medicago* arborea, (e) *M*. *sativa* ecotype Ayna and (f) Dactylis glomerata ecotype Barriopedro were transplanted into a calcareous soil in the Carralejo *forest* (Guadalajara) with a NW aspect. Establishment became stabilized by the 2nd summer and, despite the...

21/K,6/80 (Item 80 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0007408350 CAB Accession Number: 19970707563

Fodder and landscape aspects of herbaceous *meadows*.

Original Title: aki zioowe w aspekcie paszowym i krajobrazowym.

Publication Year: 1996

Forb *meadows* in the valleys of the Obrzan and Wyskoc *canals* were studied in 1992-94. Among the dominant species, Trifolium repens, Plantago lanceolata and Ranunculus acer [R. acris] were rich in chlorophyll, carotenoids and beta-carotene. *Medicago* lupulina, T. repens, Achillea millefolium, Cirsium oleraceum and P. lanceolata contained >12% total protein. The...

21/K,6/83 (Item 83 from file: 203)
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01102937

Function of *alfalfa* *meadow*-grass *Medicago* sativus in the soils
(La funzione del medicaio Medicagus sativus nei terreni in pendio)
1984

21/K,6/84 (Item 84 from file: 203)

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reserv.

01925087

(Phenological development of different wildflower-*meadows* during the
period of vegetation) (Phaenologische Entwicklung verschiedener
Blumenwiesenmischungen im Verlauf einer Vegetationsperiode)
1994

... show an unharmonious picture and the appearance of individually
dominating species (e.g. Lotus corniculatus, *Medicago* sativa) prevents
the development of a many coloured aspect when blossoming. The flowering
aspect of...coloured plot, blooming till autumn, which is very close
to the
conceptions of a flower *meadow*.

21/K,6/90 (Item 90 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0007550654 CAB Accession Number: 19981607057

Genetic diversity in *wild* accessions of Medicago sativa in Spain.

Book Title: Seed production of lucerne. Proceedings of the 12th
Eucarpia Meeting of the Group Medicago, Brno, Czech Republic, 2-5 July
1996.

Publication Year: 1997

During 1985-87, 104 natural populations of *M*. *sativa* were collected
from *roadsides*, unirrigated and grazed rangelands, and orchards in
Spain. These populations have been evaluated under grazing...
...plants had prostrate habit and good soil colonizing ability. Populations
had greater perennality than cultivated *lucerne*, and good vegetative
spring yield and seed production. Populations from the northeastern Spain
could be...

21/K,6/96 (Item 96 from file: 10)

DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.

4028311 23300107 Holding Library: AGL

Gas *pipelines*: are they a detriment or an enhancement for crops?

2000

DESCRIPTORS: *medicago* sativa.....*pipelines* ; ;

21/K,6/97 (Item 97 from file: 203)

DIALOG(R)File 203:Dist by NAL, Intl Copr. All rights reserved. All rts.
reserv.

02428297

[The health of *lucerne* *meadows*-grass [*Medicago* sativa L.]] (La
salute del medicaio [Medicago sativa L.])
1999

21/K,6/98 (Item 98 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0006930520 CAB Accession Number: 19941909014

The humus in eroded Gray *Forest* soils in the region west of the Urals
and changes effected by planting mixed grasses.

Publication Year: 1993

...of growing perennial grass and legumes on the quantity and quality of humus in Grey *Forest* soils in the northern *forest* steppe zone of Bashkiria was investigated. Legumes (blue hybrid *lucerne*), grass (tall fescue) and a legume-grass mix (red clover, blue hybrid *lucerne* and tall fescue) were grown for 5 years on soils at different stages of erosion...
 ... humus accumulation depended on the kind of grass, accumulation being faster under legume-grass. For *lucerne* and grass, accumulation was more rapid in the early years and later years, respectively. Humus...
 ... The content of humic acid increased by 12%, 8% and 6% in legume-grass mix, *lucerne* and grass, resp. in slightly eroded soil. The humus of all soils had a higher...
 ... acid under pure grass were lower than for those under legume-grass mix and pure *lucerne* and this is attributed to faster accumulation of HA-1, which has a low optical...

21/K,6/99 (Item 99 from file: 5)
 DIALOG(R)File 5:(c) 2008 The Thomson Corporation. All rts. reserv.
 10291848 BIOSIS NO.: 199090076327
 HEMIPTERA OF *ALFALFA* AGROCENOSIS IN NEWLY DEVELOPED LANDS IN THE KARA KUM
 CANAL AREA TURKMEN SSR USSR
 1989

21/K,6/100 (Item 100 from file: 5)
 DIALOG(R)File 5:(c) 2008 The Thomson Corporation. All rts. reserv.
 0020009629 BIOSIS NO.: 200800056568
 Herbaceous plant cover establishment on *highway* road sides
 BOOK TITLE: Developments in Plant and Soil Sciences
 2007
 ...ABSTRACT: types of plants to become established was studied on the road sides of the Egnatia *highway*, Thessaloniki, Greece. A mixture of perennial plants (grasses, legumes and forbs) was sown at equal...
 ...Agropyrum cristatum L., Bromus inermis Leyss., Dactylis glomerata L. and Festuca valesiaca Schleich, the legume *Medicago* sativa L. and the forb Sanguisorba minor Scop.

21/K,6/102 (Item 102 from file: 266)
 DIALOG(R)File 266:Comp & dist by NTIS, Intl Copyright All Rights Res. All rts. reserv.
 00561691
 IDENTIFYING NO.: 0191385 AGENCY CODE: AGRIC
 Impacts of Interactions among Generalist Arthropod Predators in Two Complex Food Webs: Vegetable-Crop Gardens and *Forest*-Floor Leaf Litter
 ...SUMMARY: of rainfall in field experiments.PR publication from the experiment on linyphiid dispersion patterns in *alfalfa*, and the impact on the *forest* -floor food web and rates of decomposition of changes in rainfall induced by global climate change; (2) further analysis of data from the *forest*-floor experiment using multivariate techniques; and (3) initiation of field experiments in the forest system...

21/K,6/109 (Item 109 from file: 203)
 DIALOG(R)File 203:Dist by NAL, Intl Copr. All rights reserved. All rts. reserv.
 02551719
 Investigations into the causes of poor *alfalfa* development and early weed infestation on calcareous *meadow* soils (A lucerna gyenge fejlodese es korai gyomosodasa okainak vizsgalata meszes reti talajokon)
 The reasons for the poor development of *alfalfa* on calcareous *meadow*

soils at many sites, leading to the thinning of the stands within 2-3 years...

21/K,6/113 (Item 113 from file: 203)
DIALOG(R)File 203:Dist by NAL, Intl Copr. All rights reserved. All rts.
reserv.

01578449
Lucerne *meadow* structure. Analysis of aerial part and roots, 1: Dry
weight

1986
New methods, techniques and applications in fodder crop breeding.
Report. EUCARPIA meeting of the Fodder Crops Section, Svaloev, Sweden,
16-19 September 1985

21/K,6/114 (Item 114 from file: 203)
DIALOG(R)File 203:Dist by NAL, Intl Copr. All rights reserved. All rts.
reserv.

01578537
Lucerne *meadow* structure. Analysis of aerial part and roots, 2: Sugar
content

1986
New methods, techniques and applications in fodder crop breeding.
Report. EUCARPIA meeting of the Fodder Crops Section, Svaloev, Sweden,
16-19 September 1985

21/K,6/115 (Item 115 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0006492791 CAB Accession Number: 19920750695

Lucerne/maize crop rotations on grey *forest* soils.
Publication Year: 1990

21/K,6/116 (Item 116 from file: 10)
DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.
1952148 82006452 Holding Library: AGL

Possibility of increasing *lucerne* yield on *meadow* clay soil.
A lucernatermes novelesenek lehetosegei reti agyagtalajon
1981

21/K,6/118 (Item 118 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0005755772 CAB Accession Number: 19861907137

Legumes for improving irrigated *meadows*.
Proceedings of the Second Intermountain *Meadow* Symposium
Publication Year: 1984
... a number of species and varieties of forage legumes have been
evaluated in the mountain *meadows* of Colorado and Wyoming. Of these,
alsike clover is particularly well adapted to the wet...
... either naturally or artificially. Red clover is widely adapted and
yields as much forage as *alfalfa* during the first two or three years
following establishment. Thereafter, red clover begins to lose stand.
Alfalfa is one of the most persistent and productive legumes on better
drained sites. Cicer milkvetch....adapted as the above four species.
ADDITIONAL ABSTRACT: The use of Trifolium hybridum, T. pratense,
Medicago sativa, Lotus corniculatus, Onobrychis viciifolia, Coronilla
varia and Astragalus cicer
alone and in mixtures with grasses in the mountain *meadows* of Colorado
and Wyoming is reviewed. T. pratense was well adapted but did not persist

beyond 2-3 years. *M*. *sativa* was the most persistent and productive legume on well drained sites and A. cicer showed...

21/K,6/119 (Item 119 from file: 10)
DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.
3518991 20520706 Holding Library: AGL
Legume seeding trials in a *forested* area of north-central Washington 1995
...are site specific. Alsike clover (*Trifolium hybridum* L.), white clover (*T. repens* L.), black medic (**Medicago** *lupulina* L.), cicer milkvetch (*Astragalus cicer* L.), two varieties of birdsfoot trefoil (*Lotus corniculatus* L... *Hederma* pine lupine (*Lupinus albicaulis* Dougl.) were planted at several elevations on the Wenatchee National *Forest* in Washington state. After 2 years, alsike clover and *Hederma* pine lupine were the most...

21/K,6/121 (Item 121 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0006136895 CAB Accession Number: 19890727849
Lime requirements of *lucerne* on *forest* land in Galicia.
Original Title: Necesidades de cal en el establecimiento de alfalfa en terrenos a monte en Galicia.
Publication Year: 1986
...or 16 t lime/ha, resp. It was concluded that it is possible to grow *lucerne* as a 1st crop in *forest* land, provided that its acidity is corrected with an amount of 4-8 t lime...

21/K,6/122 (Item 122 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0005971393 CAB Accession Number: 19881923212
Long-term effects of an oil *pipeline* installation on soil productivity.
Publication Year: 1988
Crop yields and heights and soil chemical properties on and immediately adjacent to an oil *pipeline* right-of-way (ROW) were monitored over a 10-yr period. Effects of soil mixing on chemical properties were still apparent despite good crop management. With the exception of *alfalfa*, field crop yields on the ROW were reduced by an average of 28% 10 yr...

21/K,6/124 (Item 124 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0005986376 CAB Accession Number: 19880714407
Meadows of central Pyrenees: floristical composition and quality.
Publication Year: 1987
In 1985, 45 plots in *meadows* of San Juan de Plan were sampled for DM production, botanical composition and chemical composition...
... proportion of *Agrostis capillaris* and *Festuca rubra* + *Trisetum flavescens* and those in which legumes including **Medicago** *sativa* and *Trifolium* spp. were more abundant. Cultivation was least in the 1st type and...

21/K,6/126 (Item 126 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0006733963 CAB Accession Number: 19930765682
Monitoring, modelling and management of semi-natural *meadow* ecosystems in Pieniny National Park (West Carpathians).
Original Title: Monitoring, Modellierung und Management von

halbnatürlichen Wiesenökosystemen im Pieniny-Nationalpark (West-Karpaten).
Publication Year: 1991

... a current project (planned for 1986-98) on vegetation and growth characteristics of semi-natural *meadow* ecosystems in Pieniny National Park in the W. Carpathian mountains (800 m alt), Poland. In...
... *Nardus stricta*, *Danthonia decumbens* and *Luzula nemorosa*; *Anthyllis vulneraria*, *Trifolium medium*, *Trifolium montanum*, *Ononis arvensis*, **Medicago** *falcata*, *Sanguisorba minor*, *Carlina acaulis*, *Centaurea scabiosa*, *Campanula glomerata*, *Gymnadenia conopsea*, *Trautsteinera globosa*, and *Plantanthera*...

21/K,6/127 (Item 127 from file: 5)
DIALOG(R)File 5:(c) 2008 The Thomson Corporation. All rts. reserv.
07186020 BIOSIS NO.: 198477017931
MORPHOLOGICAL FEATURES OF UNDERGROUND PARTS AND THE BIOLOGICAL PRODUCTIVITY OF NATURAL *MEADOW* COMMUNITIES IN THE VALLEY OF THE SVENTOJI RIVER AND ITS TRIBUTARIES THE MUSIA RIVER AND THE SETEKSNA RIVER LITHUANIAN-SSR USSR 1982
ABSTRACT: The total phytomass weight or the biological productivity of natural *meadow* communities growing in the floodplain *meadows* and on the slopes of the Sventoji, Musia and Seteksna Rivers was determined by the...
...soil horizons and on the environment. Dominant taxa included *Koeleria grandis*, *Phleum phleoides*, *Poa angustifolia*, **Medicago** spp., *Festuca rubra*, *Helictotrichon pubescens*, *Dactylis glomerata* and *Fragaria viridis*.

21/K,6/129 (Item 129 from file: 10)
DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.
1842481 81037110 Holding Library: AGL
Methods of *alfalfa* sowing on floodplain *meadows* (Kirov Region). 1980

21/K,6/130 (Item 130 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0005621767 CAB Accession Number: 19850775094
Methods for improving mountain *meadow* communities.
Managing intermountain rangelands - improvement of range and wildlife habitats [Monsen, S.B.; Shaw, N. (Compilers)].
Publication Year: 1983
Research on mountain *meadow* improvement for livestock, wildlife and site stability is reviewed with reference to work in Nevada...
... *E. hispidus* subsp. *barbulatus*], *A. trachycaulum* [*E. trachycaulus*], *Bromus biebersteinii*, *Festuca arundinacea*, *Onobrychis viciifolia* and **Medicago** *sativa*. Excellent control of *Iris missouriensis* was given by 2.2-4.5 kg 2...dams with trees and shrubs are also discussed. Further research on
grazing management of riparian *meadow* communities in Oregon, Wyoming, Idaho and N. California is briefly reviewed.

21/K,6/131 (Item 131 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0005834189 CAB Accession Number: 19870798784
Methods of increasing yield of *meadows* in Dagestan.
Publication Year: 1985
DM yields of low-yielding *meadows* in Dagestan, N. Caucasus, were increased by applying fertilizers, cutting *Celtis caucasica* trees, burning of old vegetation, cutting *Cirsium arvense* and undersowing **Medicago**

sativa. Yields of swards harvested at the tillering, shoot elongation, heading, flowering and seed ripening...

21/K,6/134 (Item 134 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0008656840 CAB Accession Number: 20043071878

Nitrogen balance in *alfalfa* and orchard grass *meadows*.

Original Title: Bilancio dell'azoto in prati monofiti di erba medica e di erba mazzolina.

Publication Year: 2003

... the key processes in the evaluation of the advantages derived from legume forage crops. A *lucerne* *meadow*, receiving nitrogen fertilizer application only at sowing, and an orchard grass (*Dactylis glomerata*) *meadow* regularly fertilized with nitrogen, were compared in two trials carried out in the Northern Italy...

...pools of soil and plant. Dry matter production and nitrogen content were significantly higher in *lucerne* than in *D. glomerata* . Nitrogen uptake in the legume ranged from 430 to 750 kg...

... roots. Net mineralization fluxes showed a decreasing trend throughout the 3-year period in both *meadows*. In *lucerne*, nitrogen in soil organic matter pool decreased during the first year. The reduction ranged between...

...the 3-year period ranged from 226 to 306 kg N/ha. In *D. glomerata* *meadow* the final accumulation of nitrogen in the soil organic matter was positive but insignificant, ranging...

21/K,6/138 (Item 138 from file: 203)

DIALOG(R)File 203:Dist by NAL, Intl Copr. All rights reserved. All rts. reserv.

02382937

1998

[Interspecific hybridization in creating the new *lucerne* varieties for conditions of the Ukraine's Polissya (*Forest* Zone)] (Mezhvidovaya gibridizatsiya v sozdanii novykh sortov lutserny dlya usloviy Poles'ya Ukrainy)

21/K,6/140 (Item 140 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0008922958 CAB Accession Number: 20053180510

The occurrence of legumes in *meadow* communities of the Por River valley.

Book Title: Optimal forage systems for animal production and the environment. Proceedings of the 12th Symposium of the European Grassland Federation, Pleven, Bulgaria, 26-28 May 2003

Publication Year: 2003

On the basis of 560 relevés taken on the semi-natural *meadows* in the Por River valley (in the south-east of Poland) 30 plant communities were

...
...found. The most frequently occurring were *Trifolium pratense* , *T. repens* , *T. hybridum* , *T. dubium* and **Medicago** *lupulina* , found in 10-13 communities, while the poorest were *Trifolium arvense* and *T. aureum*...

21/K,6/143 (Item 143 from file: 76)

DIALOG(R)File 76:(c) 2008 CSA. All rts. reserv.

0000933284 IP ACCESSION NO: 3600610

Study on use of alien versus native plants by nectarivorous *forest* birds on Maui, Hawaii

PUBLICATION DATE: 1993

ABSTRACT:... sources for the Hawaiian honeycreepers, there are other locally significant sources including "the introduced tree *alfalfa* Cytisus proliferus [C. palmensis] growing in certain upland pastures on Maui and to which Vestiaria....come in large numbers to feed." Several trees occurring near the upper limit of rain *forest* in Waikamoi Preserve have attracted management attention because of visitation by native *forest* birds. This study was undertaken to assess the nectar-foraging pattern of native and alien *forest* birds on Cytisus and selected native plants in the Waikamoi Preserve. The study site was...

21/K,6/144 (Item 144 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0005165459 CAB Accession Number: 19810730071

On optimum rates of fertilizers for some perennial herbage species and their mixtures grown on grey *forest* soils.

Publication Year: 1980

In trials in 1972-5 on grey *forest* soil with several herbage spp. given combinations of various rates of N, P and K, the opt. fertilizer (N + P2O5 + K2O) rates were 80 + 63 + 130 kg/ha for *lucerne* grown with lime application to soil, 108 + 94 + 145 kg/ha for Lotus corniculatus, 170...

21/K,6/146 (Item 146 from file: 10)

DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.

2003766 82048671 Holding Library: AGL

Correlation between the yield of *lucerne* and moisture-content of soil layer of 0-100 cm on *meadow* Solonetz.

Osszefugges a lucerna termese es a 0-100 cm talajreteg nedvessegtartalma kozott reti szolonyecen

1980

21/K,6/147 (Item 147 from file: 203)

DIALOG(R)File 203:Dist by NAL, Intl Copr. All rights reserved. All rts. reserv.

00879846

Problems involved in modelling tree growth [TEEM, Terrestrial Ecosystem Energy Model, SIMED, Simulation of *Medicago* Growth, SDF, Simulating a Deciduous *Forest*, PT, Production Tree, CERES]

1981

Understanding and predicting tree growth

21/K,6/149 (Item 149 from file: 10)

DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.

2575158 86048642 Holding Library: AGL

Productivity of *alfalfa* , red clover and their mixtures with Bromus inermis on drained lands of the central *forest* steppe

1985

21/K,6/152 (Item 152 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0009206656 CAB Accession Number: 20073021900

Performance of *fences* on the protection of *alfalfa* grown at Siwa aeolian sand.

Publication Year: 2006

... Farm in western desert of Egypt during 2004 to 2005 to study the performance of *fences* and to determine the best distance for the optimum protection of *lucerne*. *Fences* of single and double rows of palm leaves were investigated as well as their distance from the *lucerne* fields (10, 20, 30 and 40 m). Sand collectors were used for monitoring the quantity and shifting sand in front and behind the *fences*. The combination of double rows *fence* and distances of 10 and 20 m recorded superior growth characters and yield of *lucerne* (i.e., plant height, number of branches per plant, total, fresh and dry weight per...
 ... percentage, and green and dry forage yield), while the best protection was observed with the *fence* of double rows and a distance of 20 m. This treatment decreased wind speed and trapped most of sand drift. The efficiency of *fences* on sand accumulation was 43.8 and 54.2% for single and double *fences*, respectively. The efficiency of distances was 43.8, 43.7, 28.1 and 22.7...
 ... 40 m, respectively. Regarding the interaction efficiency, it was revealed that the treatments of double *fence* with 10 or 20 m distance gave the highest records of sand accumulation efficiency being...

21/K,6/153 (Item 153 from file: 50)
 DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
 0006545759 CAB Accession Number: 19920754154

The performance of several legume species on mine tailings in the Naseby *Forest*.

Publication Year: 1989

Lotus pedunculatus [L. uliginosus] cv. Maku, L. corniculatus cv. Tana and *Medicago* sativa cv. WL318 were inoculated with the recommended Rhizobium strain and oversown on mine tailings on an open site in the Naseby *Forest*, New Zealand between 1983 and 1987, and 0, 10, 20 or 40 kg P/ha...

21/K,6/155 (Item 155 from file: 50)
 DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
 0005027575 CAB Accession Number: 19800712421

Perennial herbage species for *meadows* on solonetz soils.

Publication Year: 1980

In trials with several herbage spp. sown on chernozem *meadow* solonetz chalk soils at 3 locations in Poltava region of the Ukraine, Melilotus alba, brome grass, *meadow* fescue and Arrhenatherum elatius gave the highest fresh fodder yields; *lucerne*, red clover, sainfoin hybrid, Lotus corniculatus, Agropyron trachycaulum and A. imbricatum gave lower yields.

21/K,6/160 (Item 160 from file: 50)
 DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
 0008671405 CAB Accession Number: 20043052195

Recultivation of natural *meadows*.

Publication Year: 2001

North-East Siberia and the territory of Baykal-Amur *Railroad*, Russia suffer ever-increasing adverse impact on natural and cultivated landscapes from mining, gold mining... Such lands represent a reserve for expanding agricultural fields. Recultivation of floodland damaged (drag dikes) *meadows* was studied in 1991-94 in Tynda district, Amur region, Russia. Plots were set up on

meadow -swamp permafrost soil. Drag dikes were flattened using a C-100 bulldozer, a fertile layer... SibNIIKhoz 189 (20 kg seeds/ha), Elymus sibiricus Guran 25, Festuca pratensis cv. Priangarskaya 10, *Medicago*

sativa cv. Onkhoiskaya 10 and Melilotus alba Sayanskii (all 12 kg seeds/ha) were sown...

... on productivity in fresh and dry weight are tabulated. The best results were obtained using *Medicago* sativa both in control and fertilizer input treatments (2.11 t/ha of dry weight...

...fertile soil layer was introduced. The species tested were the same with the exception of *M*. *sativa* which was not used. The best results were obtained using B. inermis (0.56 t...

21/K,6/161 (Item 161 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0005435949 CAB Accession Number: 19841396723

Reaction of *lucerne* varieties to Fusarium wilt under grey *forest* soil conditions.

Publication Year: 1983

21/K,6/162 (Item 162 from file: 41)

DIALOG(R)File 41:(c) 2008 CSA. All rts. reserv.

0000022687 IP ACCESSION NO: 335832

Recovery of productivity of Ontario soils disturbed by an oil *pipeline* installation.

PUBLICATION DATE: 1982

ABSTRACT:... of soil properties and field-crop yields on cropland traversed by the

Sarnia-Montreal oil *pipeline* indicated that *pipeline* installation detrimentally affected both crop yields and soil physical-chemical properties in the first year...

...5 yr, relative yields improved although reductions still persisted at most row-cropped sites. However, *alfalfa* yields at two sites appeared to be unaffected by *pipeline* construction. Soil mixing and compaction on the right-of-way were most prevalent on medium...

21/K,6/169 (Item 169 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0006216064 CAB Accession Number: 19900640302

Restoring productivity on degraded *forest* soils: two case studies.

Publication Year: 1987

...in 1981 at 40 kg/ha with a legume mixture of 3 spp. of Trifolium, *Medicago* sativa and L. corniculatus, and received NPK (19:19:19) at 300 kg/ha. Nutrient...enhancement of site nutrient capital is considered to be a gain likely to benefit commercial *forestry* production.

21/K,6/170 (Item 170 from file: 203)

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01314351

Successful *alfalfa* grass production with *meadow* fescue (Erfolgreicher Luzernegrasbau mit Wiesenschweidel)

1988

21/K,6/173 (Item 173 from file: 10)

DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.

3018170 90044268 Holding Library: AGL

Seeding techniques for *alfalfa* to improve subirrigated *meadows*

1984

21/K,6/174 (Item 174 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0005312115 CAB Accession Number: 19830747729
Sodseeding of Wyoming hay *meadows*.
Publication Year: 1981
Improvement of hay *meadows* was examined in relation to the
determination of suitable spp. for intersowing, opt. sowing date...

...Melroe grass seeder. The most suitable spp. were Alopecurus arundinaceus
cv. Garrison, tallfescue cv. Fawn, *lucerne* cv. Phytor and alsike clover.
Late May was the opt. sowing date with glyphosate applied...

21/K,6/175 (Item 175 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0007429696 CAB Accession Number: 19971910980
Safe nitrogen in sowing grass in fields and *meadows*.
Publication Year: 1996
... effectiveness of twelve different rates and mixtures of legumes,
legumes/grasses, and grasses (clover [Trifolium], *lucerne* [*Medicago*
sativa], timothy [Phleum pratense]) used in a 9-year cropping rotation
system, and also on the effectiveness of 8 different N fertilizer regimes
on perennial grasses in an irrigated floodplain *meadow* . Data are
tabulated on yields of oven-dry matter and digestible protein,
exchangeable energy, energy...

21/K,6/176 (Item 176 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0009566157 CAB Accession Number: 20083138319
Selection of suitable *wild* species for *highway* side slopes in
Heilongjiang Province.
Publication Year: 2008
... indexes were selected by the analytic hierarchy process aiming at
getting the suitable plants for *highway* side slopes. Some important
indexes, including root density, growth rate, barren resistance,
drought-resistance, root...
... utilization, were used to evaluate 21 herbaceous plants grown on the
side slopes of seven *highways* in Heilongjiang Province. Result shows
that Poa pratensis , Agropyron cristatum , *Medicago* falcate , Bromus
inermis , Silene jennisensis , Oenothera biennis , Iris lactea var.
chinensis , Viola alisoviana , Elytrigia repens...
... Plantago depressa are excellent species, which can be used as the
suitable pioneer plants for *highway* side slopes in cold regions.

21/K,6/179 (Item 179 from file: 10)
DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.
4498642 43832835 Holding Library: AGL
A survey of Lygus spp. occurring in cotton, *alfalfa*, and *roadside*
weeds in the northern Texas Rolling Plains
2006
DESCRIPTORS: ...*alfalfa*;*Medicago* sativa.....*roadside* plants;

21/K,6/180 (Item 180 from file: 203)
DIALOG(R)File 203:Dist by NAL, Intl Copr. All rights reserved. All rts.
reserv.
01330714
The use of stable N isotope for the determination of the effectiveness
of nitrogenous fertilizers for *alfalfa* Experiments on *meadow* chernozem
soils (Ispol'zovanie stabil'nogo izotopa N pri opredelenii ehffektivnosti

dejstviya azotnykh udobrenij pod lyutsernu)

1987

Increased soil fertility in West Siberia (Povyshenie plodorodiya pochv Zapadnoj Sibiri)

...use of stable N isotope for the determination of the effectiveness of nitrogenous fertilizers for *alfalfa* Experiments on *meadow* chernozem soils

21/K,6/181 (Item 181 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0007525860 CAB Accession Number: 19980704548

Structural specificities of *Medicago* sativa L. agrophytocoenosis on open cut spoil banks in the *forest*-steppe zone of Kusbas.

Publication Year: 1997

21/K,6/184 (Item 184 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0006131901 CAB Accession Number: 19890727254

Seasonal dynamics of vegetation in natural *meadows* in the Fausola mountains (Latium Appenines).

Original Title: Dinamismo stagionale della vegetazione nei prato-pascoli naturali del monte fausola (Appennino Laziale).

Publication Year: 1986 publ. 1988

Changes in botanical composition of native *meadows* which had developed on formerly arable land, were studied at 4 sites in the Fausola...

... *Poa pratensis*, *Festuca centro-appenninica*, *Lotus corniculatus*, *T. campestre*, *Poa alpina*, *Astragalus depressus*, *T. nigrescens*, **Medicago** *lupulina*, *T. striatum*, *Luzula campestris*, *Bromus erectus* and *T. arvense*. It was concluded that 20...

21/K,6/185 (Item 185 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.

0007963790 CAB Accession Number: 20000712641

Techniques for afforesting side slopes of Taiyuan-Jiuguan Express *Highway* in Shanxi.

Publication Year: 1999

... 1996-97 on the techniques for revegetating the side slopes of the Taiyuan-Jiuguan Express *Highway* in Shanxi, China, 7 species of plants were tested alone or in combinations. The species were *Astragalus adsurgens*, **Medicago** *sativa*, *Onobrychis viciaefolia* [*O. viciifolia*], *Bromus inermis*, *Festuca arundinacea*, *Lespedeza bicolor* and *Lotus corniculatus*. The first 5 species in combinations of 3-4 species were most suitable, such as *M*. *sativa* (30%) + *A. adsurgens* (30%) + *B. inermis* (40%), *M*. *sativa* (30%) + *O. viciae* (30%) + *B. inermis* (40%), *A. adsurgens* (25%) + *M*. *sativa* (25%) + *Lespedeza bicolor* (10%) + *F. arundinacea* (40%), and *M*. *sativa* (20%) + *O. viciaefolia* (20%) + *A. adsurgens* (20%) + *L. corniculatus* (10%) + *B. inermis* (30%). The optimum...

21/K,6/189 (Item 189 from file: 6)

DIALOG(R)File 6:(c) 2008 NTIS, Intl Cpyrght All Rights Res. All rts. reserv.

0854505 NTIS Accession Number: PB81-104036/XAB

Time Responses and the Susceptibility of *Roadside* Plants to Growth Regulation (Final rept. 1975-79)

1980

... *Euphorbia esula* L., leafy spurge; and *Taraxacum officinale* Weber,

common dandelion. Two were desirable as *roadside* ground cover: *Medicago* sativa L., *alfalfa*, and *Trifolium pratense* L., red clover. Methods were developed for germinating weed seeds, a process...

21/K,6/192 (Item 192 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0006612042 CAB Accession Number: 19920662634

Utilization of natural vegetation by red deer in deer *forests* from the view-point of damage to *forest* stands.

Original Title: *Moynosti vyuzitia prirodzenych vegetacnych zdrojov jelenov zverou v jelenich chovatel'skych oblastiach z hl'adiska skod nou sposobenych.*

Publication Year: 1989

A study was made of red deer [*Cervus elaphus*] browsing and damage in *forests* in Slovakia, Czechoslovakia. Protection of *forest* trees in Slovakia from 1985 to 1986 cost Kcs 33 129 298. Direct damage is...
... by red deer in fir/beech (*Abies* / *Fagus*) and spruce/beech/fir (*Picea* / *Fagus* / *Abies*) *forests* were studied. Red deer fed on about 50 herbaceous species and 16 species of trees...
... content, minerals and beta-carotene. The results were compared with analyses of agricultural forage crops (*meadow* grassland, pasture, red clover [*Trifolium pratense*] and *lucerne* [*Medicago* sativa]). Many of the *forest* species contained more nutrients than the crops. [With English captions.].

21/K,6/193 (Item 193 from file: 10)
DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.
4894825 44029773 Holding Library: AGL

Vole-feeding damage and *forest* plantation protection: Large-scale application of diversionary food to reduce damage to newly planted trees
2008

URL: <http://dx.doi.org/10.1016/j.cropro.2007.11.003>

Forest and agricultural crops periodically experience feeding damage from herbivorous rodents such as voles of the...

...B, C, and D) were conducted with long-tailed vole (*Microtus longicaudus*) populations in new *forest* plantations of lodgepole pine (*Pinus contorta*), Douglas-fir (*Pseudotsuga menziesii*), and interior spruce (*Picea glauca*x*Picea*...2003 to 2007. Diversionary food Ta pucksTa were composed of Douglas-fir

bark mulch and *alfalfa* (*Medicago* sylvatica) pellets/meal mixed with canola (*Brassica rapa*) oil and wax. Mean percentage (+SE) survival...

21/K,6/203 (Item 203 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0005740182 CAB Accession Number: 19860701721

Yield increase in temporary *meadows* under the effect of fertilization and structure of the species mixture.

Original Title: *Sporirea productiei pajistilor temporare sub influenta fertilizarii si structurii amestecurilor de specii.*

Publication Year: 1983

... grasses and perennial legumes and the most efficient dose of N fertilizer to create temporary *meadows* on leached chernozem soil in the *forested* steppes of Moldova. The best results were obtained with seed mixtures of 20 kg *Bromus inermis* + 15 kg *Medicago* sativa /ha and with 10 kg *Dactylis glomerata* + 15 kg *B. inermis* + 2 kg *Agropyron*...

26/K,6/3 (Item 3 from file: 50)

DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0006294760 CAB Accession Number: 19900398877
Influence of high salt levels on the germination and growth of five
potentially utilizable plants for median turfing in northern climates.
Publication Year: 1988
... levels. The effects of salinity on the germination and growth of
Coronilla varia, Lotus corniculatus, *Medicago* lupulina, Kochia scoparia
and Polygonum aviculare were studied. Seed germination was not affected
within the...
...DESCRIPTORS: *roadsides*; ...ORGANISM DESCRIPTORS: *Medicago* lupulina
...BROADER TERMS: *Medicago*;

26/K,6/4 (Item 4 from file: 5)
DIALOG(R)File 5:(c) 2008 The Thomson Corporation. All rts. reserv.
17952282 BIOSIS NO.: 200400323042
Factors controlling vegetation establishment and water erosion on motorway
slopes in Valencia, Spain
2004
...ABSTRACT: semiarid Mediterranean areas, the widespread environmental
impact caused by the construction of motorways, railways, and *pipelines*
has created an increasing need for effective restoration. We examined the
influence of slope characteristics...
...dominant species associated with each slope type and aspect should
improve considerably the success of *roadside* revegetation.

...ORGANISMS: *Medicago* sativa (Leguminosae

26/K,6/7 (Item 7 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0007814573 CAB Accession Number: 19990710798
Leguminous plants in swards on steep road cuttings.
Original Title: Rosliny motylkowate w runi poboczy drog.
Publication Year: 1999
... 30.34% other dicots. The most suitable plants for sward formation on
road shoulders were *Medicago* falcata , M. lupulina , Trifolium repens ,
Melilotus albus , Arrhenatherum elatius , Agropyron repens [Elymus repens
], Festuca rubra...
...DESCRIPTORS: *roadside* plants.....*roadsides*IDENTIFIERS: *highways*;
...
...*Medicago* sativa subsp. falcata...*Medicago* falcata.....*Medicago*
lupulina

26/K,6/8 (Item 8 from file: 10)
DIALOG(R)File 10:(c) format only 2008 Dialog. All rts. reserv.
2769987 87106544 Holding Library: AGL
Long-term effects of an oil *pipeline* installation on soil productivity
1988 Feb
DESCRIPTORS: zea mays; glycine max; *medicago* sativa; soil fertility
; soil chemistry; crop yield; *pipelines*; soil degradation; soil
chemistry;

26/K,6/9 (Item 9 from file: 5)
DIALOG(R)File 5:(c) 2008 The Thomson Corporation. All rts. reserv.

12678881 BIOSIS NO.: 199598146714

Manganese accumulation in *roadside* soil and plants
1994

...ORGANISMS: *Medicago* sativa (Leguminosae)

26/K,6/10 (Item 10 from file: 41)
DIALOG(R)File 41:(c) 2008 CSA. All rts. reserv.
0000287078 IP ACCESSION NO: 7174168
Metabolic and cometabolic degradation of herbicides in the fine material of
railway ballast
PUBLICATION DATE: 2007
ABSTRACT:... these were only detectably degraded in the sample with the
highest
SIR. Addition of ground *lucerne* straw to the ballast samples stimulated
microbial activity and led to increased formation of metabolites...
DESCRIPTORS: Biochemistry; Biodegradation; Biomass; Herbicides;
Kinetics; Metabolites; Microbial activity; Mineralization; Nitrogen;
Organic matter; *Railroads*; Respiration; Soil; diuron; weed control
; ISE, Pacific, New Zealand Island Terr., Niue I., Alofi, Sir

26/K,6/12 (Item 12 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0009511400 CAB Accession Number: 20083023741
Study on techniques for comprehensive improvement of degraded grasslands
in Xilamuren, Nei Menggu.
Publication Year: 2007
... degraded grasslands in Xilamuren, Nei Menggu, China. The main
measures adopted were fencing, resowing of *lucerne* + Astragalus +
Melilotus at a ratio of 1:1:1, harrowing, planting of Caragana korshinskii,
Hippophae...
...DESCRIPTORS: *fences*;*lucerne*; IDENTIFIERS: *alfalfa*;
...ORGANISM DESCRIPTORS: *Medicago*;*Medicago* sativa

26/K,6/18 (Item 18 from file: 50)
DIALOG(R)File 50:(c) 2008 CAB International. All rts. reserv.
0009050850 CAB Accession Number: 20063098828
Is seed availability enough to ensure colonization success? An
experimental study in road embankments.
Publication Year: 2006

...IDENTIFIERS: *highways*;
...ORGANISM DESCRIPTORS: *Medicago* minima.....*Medicago* orbicularis
...BROADER TERMS: *Medicago*;

26/K,6/19 (Item 19 from file: 143)
DIALOG(R)File 143:(c) 2008 The HW Wilson Co. All rts. reserv.
1929257 H.W. WILSON RECORD NUMBER: BBAI06118011
Soil water and *alfalfa* yields as affected by alternating ridges and
furrows in rainfall harvest in a semiarid environment
20060601
DESCRIPTORS: *Alfalfa*--.....Irrigation canals and *ditches*;

26/K,6/21 (Item 21 from file: 5)
DIALOG(R)File 5:(c) 2008 The Thomson Corporation. All rts. reserv.
18177930 BIOSIS NO.: 200500084995

Site description and ecological characteristics of higher plants on the abandoned goods railway station Wien Nord (Vienna, Austria).

ORIGINAL LANGUAGE TITLE: Der stillgelegte Frachtenbahnhof Wien-Nord Standortbedingungen und oekologische Charakteristik der Gefaesspflanzen einer Bahnbrache.

2002

...ABSTRACT: Ailanthus altissima dominating in the railtrack ballast. Erysimum diffusum, Gypsophila scorzonifolia, Hieracium echinoides, Holosteum umbellatum, *Medicago* minima, Petrorhagia prolifera, Rosa corymbifera and the mosses Tortula canescens, Ceratodon conicus and Didymodon rigidulus...

MISCELLANEOUS TERMS: ...urban *wasteland*

ADDITIONAL MORE GENERAL TITLES

40/6/2 (Item 2 from file: 50)
0007856926 CAB Accession Number: 20000504012
About species abundances approximation. 1. *Wild* bees (Hymenoptera, Apoidea) on *alfalfa*.
Proceedings of the International Colloquia on Social Insects: Volume 3-4.
Publication Year: 1997

40/6/9 (Item 9 from file: 50)
0005260619 CAB Accession Number: 19830747136
Adaptation and utilization of three legumes in China.
Proceedings of the XIV International Grassland Congress, held at Lexington, Kentucky, USA, June 15-24, 1981 [Smith, J.A.; Hays, V.W. (Editors)].
Publication Year: 1983

40/6/12 (Item 12 from file: 50)
0008642355 CAB Accession Number: 20043084998
Alfalfa black aphid, Aphis craccivora Koch (Hom.: Aphididae) stage preferences by Lysiphlebus fabarum Marshall (Hym.: Aphididae).
Publication Year: 2004

40/6/13 (Item 13 from file: 10)
3080193 91020637 Holding Library: AGL
Alfalfa controls nodulation during the onset of Rhizobium-induced cortical cell division
1991 Feb

40/6/16 (Item 16 from file: 10)
3073805 91017771 Holding Library: AGL
Alfalfa mosaic virus RNA3 mutants do not replicate in transgenic plants expressing RNA3-specific genes
1991 Feb

40/6/17 (Item 17 from file: 5)
08760677 BIOSIS NO.: 198784114826
ALFALFA MOSAIC VIRUS TEMPERATURE-SENSITIVE MUTANTS IV. TBTS 7 A COAT PROTEIN MUTANT DEFECTIVE IN AN EARLY FUNCTION
1987

40/6/18 (Item 18 from file: 5)
06652720 BIOSIS NO.: 198274069143
ALFALFA POLLINATING BEES HYMENOPTERA APOIDEA IN THE REGION OF PLEVEN
BULGARIA 1. SPECIES COMPOSITION AND NUMBERS
1981

40/6/22 (Item 22 from file: 5)
16545468 BIOSIS NO.: 200200138979
Analysis of gene expression during flowering in apomeiotic mutants of
Medicago spp.: Cloning of ESTs and candidate genes for 2n eggs
2001

40/6/37 (Item 37 from file: 266)
00570924
IDENTIFYING NO.: 0203095 AGENCY CODE: AGRIC
Assessing RNAi as a Reverse Genetic Tool for Global Analysis of NBS-LRR
Gene Function in *Medicago* Truncatula

40/6/59 (Item 59 from file: 24)
0001646391 IP ACCESSION NO: 3951739
A cDNA encoding a PR-1-like protein in the model legume *Medicago* truncatula
PUBLICATION DATE: 1995

40/6/60 (Item 60 from file: 10)
4545566 43858228 Holding Library: AGL
A CDPK isoform participates in the regulation of nodule number in
Medicago truncatula
2006
URL: <http://dx.doi.org/10.1111/j.1365-313X.2006.02910.x>

40/6/63 (Item 63 from file: 76)
0000557399 IP ACCESSION NO: 1892518
Characterization and culture of Agrobacterium rhizogenes transformed roots
of forage legumes.
PUBLICATION DATE: 1988

40/6/65 (Item 65 from file: 266)
00577069
IDENTIFYING NO.: 0210647 AGENCY CODE: AGRIC
Characterization of the effect of light signaling on the formation of
nitrogen-fixing nodules in *Medicago* truncatula and Pisum sativum.

40/6/71 (Item 71 from file: 5)
18033457 BIOSIS NO.: 200400404246
Characterisation of *wild* legume nodulating bacteria (LNB) in the
infra-arid zone of Tunisia
2003

40/6/72 (Item 72 from file: 5)
17185621 BIOSIS NO.: 200300144340
Characterization of zinc inefficient mutants in *Medicago* truncatula.
1999

40/6/74 (Item 74 from file: 10)
3986824 23267410 Holding Library: AGL
Chronic intracellular infection of *alfalfa* nodules by Sinorhizobium
meliloti requires correct lipopolysaccharide core

2002

40/6/78 (Item 78 from file: 5)
12074172 BIOSIS NO.: 199497095457
Complementation and disruption of viral processes in transgenic plants
1993

40/6/79 (Item 79 from file: 5)
10836589 BIOSIS NO.: 199192082360
COMPLEX SYMBIOTIC PHENOTYPES RESULT FROM GLUCONEOGENIC MUTATIONS IN
RHIZOBIUM-MELILOTI
1991

40/6/82 (Item 82 from file: 5)
08160980 BIOSIS NO.: 198682007367
COMPARATIVE ANALYSIS OF THE NITROGEN-FIXING ACTIVITY AND PLASMID
COMPOSITION OF RHIZOBIUM TRANSCONJUGANTS IN THE INTRODUCTION OF THE PRD-1
PLASMID
1985

40/6/85 (Item 85 from file: 10)
2724383 87074478 Holding Library: AGL
Competitive effects of *wild* barley in seedling *alfalfa*
1986

40/6/88 (Item 88 from file: 50)
0007255631 CAB Accession Number: 19960708746
The capability of *wild* species of *Medicago* L. and *Melilotus officinalis* (L.) Pall., widespread in Dagestan, for symbiosis with *Rhizobium meliloti* .
Publication Year: 1995

40/6/89 (Item 89 from file: 5)
17601722 BIOSIS NO.: 200300558153
Coordinate replication of *alfalfa* mosaic virus RNAs 1 and 2 involves cis-
and trans-acting functions of the encoded helicase-like and polymerase-like
domains.
2003

40/6/90 (Item 90 from file: 10)
3022094 90039237 Holding Library: AGL
Correlation between ultrastructural differentiation of bacterioids and
nitrogen fixation in *alfalfa* nodules
1990 Aug

40/6/91 (Item 91 from file: 5)
11898444 BIOSIS NO.: 199396062860
Creation of *Rhizobium meliloti*
1992

40/6/95 (Item 95 from file: 10)
4072174 23333763 Holding Library: AGL
Calcium oxalate crystal morphology mutants from *Medicago* *truncatula*
2002

40/6/109 (Item 109 from file: 10)
2936192 89051975 Holding Library: AGL

Differential histone acetylation in *alfalfa* (*Medicago* sativa) due to growth in NaCl: responses in salt stressed and salt tolerant callus cultures

1989 May

40/6/112 (Item 112 from file: 5)
17253793 BIOSIS NO.: 200300212512
Dual genetic pathways controlling nodule number in *Medicago* truncatula.
2003

40/6/117 (Item 117 from file: 5)
19050976 BIOSIS NO.: 200600396371
Domestication history in the *Medicago* sativa species complex: inferences from nuclear sequence polymorphism
2006

40/6/121 (Item 121 from file: 5)
08622370 BIOSIS NO.: 198783101261
DETECTION OF NODULE-SPECIFIC POLYPEPTIDES FROM EFFECTIVE AND INEFFECTIVE ROOT NODULES OF *MEDICAGO*-SATIVA L
1986

40/6/126 (Item 126 from file: 50)
0005794366 CAB Accession Number: 19870795877
Distribution of triterpene glycosides in legumes of the flora of the Crimea.
Publication Year: 1985

40/6/128 (Item 128 from file: 10)
2804345 88906026 Holding Library: AGL
Ecology and geography of certain *wild* *alfalfa* species in Central Asia = K ekologii i geografii nekotorykh dikorastushchikh vidov liutsern v Srednei Azii / O.Kh. Khasanov and E. Abdullazhanov
K ekologii i geografii nekotorykh dikorastushchikh vidov liutsern v Srednei Azii
1987

40/6/129 (Item 129 from file: 5)
17320385 BIOSIS NO.: 200300274918
Influence of the calcium oxalate defective 4 (cod4) mutation on the growth, oxalate content, and calcium content of *Medicago* truncatula.
2003

40/6/136 (Item 136 from file: 76)
0001414612 IP ACCESSION NO: 4773871
The Effect of a Genetically Modified Rhizobium meliloti Inoculant on Fungal Alkaline Phosphatase and Succinate Dehydrogenase Activities in Mycorrhizal *Alfalfa* Plants as Affected by the Water Status in Soil
PUBLICATION DATE: 2000

40/6/144 (Item 144 from file: 50)
0006533940 CAB Accession Number: 19920231619
Effect of the population density of *wild* bees (Apoidea) on the percentage of pollination of *lucerne* flowers.
Publication Year: 1990

40/6/146 (Item 146 from file: 10)
4058412 23321154 Holding Library: AGL
Influence of arbuscular mycorrhizae and a genetically modified strain of Sinorhizobium on growth, nitrate reductase activity and protein content in shoots and roots of *Medicago* sativa as affected by nitrogen concentrations
2002

40/6/147 (Item 147 from file: 50)
0006828534 CAB Accession Number: 19940200392
Effect of relative air humidity on the flight of *wild* bees (Apoidea), pollinators of *lucerne*.
Publication Year: 1992

40/6/150 (Item 150 from file: 50)
0006828533 CAB Accession Number: 19940200391
Effect of air temperature on the flight dynamics of *wild* bees (Apoidea), pollinators of *lucerne*.
Publication Year: 1992

40/6/153 (Item 153 from file: 10)
4242730 43677704 Holding Library: AGL
Effect of zinc and manganese supply on the activities of superoxide dismutase and carbonic anhydrase in *Medicago* truncatula *wild* type and raz mutant plants
2005

40/6/159 (Item 159 from file: 5)
09223391 BIOSIS NO.: 198886063312
ENHANCED NODULE INITIATION ON *ALFALFA* BY *WILD*-TYPE RHIZOBIUM-MELILOTI CO-INOCULATED WITH NOD GENE MUTANTS AND OTHER BACTERIA
1988

40/6/163 (Item 163 from file: 5)
15921514 BIOSIS NO.: 200100093353
Early symbiotic responses induced by Sinorhizobium meliloti ilvC mutants in *alfalfa*
2001

40/6/171 (Item 171 from file: 5)
18919523 BIOSIS NO.: 200600264918
Evolutionary responses of native plants to novel community members
2006

40/6/172 (Item 172 from file: 10)
3193417 92042870 Holding Library: AGL
Exogenous suppression of the symbiotic deficiencies of Rhizobium meliloti exo mutants
1992 May

40/6/173 (Item 173 from file: 5)
08053274 BIOSIS NO.: 198681017165
EXOPOLYSACCHARIDE-DEFICIENT MUTANTS OF RHIZOBIUM-MELILOTI THAT FORM INEFFECTIVE NODULES
1985

40/6/176 (Item 176 from file: 10)

3548594 20543500 Holding Library: AGL
 An experimental test of the rhizopine concept in *Rhizobium meliloti*
 1996 Nov

40/6/177 (Item 177 from file: 24)
 0002746357 IP ACCESSION NO: 6474024
 Expression of the **Medicago** *truncatula* DMI2 Gene Suggests Roles of the
 Symbiotic Nodulation Receptor Kinase in Nodules and During Early Nodule
 Development
 PUBLICATION DATE: 2005

40/6/179 (Item 179 from file: 144)
 16929646 PASCAL No.: 04-0594176
 Expression profiling in **Medicago** *truncatula* identifies more than 750
 genes differentially expressed during modulation, including many potential
 regulators of the symbiotic program
 2004

40/6/184 (Item 184 from file: 50)
 0006743209 CAB Accession Number: 19931981291
 Expression of *Serratia marcescens* chitinase gene in *Rhizobium meliloti*
 during symbiosis on *alfalfa* roots.
 Publication Year: 1993

40/6/188 (Item 188 from file: 5)
 0020193387 BIOSIS NO.: 200800240326
 Factors affecting pesticides hazard to different kinds of pollinators
 2007

40/6/189 (Item 189 from file: 76)
 0000556691 IP ACCESSION NO: 1885342
 Feedback regulation of nodule formation in *alfalfa*.
 PUBLICATION DATE: 1988

40/6/190 (Item 190 from file: 5)
 16581405 BIOSIS NO.: 200200174916
 A *fadD* mutant of *Sinorhizobium meliloti* shows multicellular swarming
 migration and is impaired in nodulation efficiency on *alfalfa* roots
 2002

40/6/194 (Item 194 from file: 144)
 16009899 PASCAL No.: 03-0155418
 Floral development of the model legume **Medicago** *truncatula*: ontogeny
 studies as a tool to better characterize homeotic mutations
 2003

40/6/197 (Item 197 from file: 203)
 02573726
 Flow cytometric analysis in diploid **Medicago** species from Algeria:
 Relationship between genome size and competence for direct somatic embryo
 formation
 2003

40/6/201 (Item 201 from file: 50)
 0008932988 CAB Accession Number: 20053185225
 Does fundamental host range match ecological host range? A retrospective
 case study of a *Lygus* plant bug parasitoid.

Publication Year: 2005

- 40/6/202 (Item 202 from file: 5)
16606354 BIOSIS NO.: 200200199865
Phenotypic selection and phase variation occur during *alfalfa* root
colonization by *Pseudomonas fluorescens* F113
2002
- 40/6/206 (Item 206 from file: 5)
17786673 BIOSIS NO.: 200400153334
Phytohormonal responses in enod40-overexpressing plants of *Medicago*
truncatula and rice.
2004
- 40/6/210 (Item 210 from file: 10)
4718088 43963102 Holding Library: AGL
Glucosylceramide synthase is essential for *alfalfa* defensin-mediated
growth inhibition but not for pathogenicity of *Fusarium graminearum*
2007
URL: <http://dx.doi.org/10.1111/j.1365-2958.2007.05955.x>
- 40/6/213 (Item 213 from file: 5)
06289904 BIOSIS NO.: 198172023855
A GENERAL METHOD FOR SITE DIRECTED MUTAGENESIS IN PROKARYOTES
1981
- 40/6/228 (Item 228 from file: 10)
3190252 92039234 Holding Library: AGL
Growth and movement of spot inoculated *Rhizobium meliloti* on the root
surface of *alfalfa*
1992 Mar
- 40/6/231 (Item 231 from file: 76)
0001197404 IP ACCESSION NO: 4207650
Growth and nodulation competitiveness of *Sinorhizobium meliloti* L1 (RecA
super(-)) is less than that of its isogenic strain L33 (RecA super(+)) but
comparable to that of two *S. meliloti* *wild*-type isolates
PUBLICATION DATE: 1997
- 40/6/232 (Item 232 from file: 203)
02169992
Guizhou natural legume herbage-Introduction and domestication of
Medicago lupulina
1996
- 40/6/239 (Item 239 from file: 144)
05198276 PASCAL No.: 83-0464519
Herbicides applied to Dodder (*Cuscuta* spp.) after attachment to *alfalfa*
(*Medicago* sativa)
1983
- 40/6/242 (Item 242 from file: 50)
0005078868 CAB Accession Number: 19801958815
Histological comparisons of plant and *Rhizobium* induced ineffective
nodules in *alfalfa*.
Publication Year: 1980

40/6/243 (Item 243 from file: 76)
0000637523 IP ACCESSION NO: 2263066
Host-specificity mutants of *Rhizobium meliloti* have additive effects in situ on initiation of *alfalfa* nodules.
PUBLICATION DATE: 1990

40/6/254 (Item 254 from file: 50)
0008808723 CAB Accession Number: 20053057348
Impact of agrochemicals on non- Apis bees.
Book Title: Honey bees: estimating the environmental impact of chemicals
Publication Year: 2002

40/6/255 (Item 255 from file: 50)
0009424353 CAB Accession Number: 20073294185
Impacts of initial species richness and deer browsing on the quality of restored prairie in central Illinois.
Publication Year: 2007

40/6/261 (Item 261 from file: 76)
0000756971 IP ACCESSION NO: 2734177
Interactions between three *alfalfa* nodulation genotypes and two *Glomus* species.
PUBLICATION DATE: 1991

40/6/264 (Item 264 from file: 5)
18755048 BIOSIS NO.: 200600100443
The introduction of grapes and *alfalfa* into China: A reflection on the role of Zhang Qian
2005

40/6/266 (Item 266 from file: 5)
11627364 BIOSIS NO.: 199345058345
Introduction of plants with special regard to cultigens running *wild*
BOOK TITLE: Advances in Life Sciences; Transgenic organisms: Risk assessment of deliberate release
1993

40/6/273 (Item 273 from file: 5)
08236340 BIOSIS NO.: 198682082727
IN-VITRO TRANSLATION OF NODULE SPECIFIC MESSENGER RNA FROM *ALFALFA*
MEDICAGO-SATIVA ROOT NODULES
1986

40/6/275 (Item 275 from file: 50)
0009167912 CAB Accession Number: 20063219405
An investigation on *alfalfa* aphids and their parasitoids in different parts of iran, with a key to the parasitoids (Hemiptera: Aphididae; Hymenoptera: Braconidae: Aphidiinae).
Publication Year: 2006

40/6/276 (Item 276 from file: 76)
0001884426 IP ACCESSION NO: 6910690
Investigation of the potential of two *wild* *Medicago* species - *Medicago* orbicularis and *Medicago* arabica for in vitro callusogenesis and direct organogenesis
PUBLICATION DATE: 2005

40/6/288 (Item 288 from file: 50)
0005032756 CAB Accession Number: 19810722899
Isolation of a mutant of *Rhizobium meliloti* adapted to *lucerne*
cultured on acid soil.
Publication Year: 1981

40/6/291 (Item 291 from file: 5)
17232434 BIOSIS NO.: 200300191153
Kinetics and strain specificity of rhizosphere and endophytic colonization by
enteric bacteria on seedlings of *Medicago* sativa and *Medicago*
truncatula.
2003

40/6/294 (Item 294 from file: 5)
12661502 BIOSIS NO.: 199598129335
Localization of poly(A)+-containing RNA during female gametophyte
development in *Medicago* sativa and the diploid mutant *Medicago* sativa
ssp. falcata using digoxigenin-labelled oligo-dT probes
1995

40/6/295 (Item 295 from file: 50)
0006360673 CAB Accession Number: 19910229851
Local *wild* bee species are the main *lucerne* pollinators in the
steppe zone of the northwestern Transcaucasus [USSR].
Publication Year: 1987

40/6/304 (Item 304 from file: 50)
0006147102 CAB Accession Number: 19891937040
Microscopic structure of ineffective *alfalfa* nodules formed by
auxotrophic mutants of *Rhizobium meliloti*.
Publication Year: 1988

40/6/306 (Item 306 from file: 50)
0006637058 CAB Accession Number: 19930760077
Microsite differentiation in a Mediterranean oak savanna.
Publication Year: 1992

40/6/307 (Item 307 from file: 5)
08559098 BIOSIS NO.: 198783037989
MEDICAGO CELL VARIANTS SHOWING ALTERED NITROGEN UTILIZATION
1986

40/6/308 (Item 308 from file: 5)
17253806 BIOSIS NO.: 200300212525
The *Medicago* species A2-type cyclin is auxin regulated and involved in
meristem formation but dispensable for endoreduplication-associated
developmental programs.
2003

40/6/318 (Item 318 from file: 50)
0007149869 CAB Accession Number: 19960200034
Methods of domiciling and beekeeping with *alfalfa* pollinating
sub-tropical megachilid bees.
Publication Year: 1991

40/6/321 (Item 321 from file: 6)
1080708 NTIS Accession Number: DE83703485

Mutants of *Alfalfa* Mosaic Virus
1983

40/6/323 (Item 323 from file: 5)
10265836 BIOSIS NO.: 199090050315
MUTANTS OF RHIZOBIUM-MELILOTI AFFECTED IN NODULATION ABILITY
1989

40/6/325 (Item 325 from file: 5)
09248464 BIOSIS NO.: 198886088385
MATERIALS FOR THE NATURALIZED FLORA OF JAPAN 2
1988

40/6/329 (Item 329 from file: 50)
0006407914 CAB Accession Number: 19910745048
Moose and deer habitat use and diet on a reclaimed mine in west-central
Alberta.
Proceedings of the conference: Reclamation, a global perspective, Aug.
27-31, 1989, Calgary, Alberta, Canada.
Publication Year: 1989

40/6/332 (Item 332 from file: 10)
3068208 91015685 Holding Library: AGL
Measurement of the ovipositional potential of potato leafhopper, *Empoasca fabae* (Homoptera: Cicadellidae): a comparison of *feral* and culture
populations
1990 Jul

40/6/354 (Item 354 from file: 203)
01879677
The naturalised flora of South Australia 2. Its development through time
1987

40/6/361 (Item 361 from file: 50)
0006032693 CAB Accession Number: 19880226305
Observations on the insect pollinators of some Leguminosae (*Onobrychis viciifolia*, *Lotus corniculatus*, **Medicago** *arborea*, **Medicago** *sativa*) in
a specialized area.
Original Title: Osservazioni sugli insetti pronubi di alcune
Leguminosae (*Onobrychis viciifolia* Scop., *Lotus corniculatus* L.,
Medicago *arborea* L., **Medicago** *sativa* L.) in un areale specializzato.
Publication Year: 1984

40/6/365 (Item 365 from file: 50)
0006127721 CAB Accession Number: 19890227662
Studies on the diurnal flight activity of *wild* bees (Apoidea),
pollinators of *lucerne*.
S'vremenni postizheniya na bulgarskata zoologiya.
Publication Year: 1987

40/6/367 (Item 367 from file: 203)
00973985
1982
Studies on the *wild* bees of Family: Andrenidae (Hymenoptera) in Egypt
[A study for utilizing the *wild* bees for inoculation of **Medicago**
sativa, *Trifolium alexandrium*, *Vicia faba*]

40/6/370 (Item 370 from file: 10)
4554382 43835773 Holding Library: AGL
Overexpression of BetS, a Sinorhizobium meliloti High-Affinity Betaine
Transporter, in Bacteroids from *Medicago* sativa Nodules Sustains Nitrogen
Fixation During Early Salt Stress Adaptation
2006

40/6/376 (Item 376 from file: 203)
01623240
[Apoidea are the pollinators of *lucerne* in the Republic of Moldova] (
Apoidea - opyliteli lyutserny v respublike Moldovy)
1991

40/6/377 (Item 377 from file: 10)
2017388 82060896 Holding Library: AGL
Pollination of *alfalfa* (by honeybees and *wild* bees).
1981

40/6/382 (Item 382 from file: 5)
12432938 BIOSIS NO.: 199497454223
Plants transformed with a mutant *alfalfa* mosaic virus coat protein gene
are resistant to the mutant but not to *wild*-type virus
1994

40/6/383 (Item 383 from file: 10)
3526779 20527324 Holding Library: AGL
Plant signals to soil microbes: regulators of rhizosphere colonization
1995

40/6/388 (Item 388 from file: 5)
15165426 BIOSIS NO.: 199900425086
Population dynamics of Lygus hesperus (Heteroptera: Miridae) on selected
weeds in comparison with *alfalfa*
1999

40/6/396 (Item 396 from file: 10)
2320809 84059420 Holding Library: AGL
Propagation of *wild* pollinators (Leafcutting solitary bees as
pollinators of *alfalfa*, Ukrainian SSR).
1983

40/6/397 (Item 397 from file: 203)
01490241
Properties of the neutral foliar phosphatases in the *wild* *lucerne*,
Medicago minima. 1. Kinetic parameters and natural variability (
Proprietes des phosphatases foliaires neutres de la luzerne sauvage,
Medicago minima. 1. Parametres cinetiques et leur variabilite naturelle)
1989

40/6/399 (Item 399 from file: 203)
01490242
Properties of the neutral foliar phosphatases of the *wild* *lucerne*,
Medicago minima. 2. Comparison between Hill coefficients of five natural
phosphorylated esters (Proprietes des phosphatases foliaires neutres de la
luzerne sauvage, *Medicago* minima. 2. Comparaison des coefficients de Hill
de cinq esters phosphoriques naturels)
1989

40/6/402 (Item 402 from file: 203)
01490243
Properties of the neutral foliar phosphatases of the *wild* *lucerne*,
Medicago minima. 3. Determination of Ks in five phosphorylated esters
from glycolysis by substrate competition (Proprietes des phosphatases
foliaires neutres de la luzerne, *Medicago* minima. 3. Determination du Ks
de cinq esters phosphoriques de la glycolyse par competition de substrats)
1989

40/6/404 (Item 404 from file: 5)
17132549 BIOSIS NO.: 200300091268
Proteome analysis of nodulation-related proteins in the *wild* type and a
supernodulation mutant (sunn) of the model legume, *Medicago* truncatula.
BOOK TITLE: Nitrogen fixation: Global perspectives
2002

40/6/409 (Item 409 from file: 10)
1890885 81069664 Holding Library: AGL
Parasites (Chalcidoidea) and pests (Coleoptera, Lepidoptera) in the nests
of the *wild* (*alfalfa* -pollinating) bee *Megachile rotundata* Fabr.
(Romania).
Paraziti si daunatori in cuiburile albinei salbatice *Megachile rotundata*
Fabr
1980

40/6/412 (Item 412 from file: 10)
4772733 44002414 Holding Library: AGL
The potential role of waterbirds in dispersing invertebrates and plants
in arid Australia
2008
URL: <http://dx.doi.org/10.1111/j.1365-2427.2007.01901.x>

40/6/413 (Item 413 from file: 50)
0006884996 CAB Accession Number: 19941905955
Patterns of nodule development and nodulin gene expression in *alfalfa*
and afghanistan pea.
Advances in molecular genetics of plant-microbe interactions.
Publication Year: 1991

40/6/415 (Item 415 from file: 5)
07226343 BIOSIS NO.: 198477058254
PESTICIDES AND BEES
1983

40/6/418 (Item 418 from file: 5)
15674737 BIOSIS NO.: 200000393050
Qualitative and quantitative analysis of carbohydrates in green juices
(*wild* mix grass and *alfalfa*) from a green biorefinery by gas
chromatography/mass spectrometry
2000

40/6/422 (Item 422 from file: 5)
0019714281 BIOSIS NO.: 200700374022
Recent advances in biological control of pest insects by using viruses in
China
2007

40/6/424 (Item 424 from file: 143)
 2113128 H.W. WILSON RECORD NUMBER: BBAI07141525
 Reaction Tissue Formation and Stem Tensile Modulus Properties in *Wild*
 -type and p-Coumarate-3-hydroxylase Downregulated Lines of *Alfalfa*,
 Medicago sativa (Fabaceae)

20070600

40/6/428 (Item 428 from file: 76)
 0000370881 IP ACCESSION NO: 1037440
 Regulation of nodulation by Rhizobium meliloti 102F15 on its mutant which
 forms an unusually high number of nodules on *alfalfa*.
 PUBLICATION DATE: 1985

40/6/433 (Item 433 from file: 10)
 2868852 89001631 Holding Library: AGL
 Rhizobium meliloti host range nodH gene determines production of an
 alfalfa-specific extracellular signal
 1988 Dec

40/6/435 (Item 435 from file: 10)
 3230175 92066729 Holding Library: AGL
 A Rhizobium meliloti lipopolysaccharide mutant altered in competitiveness
 for nodulation of *alfalfa*
 1992 Sep

40/6/437 (Item 437 from file: 10)
 3319933 20337597 Holding Library: AGL
 Rhizobium meliloti mutants defective in symbiotic nitrogen fixation
 affect the oxygen gradient in *alfalfa* (*Medicago* sativa) root nodules
 1993 Feb

40/6/440 (Item 440 from file: 5)
 08611437 BIOSIS NO.: 198783090328
 A RHIZOBIUM-MELILOTI MUTANT THAT FORMS INEFFECTIVE PSEUDONODULES IN
 ALFALFA PRODUCES EXOPOLYSACCHARIDE BUT FAILS TO FORM BETA-1-2 GLUCAN
 1987

40/6/448 (Item 448 from file: 76)
 0000471147 IP ACCESSION NO: 1572328
 Requirement of succinate dehydrogenase activity for symbiotic bacteroid
 differentiation of Rhizobium meliloti in *alfalfa* nodules.
 PUBLICATION DATE: 1987

40/6/452 (Item 452 from file: 5)
 13882005 BIOSIS NO.: 199799516065
 Role of the K-antigen subgroup of capsular polysaccharides in the early
 recognition process between Rhizobium meliloti and *alfalfa* leaves
 1997

40/6/464 (Item 464 from file: 5)
 18473211 BIOSIS NO.: 200510167711
 Role of trehalose transport and utilization in Sinorhizobium meliloti -
 Alfalfa interactions
 2005

40/6/465 (Item 465 from file: 10)
 4802578 43731174 Holding Library: AGL
 Role of trehalose transport and utilization in Sinorhizobium meliloti-
 alfalfa interactions. [Erratum: 2005 Nov., v. 18, no. 11, p. 1243.]
 2005

40/6/468 (Item 468 from file: 50)
 0007291607 CAB Accession Number: 19961909908
 Role of surface factors in plant-microbe interactions: involvement of
 Rhizobium meliloti exopolysaccharide during early infection events in
 alfalfa [*Medicago* sativa].
 Advances in molecular genetics of plant-microbe interactions: volume 3.
 Proceedings 7th International Symposium, Edinburgh, UK, June 1994.
 Publication Year: 1994

40/6/472 (Item 472 from file: 10)
 2382459 84107907 Holding Library: AGL
 Reproduction of *wild* *alfalfa* pollinators (*Wild* bees, Krasnodar
 Territory, RSFSR-in-Europe).
 1984

40/6/479 (Item 479 from file: 50)
 0008751060 CAB Accession Number: 20043206871
 Revegetation and reclamation of soils using *wild* leguminous shrubs in
 cold semiarid Mediterranean conditions: litterfall and carbon and nitrogen
 returns under two aridity regimes.
 Publication Year: 2004

40/6/480 (Item 480 from file: 50)
 0009452547 CAB Accession Number: 20083007482
 A review of weeds in Australia resistant to herbicides.
 Book Title: Proceedings of the Eighth Australian Weeds Conference,
 Sydney, New South Wales, Australia, 21-25 September, 1987
 Publication Year: 1987

40/6/484 (Item 484 from file: 5)
 09645078 BIOSIS NO.: 198987092969
 SCREENING OF *MEDICAGO* *WILD* SPECIES FOR CALLUS FORMATION AND THE
 GENETICS OF SOMATIC EMBRYOGENESIS
 1988

40/6/488 (Item 488 from file: 5)
 14386231 BIOSIS NO.: 199800180478
 Selection of methionine-resistant variant of *Medicago* sativa
 1997

40/6/489 (Item 489 from file: 144)
 08290577 PASCAL No.: 88-0291128
 Solanum nigrum L. and *wild* *alfalfa* plants as natural hosts for
 alfalfa mosaic virus, in Portugal
 1987

40/6/490 (Item 490 from file: 144)
 08229871 PASCAL No.: 88-0230332
 (Resistance au sel et teneur en composés ammonium quaternaire d'espèces
 sauvages de luzerne)

(Salt resistance and the level of quaternary ammonium compounds in *wild*
lucerne species)
1987

40/6/491 (Item 491 from file: 144)
08246688 PASCAL No.: 88-0247151
Salt tolerance and content of quaternary ammonium compounds in *wild*
species of *Medicago*
1988 publ. 1977

40/6/492 (Item 492 from file: 50)
0005895664 CAB Accession Number: 19870706104
Salt tolerance of *wild* *lucerne* species and contents of quaternary
ammonium compounds.
Publication Year: 1987

40/6/521 (Item 521 from file: 144)
17983911 PASCAL No.: 07-0044856
Strategies to obtain stable transgenic plants from non-embryogenic lines
: complementation of the nn SUB 1 mutation of the NORK gene in *Medicago*
sativa MN1008
2006

40/6/527 (Item 527 from file: 76)
0001843030 IP ACCESSION NO: 6725879
Symbiosis between the Root-Nodule Bacterium Sinorhizobium meliloti and
Alfalfa (*Medicago* sativa) under Salinization Conditions
PUBLICATION DATE: 2006

40/6/545 (Item 545 from file: 144)
16565718 PASCAL No.: 04-0214103
Transgenic tobacco plants overproducing *alfalfa* aldose/aldehyde
reductase show higher tolerance to low temperature and cadmium stress
2004

40/6/546 (Item 546 from file: 5)
09201813 BIOSIS NO.: 198886041734
TRANSGENIC TOBACCO EXPRESSING TOBACCO STREAK VIRUS OR MUTATED *ALFALFA*
MOZAIC VIRUS COAT PROTEIN DOES NOT CROSS-PROTECT AGAINST *ALFALFA* MOZAIC
VIRUS INFECTION
1988

40/6/552 (Item 552 from file: 10)
2625876 87002794 Holding Library: AGL
Taxonomy of glandular *wild* *alfalfa* (*Medicago* sativa)
1986 Sep

40/6/553 (Item 553 from file: 5)
11766054 BIOSIS NO.: 199395068320
Ultrastructure of infection mode of Rhizobium meliloti exopolysaccharide
mutant in *alfalfa*
1992

40/6/556 (Item 556 from file: 203)
01006295
1982
[Evaluation of production curves for *wild* medic (*Medicago* sp.)] (

Evaluacion de curvas de produccion de hualputras silvestres (*Medicago* sp.))

40/6/563 (Item 563 from file: 10)

2434416 85015838

Visiting rate of *wild* *alfalfa* species by bees
1983

40/6/564 (Item 564 from file: 50)

0005756425 CAB Accession Number: 19860218557

Visits to *wild* *lucerne* species by bees.
Publication Year: 1983

40/6/567 (Item 567 from file: 50)

0006121778 CAB Accession Number: 19890227558

Wild bees (Apoidea) as pollinators of *lucerne* in the Krasnodar region.

Zashchita semenovodcheskikh posevov lyutserny ot kompleksa vrednykh organizmov v stepnoi zone severnogo kavkaza.

Publication Year: 1988

40/6/568 (Item 568 from file: 10)

1801065 81002531 Holding Library: AGL

Wild bees as pollinators of plants (including *alfalfa*, USSR).
1980

40/6/569 (Item 569 from file: 10)

2741698 87087359 Holding Library: AGL

Wild barley (foxtail) control in *alfalfa*
1987

40/6/570 (Item 570 from file: 10)

1801087 81002553 Holding Library: AGL

Wild insect pollinators of *alfalfa* (Poltava Region, Ukrainian SSR).
1980

40/6/572 (Item 572 from file: 203)

00725212

[Wild pollinators of *alfalfa* [bees (general), Ukrainian SSR]] (Dikie opyliteli posevnoj lyutserny)
1980

40/6/573 (Item 573 from file: 10)

2837593 88047958 Holding Library: AGL

Wild proso millet and broadleaf weed control in seedling *alfalfa*
1988

40/6/577 (Item 577 from file: 203)

01624072

[The stability of collected strain samples of *alfalfa* to fusarial wilt root rot in Western Siberia] (Ustojchivost' kollektsionnykh sortoobraztsov lyutserny k fuzarioznoj kornevoj gnili v Zapadnoj Sibiri)

1991

H-3 Supplemental Searches

Engine	Term	# Titles Reviewed
Yahoo	Nomad alfalfa	20
Google	feral alfalfa	100
Goggle	yellow-blossomed alfalfa on rangeland	20
Google	rangeland alfalfa	30
Google	fire damage alfalfa	20
Google	fire recovery alfalfa	10
Google	erosion control alfalfa	10
Google	roadside alfalfa	20
Google	alfalfa seedbank	20
Scirus	feral alfalfa	30

Appendix H-3. Alfalfa Naturalized Status in the United States

Figure H-1. *Medicago sativa* Naturalized Status (USDA Plants Database)³³

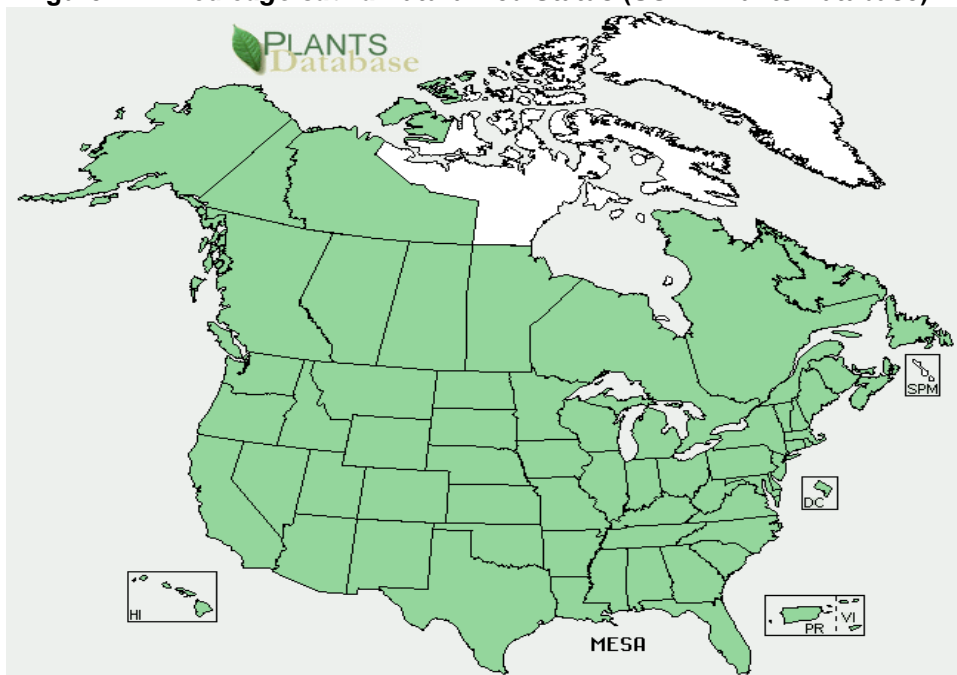
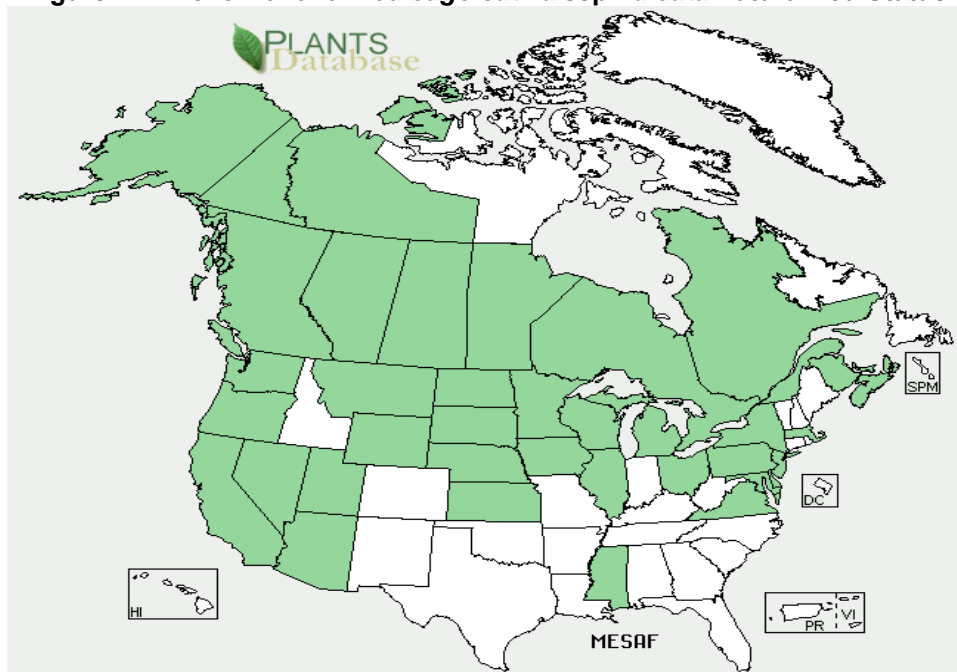


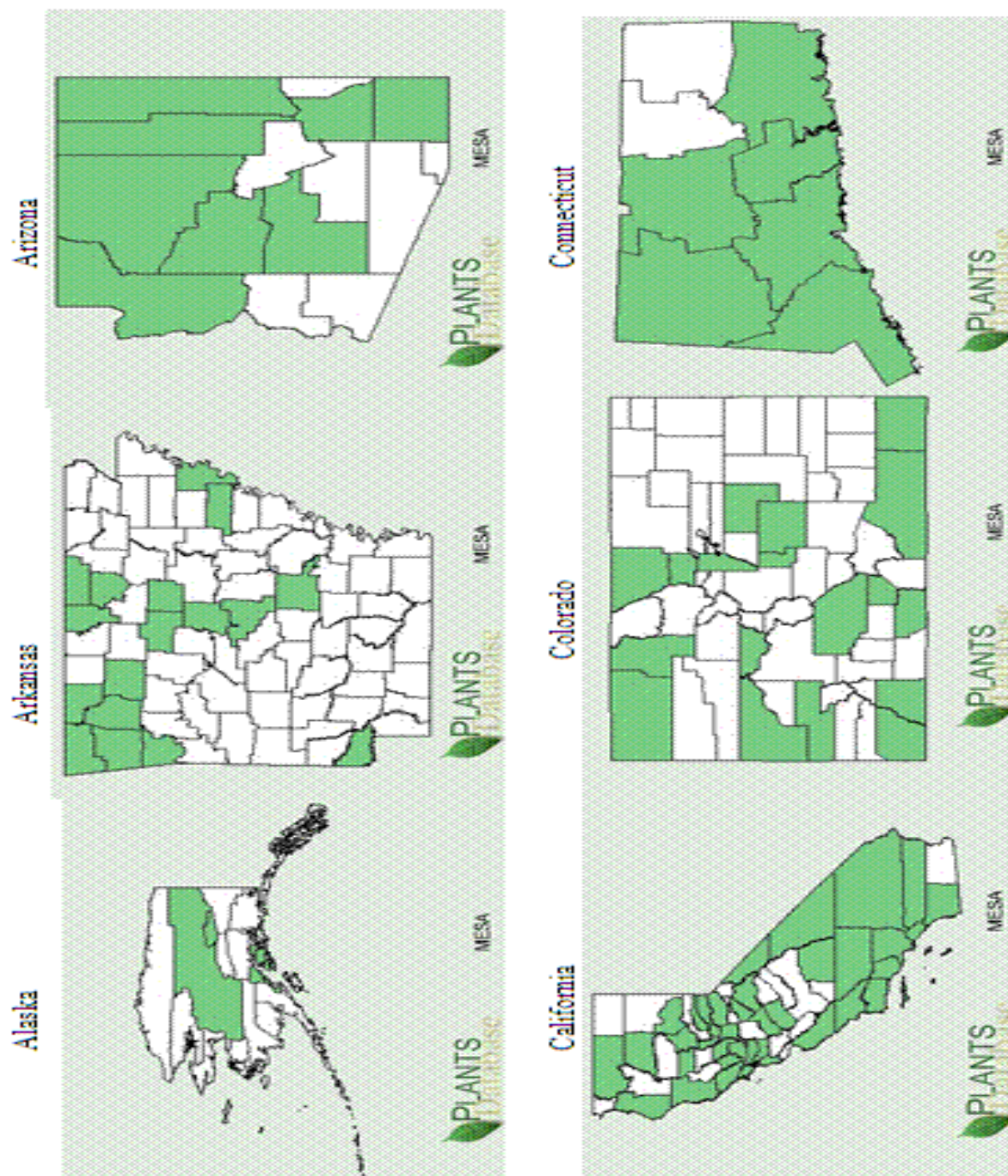
Figure H-2..Yellow alfalfa *Medicago sativa* ssp. *falcata* Naturalized Status



³³ <http://plants.usda.gov/index.html>

Figure H-3. *Medicago sativa* Naturalized Status by State (USDA Plants Database)³⁴

The USDA Plants Database “county data are based primarily on the literature, herbarium specimens, and confirmed observations. Not all populations have been documented, however, and significant gaps in the distribution shown [below] may not be real... Remember that only native and naturalized populations are mapped!”

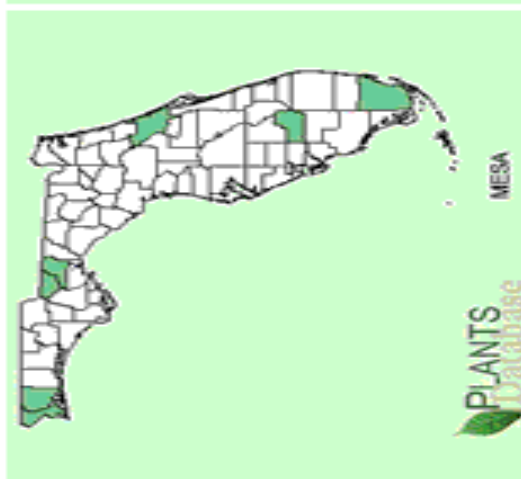


³⁴ <http://plants.usda.gov/index.html>

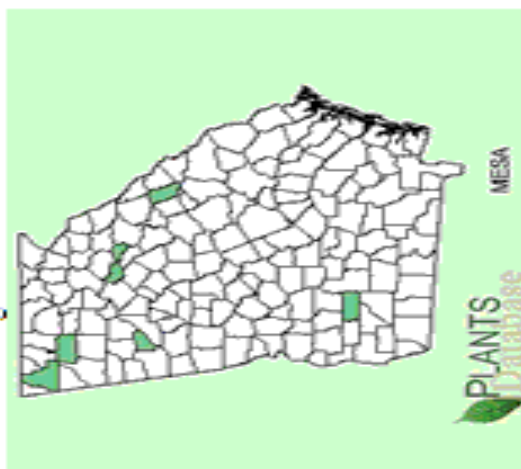
District of Columbia



Florida



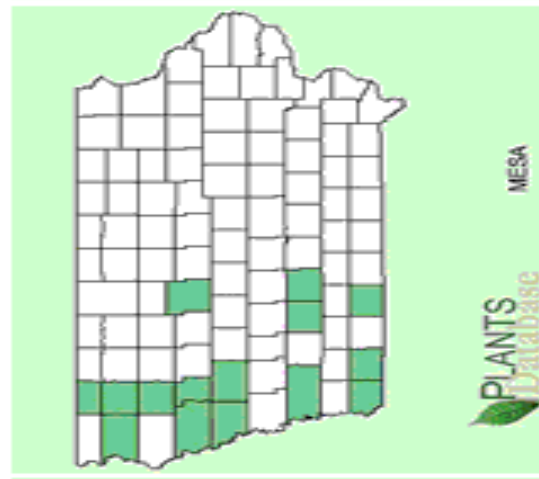
Georgia



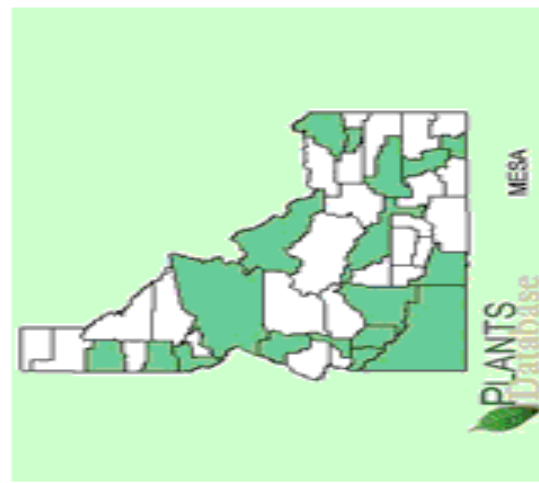
Hawaii



Iowa



Idaho



Illinois



Indiana



Kansas



Kentucky



Louisiana



Massachusetts



Maine



Michigan



Minnesota



Missouri



Mississippi



Montana



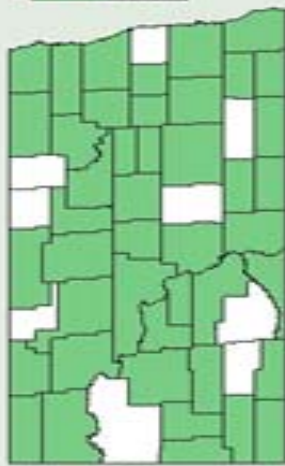
North Carolina



PLANTS
Database

MESA

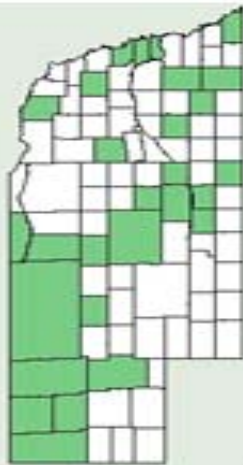
North Dakota



PLANTS
Database

MESA

Nebraska



PLANTS
Database

MESA

New Hampshire



PLANTS
Database

MESA

New Jersey



PLANTS
Database

MESA

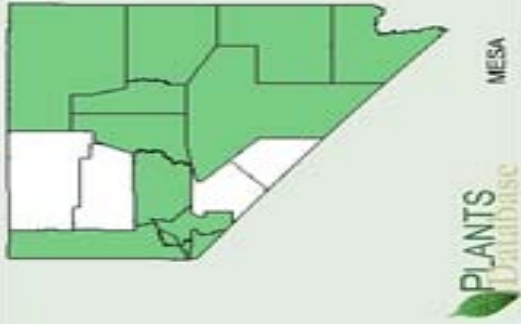
New Mexico



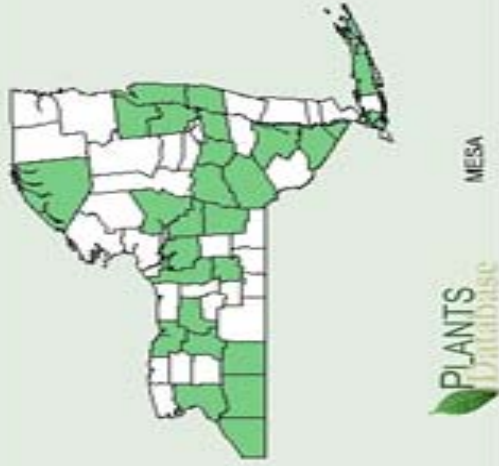
PLANTS
Database

MESA

Nevada



New York



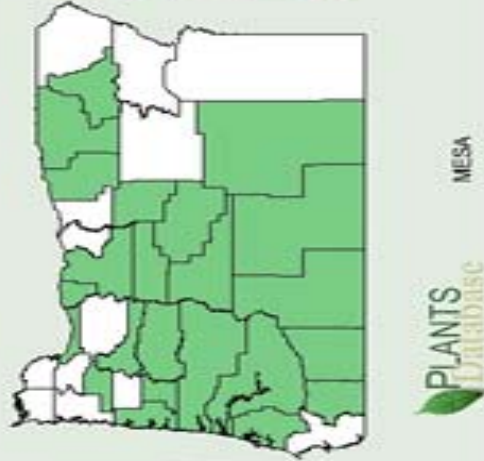
Ohio



Oklahoma



Oregon



Pennsylvania



Rhode Island



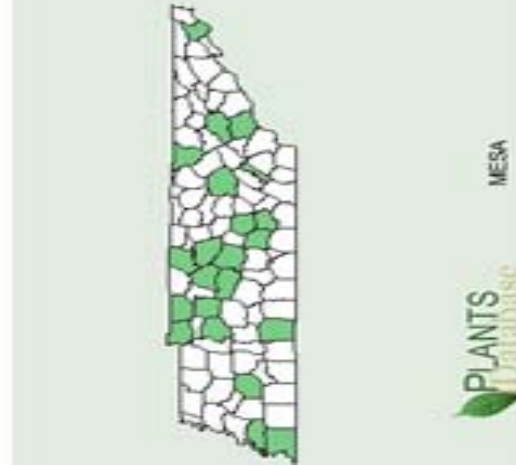
South Carolina



South Dakota



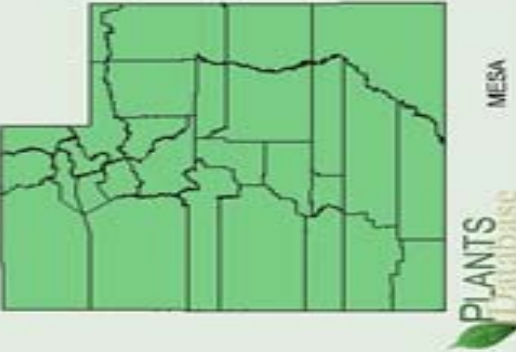
Tennessee



Texas



Utah



Virginia



PLANTS
Database

MESA

Vermont



PLANTS
Database

MESA

Washington



PLANTS
Database

MESA

Wisconsin



PLANTS
Database

MESA

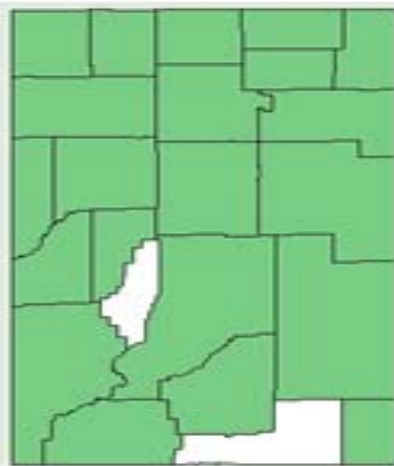
West Virginia



PLANTS
Database

MESA

Wyoming



PLANTS
Database

MESA

Appendix H-4. Glyphosate Resistant Weeds – United States Distribution

Common Name	Scientific Name	U.S. Range ³⁵ for Resistant and Susceptible Biotypes	U.S. Reports of Resistant Biotypes	Listed on Roundup® Label ³⁶	Noxious Status ⁵	Source
Recently Evolved or Selected Resistant Biotypes						
Common Ragweed	<i>Ambrosia artemisiifolia</i>	All states except AL	2004 - Arkansas 2004 - Missouri 2007 - Kansas	Yes (with resistant biotype note)	IL: Noxious weed (within the corporate limits of cities, villages, and incorporated towns) MI: <i>Ambrosia elatior</i> , Noxious weed OR: "B" designated weed, Quarantine	Heap et al., 2008
Common Waterhemp	<i>Amaranthus rudis</i> and <i>Amaranthus tuberculatus</i>	All except, AK, AZ, DC, FL, HI, MD, MT, NV, OR, UT, VA, WY	2005 - Missouri – (3 MOA's) 2006 - Illinois - (2 MOA's) 2006 - Kansas 2007 - Minnesota	Yes (with resistant biotype note)	No	Heap et al., 2008; Nandula et al., 2005 ; Cerdeira and Duke 2006
Giant Ragweed	<i>Ambrosia trifida</i>	All except AK, HI, NV	2004 - Ohio 2005 - Arkansas 2005 - Indiana 2006 - Kansas 2006 - Minnesota 2007 - Tennessee	Yes (with resistant biotype note)	CA: B list (noxious weeds) DE: Noxious weed IL: Noxious weed (within the corporate limits of cities, villages, and incorporated towns)	Heap et al., 2008
Hairy Fleabane	<i>Conyza bonariensis</i>	AL, AZ, CA, FL, GA, LA, MS, NC, NM, NV, OR, SC, TX, UT, VA	2007 – California	Yes	No	Heap et al., 2008; Nandula et al., 2005
Horseweed	<i>Conyza canadensis</i>	All States	2000 - Delaware 2001 - Kentucky	Yes (with resistant)	No	Heap et al., 2008;

³⁵ <http://plants.usda.gov/index.html>

³⁶ http://www.monsanto.com/monsanto/ag_products/pdf/labels_msds/roundup_orig_max_label.pdf

Common Name	Scientific Name	U.S. Range ³⁵ for Resistant and Susceptible Biotypes	U.S. Reports of Resistant Biotypes	Listed on Roundup® Label ³⁶	Noxious Status ⁵	Source
			2001 - Tennessee 2002 - Indiana 2002 - Maryland 2002 - Missouri 2002 - New Jersey 2002 - Ohio 2003 - Arkansas 2003 - Mississippi 2003 - North Carolina 2003 - Ohio (2 MOA's) 2003 - Pennsylvania 2005 - California 2005 - Illinois 2005 - Kansas 2007 - Michigan	biotype note)		Nandula et al., 2005
Italian Ryegrass	<i>Lolium multiflorum</i>	All States	2004 - Oregon 2005 - Mississippi	Yes (with resistant biotype note)	No	Heap et al., 2008; Nandula et al., 2005
Johnsongrass	<i>Sorghum halepense</i>	All except AK, ME, MN	2007 - Arkansas	Yes (mixture also recommended)	AR, DE, ID, IL, IN, KS, KY, MD, MO, NV, PA, WV, UT: noxious weed CA, CO: class C noxious weed OH: Prohibited noxious weed OR: "B" designated weed, Quarantine SD: Regulated non-native plant species	Heap et al., 2008

Common Name	Scientific Name	U.S. Range ³⁵ for Resistant and Susceptible Biotypes	U.S. Reports of Resistant Biotypes	Listed on Roundup® Label ³⁶	Noxious Status ⁵	Source
					WA: Class A noxious weed, Noxious weed seed and plant quarantine	
Palmer Amaranth	<i>Amaranthus palmeri</i>	AR, AZ, CA, CO, FL, GA, IL, KS, KY, LA, MA, MD, MO, MS, NC, NE, NJ, NM, NV, NY, OH, OK, PA, SC, TN, TX, UT, VA, WI, WV	2005 - Georgia 2006 - Arkansas 2006 – Tennessee	Yes (with resistant biotype note)	No	Heap et al., 2008
Rigid Ryegrass	<i>Lolium rigidum</i>	AZ, CA, LA, MS, MO, OR, TX	1998 - California	Yes (with resistant biotype note)	No	Heap et al., 2008; Nandula et al., 2005
Buckhorn Plantain*	<i>Plantago lanceolata</i>	All States	Not reported in U.S. yet	No	AR: Noxious weed IA: Secondary noxious weed	Heap et al., 2008
Goosegrass	<i>Eleusine indica</i>	All except AK, ID, MT, WA, WY	Not reported in U.S. yet	Yes	No	Heap et al., 2008; Nandula et al., 2005
Junglerice	<i>Echinochloa colona</i>	AL, AR, AZ, CA, FL, GA, HI, IL, KS, KY, LA, MA, MD, MO, MS, MT, NC, NJ, NM, OK, OR, PA, SC, TN, TX, VA, VT	Not reported in U.S. yet	Yes (mixture also recommended)	No	Heap et al., 2008
Sourgrass	<i>Digitaria insularis</i>	AL, AZ, FL, HI, IL, MS, TX	Not reported in U.S. yet	No	No	Heap et al., 2008
Wild Poinsettia	<i>Euphorbia heterophylla</i>	AL, AZ, CA, FL, GA, HI, LA, MS, NM, TX	Not reported in U.S. yet	No	No	Heap et al., 2008
Historically Naturally Resistant						
Asiatic dayflower	<i>Commelina communis</i>	AL, AR, CT, DC, DE, FL, GA, IA, IL, IN, KS,		No	No	Nandula et al., 2005

Common Name	Scientific Name	U.S. Range ³⁵ for Resistant and Susceptible Biotypes	U.S. Reports of Resistant Biotypes	Listed on Roundup® Label ³⁶	Noxious Status ⁵	Source
		KY, LA, MA, ME, MI, MN, MO, MS, NC, ND, NE, NH, NJ, NY, OH, OK, OR, PA, RI, SC, SD, TN, TX, VA, VT, WA, WI, WV				
Birdsfoot trefoil	<i>Lotus corniculatus</i>	All except AK, FL, HI, LA, MS, NV, SC		No	No	Nandula et al., 2005
Bermudagrass	<i>Cynodon dactylon</i>	All except AK, MN, ND, SD, VT, WI, WY		Yes (partial control notes)	AR: Noxious weed CA: C list (noxious weeds) UT: Noxious weed (Bermudagrass shall not be a noxious weed in Washington County and shall not be subject to provisions of the Utah noxious Weed Act within the boundaries of the county)	Cerdeira and Duke 2006
Burning nettle	<i>Urtica uren</i>	AK, AL, AZ, CA, CT, FL, GA, HI, IA, IL, MA, MD, ME, MI, MO, NH, NJ, NM, NV, NY, OK, OR, PA, SC, TX, VA, VT, WA, WI		No (mixture recommended)	No	Van Deynze et al., 2004; Canevari et al., 2004
Cheeseweed	<i>Malva parviflora</i>	AZ, CA, CO, FL, GA, HI, IA, ID, KS, LA, MA, MD, MO, MT, ND, NE, NJ, NM, NV, NY, OR, SC, TX, WA, WY		No (mixture recommended)	No	Van Deynze et al., 2004
Chinese foldwig	<i>Dicliptera chinensis</i>	HI		No	No	Nandula et al., 2005

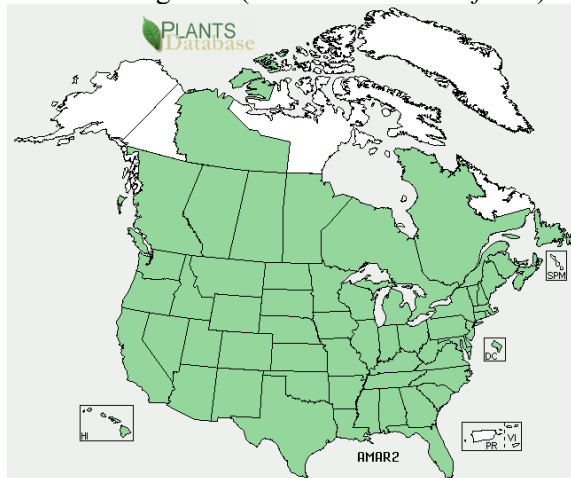
Common Name	Scientific Name	U.S. Range ³⁵ for Resistant and Susceptible Biotypes	U.S. Reports of Resistant Biotypes	Listed on Roundup® Label ³⁶	Noxious Status ⁵	Source
Common lambsquarters	<i>Chenopodium album</i>	All States		Yes (mixture also recommended)	No	Nandula et al., 2005
Field bindweed*	<i>Convolvulus arvensis</i>	All States except AK		No (mixture recommended)	AK, AR, HI, ID, KS, MI, MO, ND, UT, WI, WY: Noxious weed AZ: Prohibited noxious, Regulated noxious weeds weed CA, CO: C list (noxious weeds) IA: Primary noxious weed MN: Prohibited noxious weed MT: Category 1 noxious weed NM: Class C noxious weed OR: "B" designated weed Quarantine SD: Regulated non-native plant species TX: Noxious plant WA: Class C noxious weed	Nandula et al., 2005
Filaree	<i>Erodium</i> spp. (e.g., <i>Erodium cicutarium</i>)	All except FL and MS (Redstem filaree)		Yes (mixture also recommended)	CO: B list (noxious weeds)	Van Deynze et al., 2004
Florida pellitory	<i>Parietaria debilis</i> (aka <i>Parietaria floridana</i>)	AL, FL, GA, KY, LA, MD, MS, NC, NH, SC, TX		No	No	Cerdeira and Duke 2006
Hemp sesbania	<i>Sesbania exalta</i>	AL, AR, AZ, CA, FL, GA, IL, KS, KY, LA, MA, MD, MO, MS, NC,		Yes	AR: Noxious weed	Cerdeira and Duke 2006

Common Name	Scientific Name	U.S. Range ³⁵ for Resistant and Susceptible Biotypes	U.S. Reports of Resistant Biotypes	Listed on Roundup® Label ³⁶	Noxious Status ⁵	Source
		NY, OK, PA, SC, TN, TX, VA				
Large crabgrass	<i>Digitaria sanguinalis</i>	All except AK, HI, FL		Yes (mixture also recommended)	No	Cerdeira and Duke 2006
Morning glory	<i>Ipomoea purpurea</i>	All except AK, ID, WY		Yes (mixture also recommended)	AZ: Prohibited noxious weed (all species except <i>Ipomoea carnea</i> , Mexican bush morning glory, <i>I. triloba</i> , three-lobed morning glory, and <i>I. arborescens</i> , morning glory tree) AR: Noxious weed	Hilgenfeld et al., 2004; Cerdeira and Duke 2006
Nutsedge*	<i>Cyperus</i> spp. (<i>Cyperus esculentus</i>)	All except MT, WY		Yes	CA, CO: B list (noxious weeds) HI: Noxious weed OR: "B" designated weed Quarantine WA: Class B noxious weed Quarantine	Cerdeira and Duke 2006
Oval-leaf false buttonweed	<i>Spermacoce latifolia</i>	HI		No	No	Cerdeira and Duke 2006
pillpod sandmat	<i>Chamaesyce hirta</i>	AL, AZ, CA, FL, GA, HI, LA, MD, MI, MS, NC, NM, NY, SC, TX		No	No	Cerdeira and Duke 2006
Purslane	<i>Portulaca oleracea</i>	All except AK		Yes (mixture also recommended)	AZ: Prohibited noxious weed, Regulated noxious weeds	Van Deynze et al., 2004
Tropical Mexican clover	<i>Richardia brasiliensis</i>	AL, FL, GA, HI, LA, MS, NC, NJ, PA, SC, TN, TX, VA		No	No	Cerdeira and Duke 2006

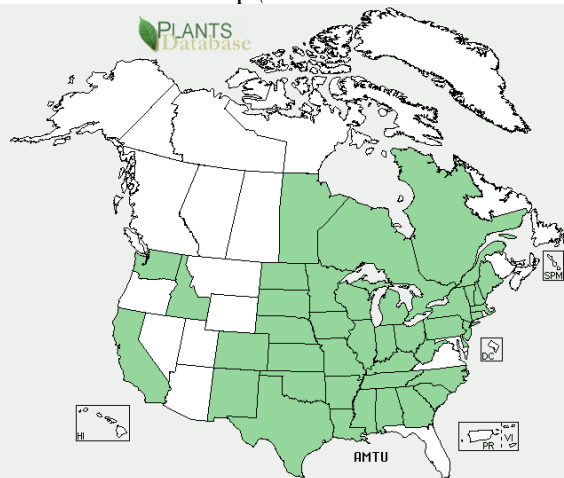
Common Name	Scientific Name	U.S. Range ³⁵ for Resistant and Susceptible Biotypes	U.S. Reports of Resistant Biotypes	Listed on Roundup® Label ³⁶	Noxious Status ⁵	Source
Tropical spiderwort (Benghal dayflower)	<i>Commelina benghalensis</i>	CA, FL, GA, HI, LA, NC		No	United States: - Noxious weed AL: Class A noxious weed CA: Quarantine FL: Noxious weed MA: Prohibited MN: Prohibited noxious weed NC: Class A noxious weed OR: Quarantine SC: Plant pest VT: Class A noxious weed	Nandula et al., 2005
Velvet leaf	<i>Abutilon theophrasti</i>	Al except AK, HI		Yes (mixture also recommended)	CO: C list (noxious weeds) IA: Secondary noxious weed OR: "B" designated weed Quarantine WA: Class A noxious weed, Noxious weed seed and plant, quarantine	Nandula et al., 2005

Cline 2004 reports that fleabane and henbit are also difficult to control with glyphosate. *These 3 weeds are not fully controlled by any of the 16 herbicides listed in the University of California Pest Management Guidelines (Rogan and Fitzpatrick 2004).

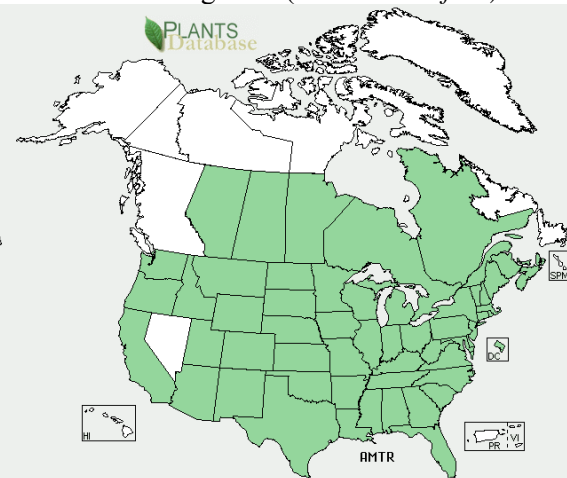
Common Ragweed (*Ambrosia artemisiifolia*)



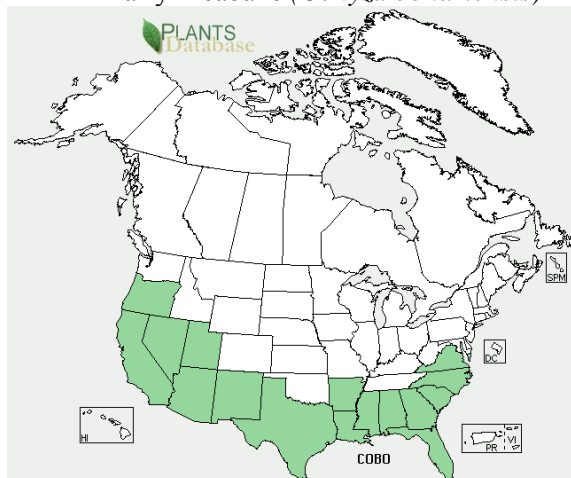
Common waterhemp (*Amaranthus tuberculatus*)



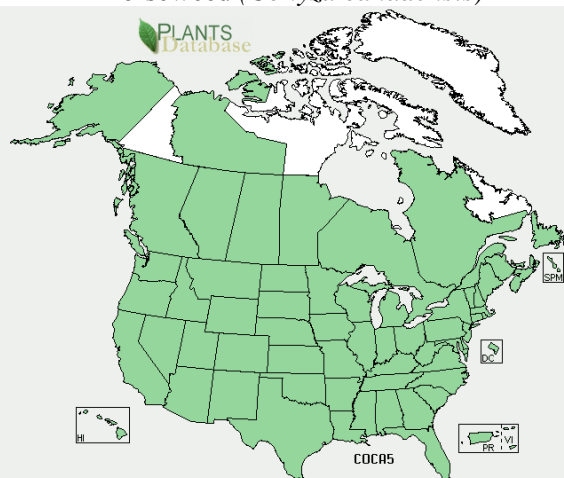
Giant ragweed (*Ambrosia trifida*)



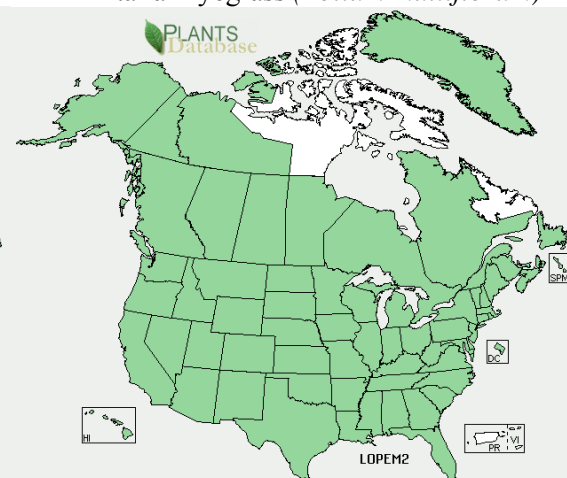
Hairy Fleabane (*Conyza bonariensis*)

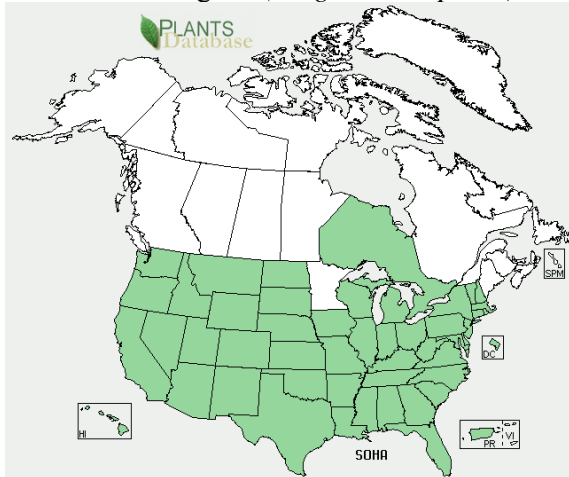
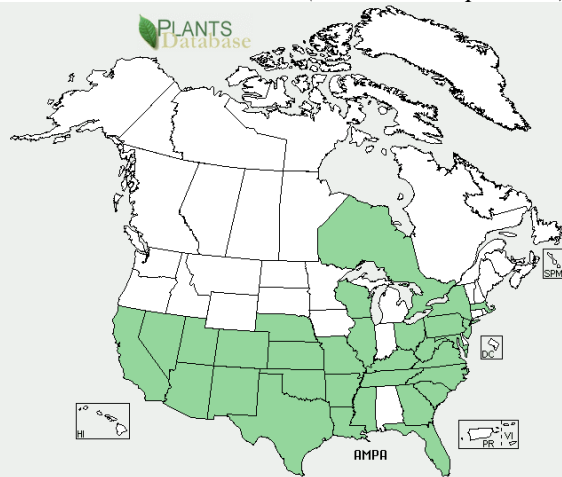
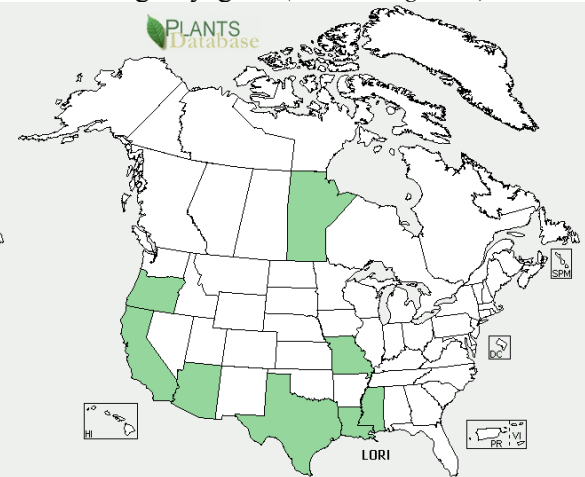
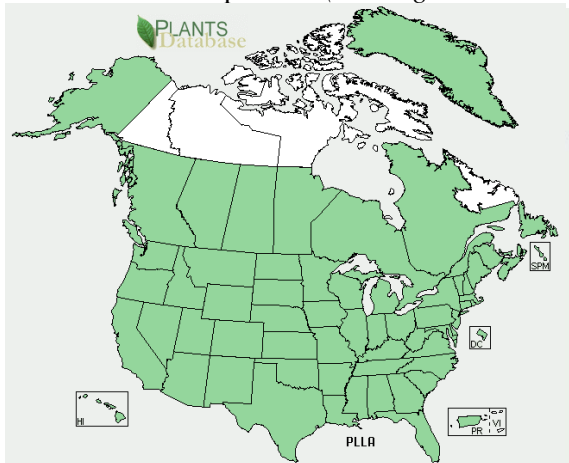
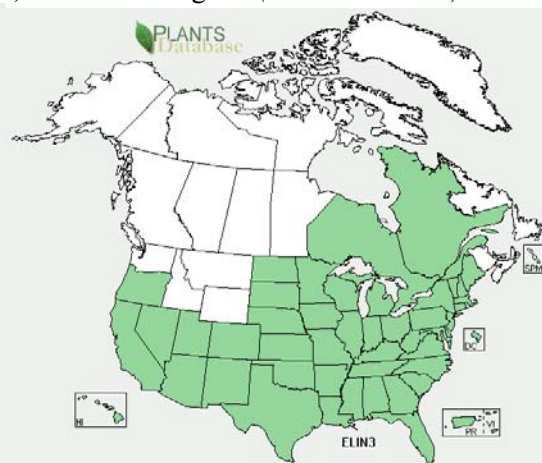
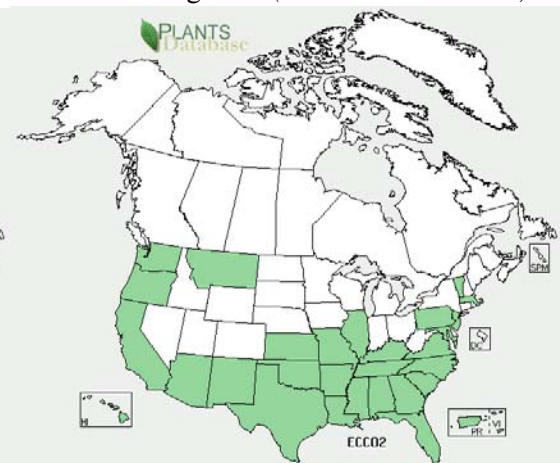


Horseweed (*Conyza canadensis*)

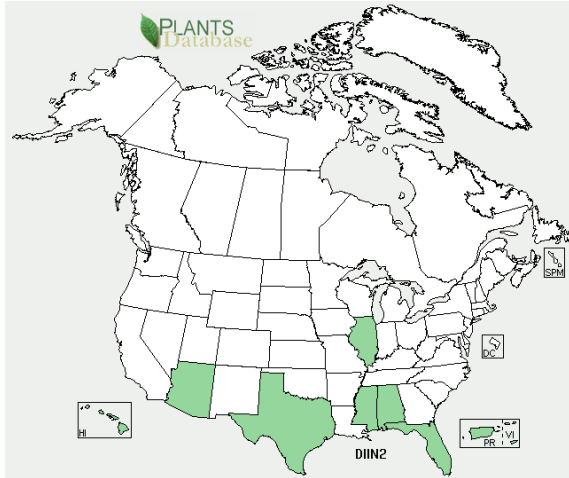


Italian ryegrass (*Lolium multiflorum*)

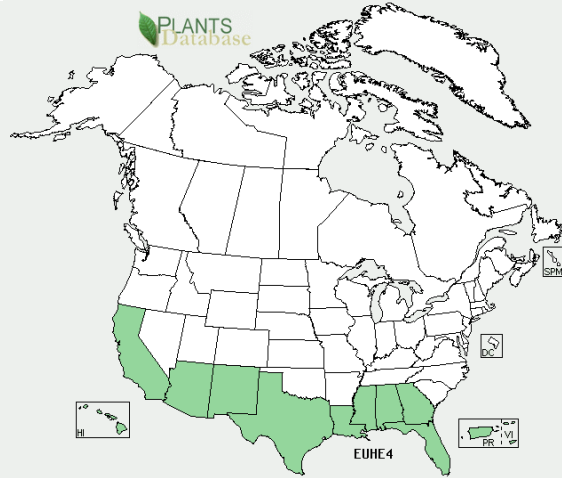


Johnsongrass (*Sorghum halapense*)Palmer amaranth (*Amaranthus palmeri*)Rigid ryegrass (*Lolium rigidum*)Buckhorn plantain (*Plantago lanceolata*)Goosegrass (*Eleusine indica*)Junglerice (*Echinochloa colona*)

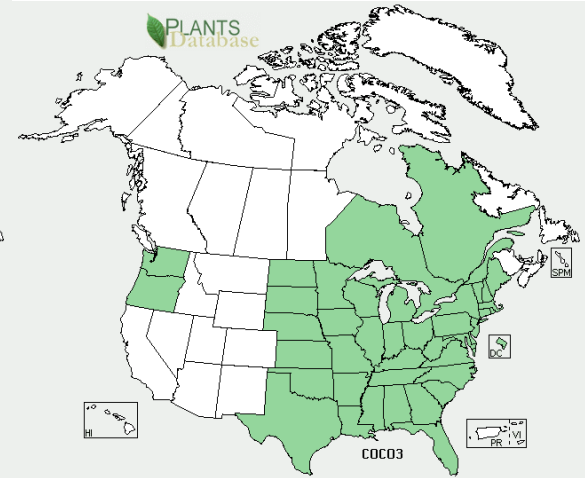
Sourgrass (*Digitaria insularis*)



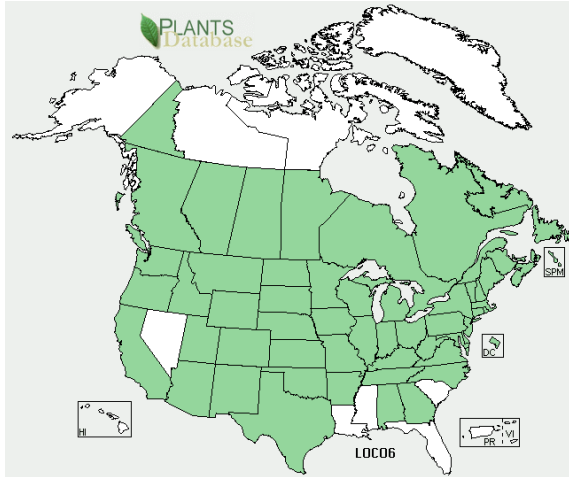
Wild Poinsettia (*Euphorbia heterophylla*)



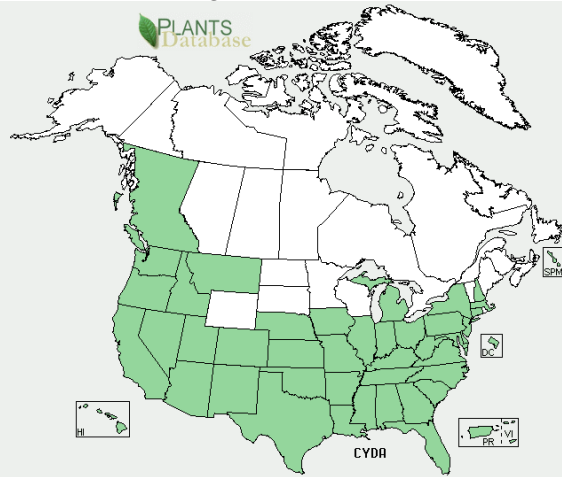
Asiatic dayflower (*Commelina communis*)



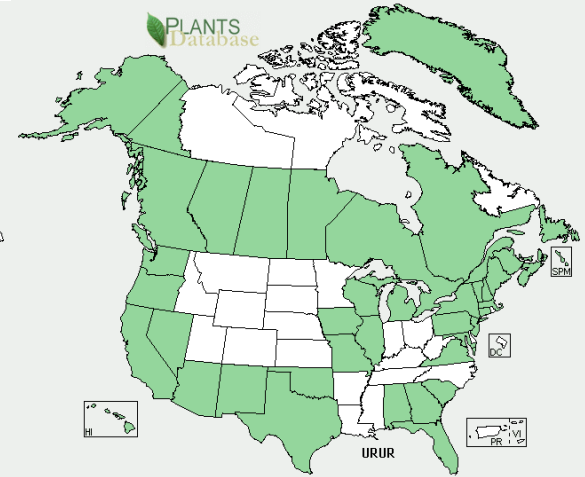
Birdsfoot trefoil (*Lotus corniculatus*)

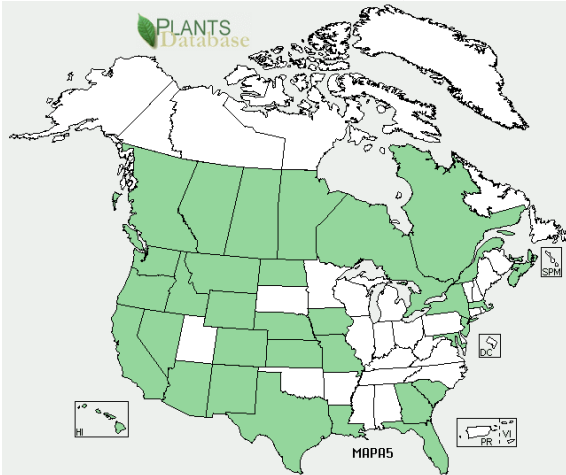
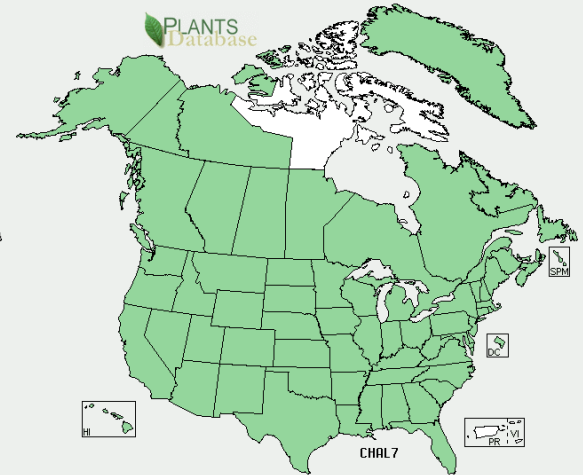
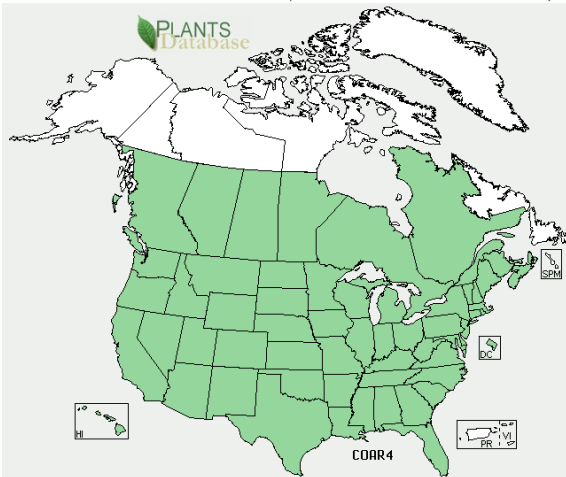
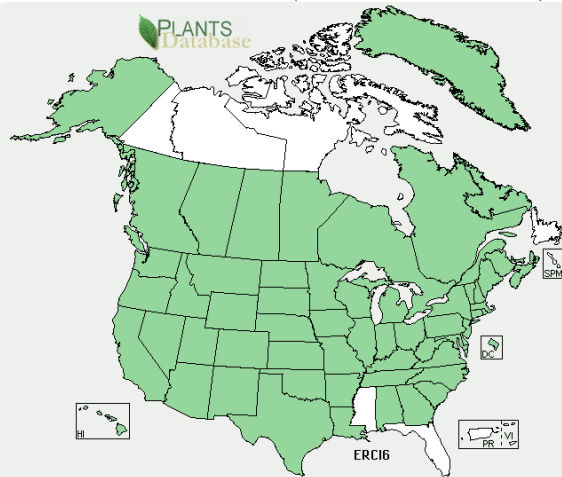
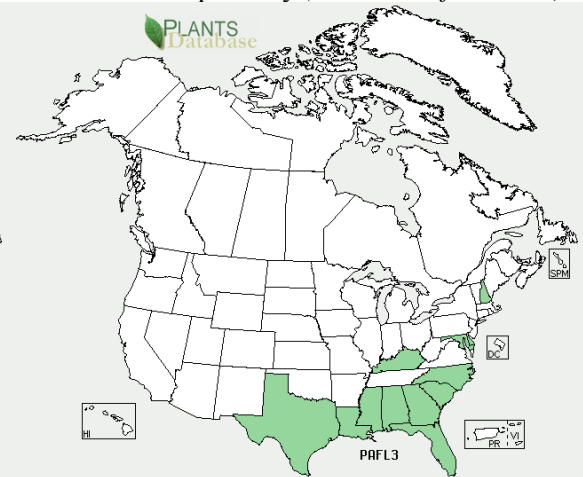


Bermudagrass (*Cynodon dactylon*)

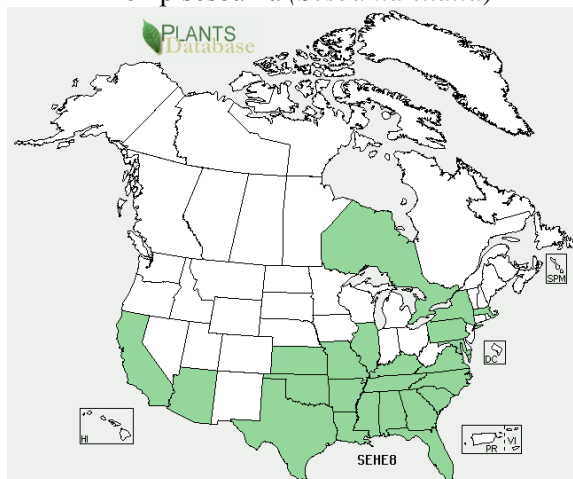


Burning nettle (*Urtica uren*)

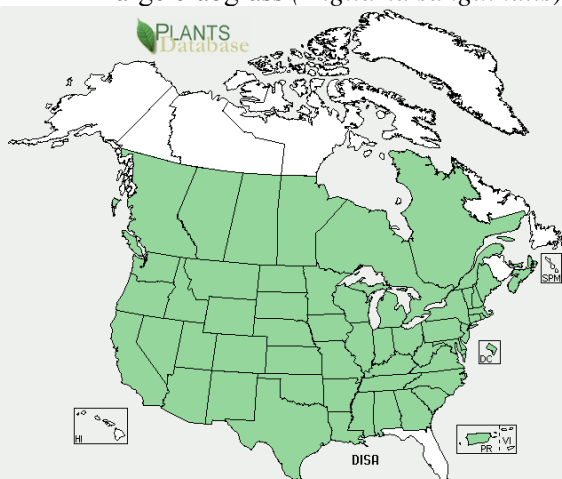


Cheeseweed (*Malva parviflora*)Chinese foldwing (*Dicliptera chinensis*)Common lambsquarters (*Chenopodium album*)Field bindweed (*Convolvulus arvensis*)Redstem filaree (*Erodium cicutarium*)Florida pellitory (*Parietaria floridana*)

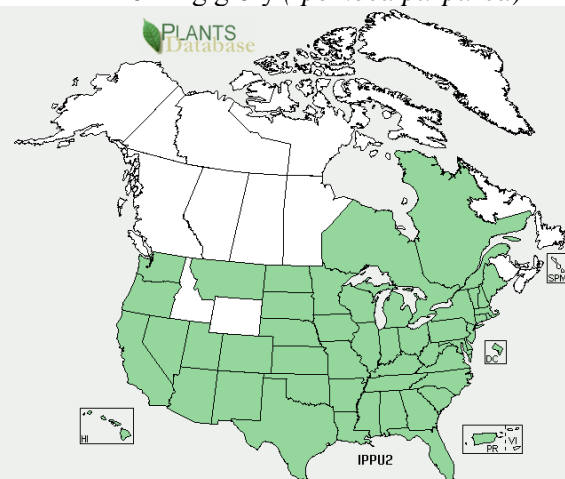
Hemp sesbania (*Sesbania exalta*)



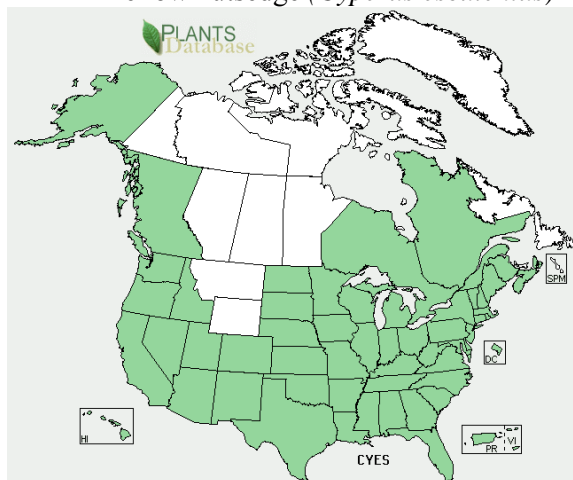
Large crabgrass (*Digitaria sanguinalis*)



Morning glory (*Ipomoea purpurea*)



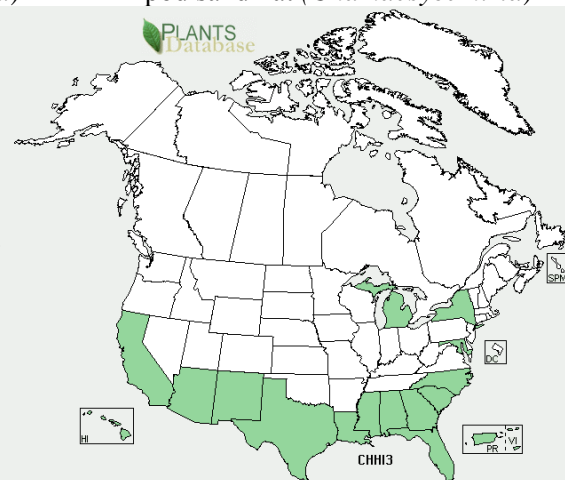
Yellow nutsedge (*Cyperus esculentus*)

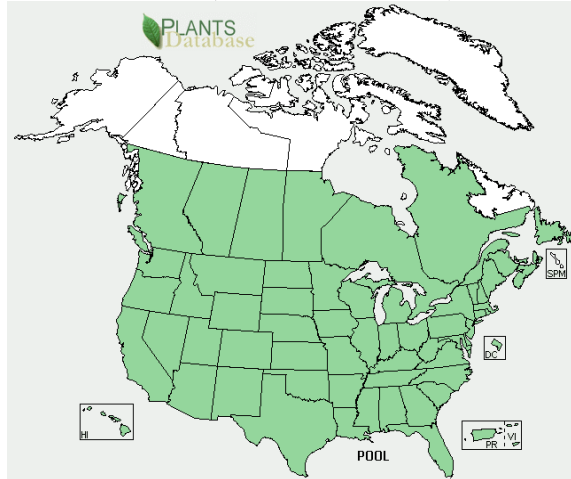
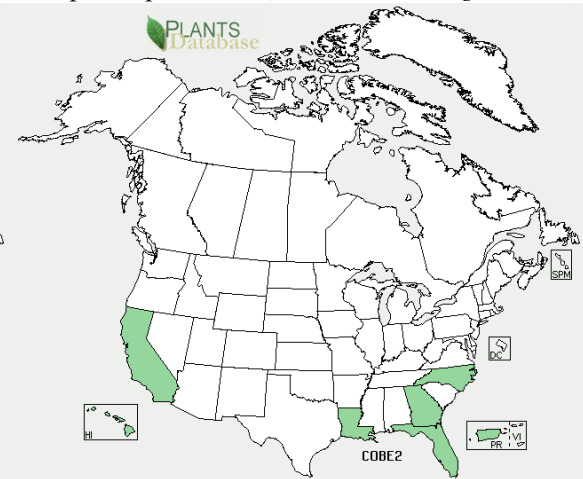
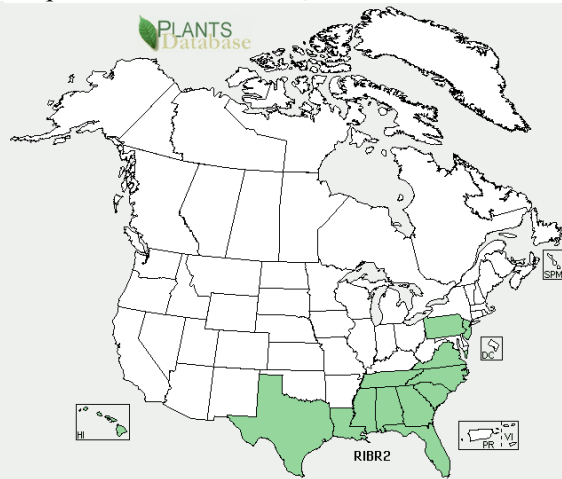
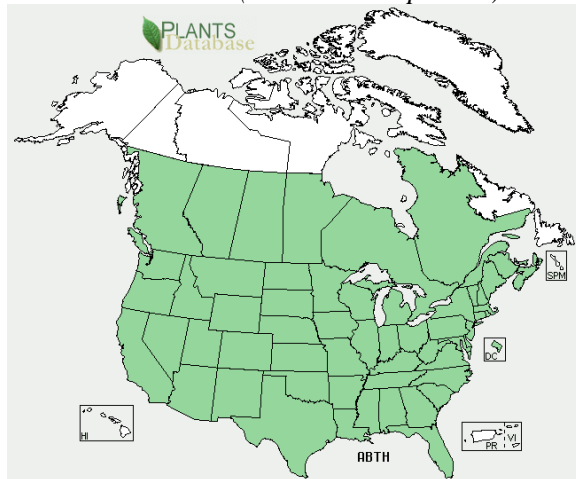


Oval-leaf false buttonweed (*Spermacoce latifolia*)



Pillpod sandmat (*Chamaesyce hirta*)



Purslane (*Portulaca oleracea*)Tropical Mexican clover (*Richardia brasiliensis*) Tropical spiderwort (*Commelina benghalensis*)Velvet leaf (*Abutilon theophrasti*)

**Appendix I. The Potential for Gene Flow from
Glyphosate-Tolerant Alfalfa (*Medicago
sativa* L.) to Related Species**

The Potential for Gene Flow from Glyphosate-Tolerant Alfalfa (*Medicago sativa* L.) to Related Species

1.0 Introduction

The potential for hybridization and subsequent impact of hybridization between sexually compatible species in the *M. sativa* (alfalfa) complex naturalized in North America is discussed in this report. Information on the success of crosses between taxonomically related species and a survey of related species naturalized in North America indicates that there is no evidence for sexually compatible relatives of *M. sativa* growing in North America.

The *M. sativa* complex has been sexually hybridized with 12 other perennial *Medicago* species (reviewed in Section VII, Subsection E.1 of Petition Number 04-110-01p). Two reports of successful crosses between annual medics and *M. sativa* have been reported but both are disputed by academic experts. A report by Skalska et al. (1992) was identified through a recent literature search where the authors claimed success at crossing annual medics with *M. sativa*. While the results from this report are disputed, they have no relevance to potential outcrossing in North America because the annual medics are not found in North America. Reported successful crosses between *M. lupulina* (annual medic naturalized and widespread in North America) and *M. sativa* also are disputed by several experts and are reviewed in this report.

Potential environmental impacts due to outcrossing from Roundup Ready alfalfa to cultivated or feral alfalfa (free living) are considered to be no different from cultivation of conventional alfalfa. APHIS has previously reviewed information submitted to the agency by Monsanto and FGI on the weediness characteristics of Roundup Ready alfalfa and have determined that the transformation process, and insertion of the *cp4 epsps* gene cassette in events J101 and J163 have not altered the weediness potential of alfalfa. Information submitted relating to the use of glyphosate for control of feral alfalfa indicates that feral alfalfa is rarely controlled with herbicide and if controlled, glyphosate is not the herbicide of choice for control. Thus, the herbicide tolerance trait does not provide a competitive advantage to alfalfa, and other herbicides are available to control alfalfa that may be tolerant to glyphosate.

1.1 Alfalfa taxonomy and Related Species

The taxonomy of alfalfa and related species are reviewed in Section II and VII of Petition 04-110-01p (the petition). A brief summary is provided below. The taxonomy of the genus *Medicago* has been modified periodically, and numerous misclassifications and synonyms are used (see table 1 and 2 for examples of synonymy).

Medicago sativa L. belongs in the order Fabales, family Fabaceae, tribe Trifolieae, genus *Medicago*. The genus *Medicago* is very extensive, consisting of more than 60 different species; two thirds of the species are annuals and one third are perennials (Quiros and Bauchan, 1988).

Commercially cultivated alfalfa properly belongs to the *M. sativa* complex, a group of closely related subspecies that are interfertile and share the same karyotype. The most commonly

cultivated alfalfa in the world is *M. sativa* subsp. *sativa*, but subspecies *falcata* is also cultivated on a limited basis, primarily under rangeland conditions and in colder regions (e.g., Canada and Siberia). Other subspecies in the complex include subsp. *glutinosa*, subsp. *coerulea*, subsp. *x tunetana*, subsp. *x varia*, subsp. *x polychroa*, and subsp. *x hemicycla* (Quiros and Bauchan, 1988). Two other closely related species, *M. prostrata* and *M. glomerata*, can be considered capable of limited natural hybridization with alfalfa (Quiros and Bauchan, 1988). *M. prostrata* and *M. glomerata* do not occur naturally in North America (table 3). *M. glomerata* is generally listed as one parent of subsp. *x tunetana*, which occurs in North Africa (Lesins and Lesins, 1979).

Cultivated and closely related species of alfalfa originated in Asia Minor, Transcaucasia, Turkmenistan and Iran. Particularly in Europe, Asia, the Middle East, and North Africa, current native populations of members in the *M. sativa* complex, as well as other perennial *Medicago* species, exist to which cultivated alfalfa would hybridize (Sinskaya, 1961; Lesins and Lesins, 1979; Ivanov, 1988). Based on a search for *Medicago* populations in the United States (<http://www.natureserve.org/explorer>) 14 matches were found (see table 4). All of the 14 matches were to plants non-native to North America and were either conspecific to *Medicago sativa* (three) or naturally sexually incompatible with *M. sativa* complex (eleven).

1.2 Updated Literature Search of Interspecific Hybridization in *Medicago*

In October 2007, literature databases were searched (AGRICOLA, BIOSIS, CAB, Chemical Abstracts, Chemical Engineering and Biotechnology Abstracts, Life Science Abstracts, MEDLINE) to reveal any recent or historical natural cross-hybridization information for alfalfa. Literature search results as well as the search terms used are listed in Appendix I-2. The literature search identified numerous reports regarding natural and assisted attempts of hybridization within the *M. sativa* complex. Skalska et al. (1992) reported that limited seed set occurred after hand crossing of pollen from four annual medic taxa onto *M. sativa* flowers. Skalska et al. (1992) inferred that the species were therefore “crossable” (see Appendix I-2, Section 2 for Abstract English translation); however, according to an expert in alfalfa and annual medic breeding, E. Charles Brummer, Ph.D., Iowa State University (Appendix I-4, paraphrase of Personal Communication), this single report of crossing to these annual medic species is unconvincing, has not been cited subsequently in the literature, and use of the taxonomy by Skalska et al. (1992) may be incorrect. Further, the hybridization to other annual medics has never been reported elsewhere. Evolutionarily, *M. sativa* is very distant from the annual members of *Medicago*. Regardless, the annual species named by Skalska et al. (1992) do not occur in North America.

1.3 Putative *M. lupulina* X *M. sativa* Hybrids

M. lupulina (black medic) is an annual (possibly a sometimes short-lived perennial) self-pollinating species and is known to occur throughout the United States. Successful hybridizations between *M. sativa* and *M. lupulina* were reported (Southworth, 1928; Fryer, 1930; Shrock, 1943). The validity of the *M. lupulina* x *M. sativa* putative hybridization reports were not substantiated and the hybrid cross has not been repeatable, although it was attempted numerous times (Petition appendix 4). The validity of this hybridization has been disputed since at least 1972 (Lesins and Gillies, 1972; Lesins and Lesins, 1979; Turkington and Cavers, 1979;

and the petition Section VII-E.1 and Appendix 4). According to Quiros and Bauchan (1988) and McCoy and Bingham (1988), no annual species are known to naturally hybridize with *M. sativa*. Expert alfalfa breeders provided comments on this cross in the petition's Appendix 4. *Medicago lupulina* (black medic) is the species that might be of most concern within the list of 18 annual species in the U.S. *Medicago lupulina* is considered a weed in lawns and waste places and in forages because its seeds frequently contaminate forage legume seed crops. Based on recent expert testimony (Petition Appendix 4), the documented dispute of the earlier findings, and the lack of any unambiguous scientific evidence to counter the expert testimony for the past 35 years, APHIS concurs with the expert comments presented in the petition Appendix 4 that *M. lupulina* x *M. sativa* hybridization and the potential for alfalfa gene flow to such a hybrid, is non-existent or would require as yet unfound conditions to occur successfully.

1.4 Potential Impacts from Outcrossing of Lines J101 and J163 to Wild Relatives

In 2005, APHIS evaluated the potential for hybridization and gene introgression to occur from J101 and J163 to sexually compatible wild (free-living) relatives, and considered whether such introgression would result in increased weediness. As previously discussed, there is no evidence for existence of any sexually compatible, free-living or cultivated relatives of *M. sativa* in the U.S. or North America. Thus, possible movement of the transgene via pollen from events J101 and J163 to other members of the *Medicago* genus (see table 3) would not occur in the U.S., or it would only occur following the introduction and establishment of one of the compatible species in proximity to events J101 and J163 in the U.S. Movement of the transgene to plants within the *M. sativa* complex (table 1) can be expected if the plants are located relatively near each other. Having established that there are no related wild relatives in the U.S., movement of the *cp4 epsps* gene can only occur to cultivated or feral alfalfa populations. APHIS has determined that if the glyphosate tolerance trait moves from J101 and J163 to other alfalfa populations in the U.S., this will not have a significant impact for the following reasons:

- All *Medicago* species are not native to the Western Hemisphere; hence, there will be no impact on the natural genetic resources of these species from release in the United States if glyphosate-tolerant individuals did arise through intraspecific hybridization.
- Tolerance to glyphosate would not confer any competitive advantage to these plants unless challenged by glyphosate. This would only occur in managed ecosystems where glyphosate is applied for broad-spectrum weed control or in plant varieties developed to exhibit glyphosate tolerance and in which glyphosate is used to control weeds. As with glyphosate-tolerant alfalfa volunteers, these individuals, should they arise and where they require control, could be controlled using other available chemical and/or mechanical means.
- Undesired crosses, if they developed, would not be controlled by the use of glyphosate and control would require use of non-glyphosate vegetation management practices. Currently, glyphosate is not widely used to control unwanted alfalfa vegetation (Petition Appendix 3).

Alfalfa is not considered a serious weed, a noxious weed or an invasive species in the United States, even though feral (free-living) populations are fairly common and volunteers may occur in succeeding crops. Generally feral populations, many of which are along roadsides, are not a

problem, and generally no attempts are made to control these populations. In some instances, these feral populations are considered advantageous and are encouraged (petition Appendix 3, p. 375, 12/31/02 Letter from South Dakota State University). More detailed information concerning feral populations of alfalfa and control of feral populations is in the petition's Section E.4 (p. 287), F.3 (p. 293) and Appendix 3 (p. 369). Alfalfa is frequently used in different crop rotations, varying with the region. The use of glyphosate-tolerant alfalfa is not expected to change current crop rotation options or patterns. More detailed information on crop rotations is addressed in Section F.1 (p. 291) and Section F.4 (p. 302) of the petition. Less than 100% stand termination can result in volunteer alfalfa plants in the following crop. Therefore good stand termination procedures would still be a good method of eliminating volunteer glyphosate-tolerant alfalfa plants. More detailed information on stand termination is addressed in the petition's Section B.6 (p. 259) and specifically for glyphosate-tolerant alfalfa in Section E.2 (p. 292). If volunteers of glyphosate-tolerant alfalfa are in a crop, management practices and recommendations to control these volunteers can be found in its Sections F.3 (p. 293) and F.5 (p. 303). Based on the available information on this subject, APHIS' opinion is that alfalfa is not an important weed in the United States, but care should be taken with other GT crops that may be chosen to follow GT alfalfa.

1.5 Conclusion

On the basis of information previously provided by Monsanto and FGI and reviewed in the petition as well as information provided in this report, it is concluded that alfalfa does not naturally hybridize with any related wild relatives in North America. Thus, hybridization can only occur to cultivated or feral alfalfa populations in the United States.

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Table I-1. Eight Taxa Comprising the *Medicago sativa* L. Complex and Common Synonyms.

- *Medicago sativa* subsp. *caerulea*
 - (≡) *Medicago caerulea* Less. ex Ledeb. (basionym)
 - (≡) *Medicago hemicoerulea* Sinskaya
 - (≡) *Medicago sativa* subsp. *microcarpa* Urb.
- *Medicago sativa* subsp. *falcata*
 - (≡) *Medicago borealis* Grossh.
 - (≡) *Medicago difalcata* Sinskaya
 - (≡) *Medicago falcata* L. (basionym)
 - *Medicago falcata* subsp. *glandulosa* (W. D. J. Koch) Greuter & Burdet [= *Medicago sativa* subsp. *falcata* var. *viscosa*]
 - *Medicago falcata* var. *glandulosa* W. D. J. Koch [= *Medicago sativa* subsp. *falcata* var. *viscosa*]
 - (≡) *Medicago falcata* var. *romanica* (Prodán) O. Schwarz & Klink.
 - *Medicago glandulosa* Davidov [= *Medicago sativa* subsp. *falcata* var. *viscosa*]
 - *Medicago procumbens* var. *viscosa* Rchb. [≡ *Medicago sativa* subsp. *falcata* var. *viscosa*]
 - (≡) *Medicago quasifalcata* Sinskaya
 - (≡) *Medicago romanica* Prodán
 - *Medicago sativa* f. *viscosa* (Rchb.) Urb. [≡ *Medicago sativa* subsp. *falcata* var. *viscosa*]
 - *Medicago sativa* subsp. *viscosa* (Rchb.) C. R. Gunn [≡ *Medicago sativa* subsp. *falcata* var. *viscosa*]
 - (≡) *Medicago tenderiensis* Opperman ex Klokov
- *Medicago sativa* subsp. *falcata* var. *viscosa*
 - (≡) *Medicago falcata* subsp. *glandulosa* (W. D. J. Koch) Greuter & Burdet
 - (≡) *Medicago falcata* var. *glandulosa* W. D. J. Koch
 - (≡) *Medicago glandulosa* Davidov
 - (≡) *Medicago procumbens* var. *viscosa* Rchb. (basionym)
 - (≡) *Medicago sativa* f. *viscosa* (Rchb.) Urb.
 - (≡) *Medicago sativa* subsp. *viscosa* (Rchb.) C. R. Gunn
- *Medicago sativa* subsp. *glomerata* (syn. *M. glutinosa*)
 - (≡) *Medicago glomerata* Balb. (basionym)
 - (≡) *Medicago glutinosa* M. Bieb.
 - (≡) *Medicago gunibica* Vassilcz.
 - (≡) *Medicago sativa* f. *glutinosa* (M. Bieb.) Urb.
- *Medicago sativa* nothosubsp. *hemicycla*
 - (≡) *Medicago hemicycla* Grossh. (basionym)
- *Medicago sativa* subsp. *sativa*
 - (≡) *Medicago agropyretorum* Vassilcz.
 - (≡) *Medicago asiatica* Sinskaya
 - (≡) *Medicago mesopotamica* Vassilcz.
 - (≡) *Medicago praesativa* Sinskaya
 - (≡) *Medicago rivularis* Vassilcz.
 - (≡) *Medicago sogdiana* Vassilcz.
 - (≡) *Medicago transoxana* Vassilcz.
- *Medicago sativa* nothosubsp. *tunetana*
 - (≡) *Medicago grossheimii* Vassilcz.
 - (≡) *Medicago polychroa* Grossh.
 - (≡) *Medicago sativa* subsp. *faurei* Maire
 - (≡) *Medicago sativa* f. *gaetula* Urb.
 - (≡) *Medicago tunetana* (Murb.) Vassilcz.
- *Medicago sativa* nothosubsp. *varia*
 - (≡) *Medicago falcata* var. *ambigua* Trautv.
 - (≡) *Medicago glutinosa* subsp. *praefalcata* Sinskaya
 - (≡) *Medicago komarovii* Vassilcz.
 - (≡) *Medicago media* Pers.
 - (≡) *Medicago sativa* subsp. *ambigua* (Trautv.) Tutin
 - (≡) *Medicago sativa* subsp. *praefalcata* (Sinskaya) C. R. Gunn
 - (≡) *Medicago sativa* var. *varia* (Martyn) Urb.
 - (≡) *Medicago schischkinii* Sumnev.
 - (≡) *Medicago tianschanica* Vassilcz.
 - (≡) *Medicago trautvetteri* Sumnev.

- (=) ***Medicago vardanis*** Vassilcz.
- (≡) ***Medicago xvaria*** Martyn (basionym)

Source: USDA, ARS, National Genetic Resources Program. Germplasm Resources Information Network - (GRIN) [Online Database]. National Germplasm Resources Laboratory, Beltsville, Maryland. URL: <http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?104921> (12 November 2007)

Table I-2. Numerous Species within the Genus *Medicago* with Synonyms

- ***Medicago agropyretorum*** Vassilcz. -> ***Medicago sativa*** L. subsp. ***sativa***
- ***Medicago arabica*** (L.) Huds.
- ***Medicago arabica*** (L.) Huds. subsp. ***inermis*** Ricker -> ***Medicago arabica*** (L.) Huds. **A**
- ***Medicago arborea*** L.
- ***Medicago asiatica*** Sinskaya -> ***Medicago sativa*** L. subsp. ***sativa***
- ***Medicago borealis*** Grossh. -> ***Medicago sativa*** L. subsp. ***falcata*** (L.) Arcang.
- ***Medicago caerulea*** Less. ex Ledeb. -> ***Medicago sativa*** L. subsp. ***caerulea*** (Less. ex Ledeb.) Schmalh.
- ***Medicago cancellata*** Bieb.
- ***Medicago carstiensis*** Jacq.
- ***Medicago cordata*** Desr. -> ***Medicago arabica*** (L.) Huds. **A**
- ***Medicago cuneata*** Woods -> ***Medicago orbicularis*** (L.) Bartal. **A**
- ***Medicago cupaniana*** Guss. -> ***Medicago lupulina*** L. **A**
- ***Medicago denticulata*** Willd. -> ***Medicago polymorpha*** L. **A**
- ***Medicago difalcata*** Sinskaya -> ***Medicago sativa*** L. subsp. ***falcata*** (L.) Arcang.
- ***Medicago disciformis*** DC.
- ***Medicago falcata*** L. -> ***Medicago sativa*** L. subsp. ***falcata*** (L.) Arcang.
- ***Medicago falcata*** L. var. ***romanica*** (Prodán) O. Schwarz & Klink. -> ***Medicago sativa*** L. subsp. ***falcata*** (L.) Arcang.
- ***Medicago hispida*** Gaertn. -> ***Medicago polymorpha*** L. **A**
- ***Medicago hysterix*** Ten. -> ***Medicago nigra*** (L.) Krock. **s**
- ***Medicago intertexta*** (L.) Mill.
- ***Medicago laciniata*** (L.) Mill.
- ***Medicago littoralis*** Rohde ex Loisel
- ***Medicago lupulina*** L.
- ***Medicago lupulina*** L. var. ***cupaniana*** (Guss.) Boiss. -> ***Medicago lupulina*** L. **A**
- ***Medicago maculata*** Sibth. -> ***Medicago arabica*** (L.) Huds. **A**
- ***Medicago marginata*** Willd. -> ***Medicago orbicularis*** (L.) Bartal. **A**
- ***Medicago marina*** L.
- ***Medicago mesopotamica*** Vassilcz. -> ***Medicago sativa*** L. subsp. ***sativa***
- ***Medicago minima*** (L.) Bartal.
- ***Medicago nigra*** (L.) Krock. -> ***Medicago polymorpha*** L. **A**
- ***Medicago officinalis*** (L.) E. H. Krause -> ***Melilotus officinalis*** (L.) Pallas
- ***Medicago orbicularis*** (L.) Bartal.
- ***Medicago orbicularis*** (L.) Bartal. var. ***marginata*** (Willd.) Benth. -> ***Medicago orbicularis*** (L.) Bartal. **A**
- ***Medicago orbicularis*** (L.) Bartal. var. ***microcarpa*** Rouy, nom. illeg. -> ***Medicago orbicularis*** (L.) Bartal. **A**
- ***Medicago pentacycla*** DC. -> ***Medicago nigra*** (L.) Krock. **s**
- ***Medicago polycarpa*** Willd. -> ***Medicago polymorpha*** L. **A**
- ***Medicago polymorpha*** L.
- ***Medicago polymorpha*** L. var. ***arabica*** L. -> ***Medicago arabica*** (L.) Huds. **A**
- ***Medicago polymorpha*** L. var. ***confinis*** Koch
- ***Medicago polymorpha*** L. var. ***lapponica*** Burnet
- ***Medicago polymorpha*** L. var. ***microdon*** Ehr.
- ***Medicago polymorpha*** L. var. ***orbicularis*** L. -> ***Medicago orbicularis*** (L.) Bartal. **A**
- ***Medicago praesativa*** Sinskaya -> ***Medicago sativa*** L. subsp. ***sativa***
- ***Medicago prostrata*** Jacq.

- **Medicago pubescens** (Edgew. ex Baker) Sirj.
- **Medicago quasifalcata** Sinskaya -> **Medicago sativa** L. subsp. **falcata** (L.) Arcang.
- **Medicago rigidula** (L.) All.
- **Medicago rivularis** Vassilcz. -> **Medicago sativa** L. subsp. **sativa**
- **Medicago romanica** Prodán -> **Medicago sativa** L. subsp. **falcata** (L.) Arcang.
- **Medicago rugosa** Desr.
- **Medicago sativa** L.
- **Medicago sativa** L. subsp. **caerulea** (Less. ex Ledeb.) Schmalh.
- **Medicago sativa** L. subsp. **falcata** (L.) Arcang.
- **Medicago sativa** L. subsp. **microcarpa** Urb. -> **Medicago sativa** L. subsp. **caerulea** (Less. ex Ledeb.) Schmalh.
- **Medicago sativa** L. subsp. **sativa**
- **Medicago scutellata** (L.) Mill.
- **Medicago sogdiana** Vassilcz. -> **Medicago sativa** L. subsp. **sativa**
- **Medicago suffruticosa** Ramond ex DC.
- **Medicago tenderiensis** Opperman ex Klokov -> **Medicago sativa** L. subsp. **falcata** (L.) Arcang.
- **Medicago transoxana** Vassilcz. -> **Medicago sativa** L. subsp. **sativa**
- **Medicago tribuloides** Desr. -> **Medicago truncatula** Gaertn.
- **Medicago truncatula** Gaertn.
- **Medicago x varia** Martyn

Species on this page (**A** = names approved by most authorities, **s** = approved as synonyms)

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Found on-line at: <http://www.plantnames.unimelb.edu.au/Sorting/Medicago.html>

Multilingual Multiscript Plant Name Database

[http://www.plantnames.unimelb.edu.au/Sorting/e-mailSorting Medicago names](http://www.plantnames.unimelb.edu.au/Sorting/e-mailSorting%20Medicago%20names)

Table I-3. *Medicago* Species Hybridized to Alfalfa and Their Distribution

Species	Distribution	Hybridization Method	Result ¹
<i>M. arborea</i>	Southern Europe from Canary Islands to Greece	Protoplast fusion	Viable hybrids formed between these sexually incompatible species (Nenz et al., 1996).
<i>M. cancellata</i>	Southeastern European Russia, north of Caucasus	Hand-pollination	Successful, but ploidy may interfere in crosses of certain genotypes because <i>cancellata</i> is a hexaploid.
<i>M. daghestanica</i>	Mid-mountain zone of Daghestan, Russia	Hand-pollination Ovule/embryo culture Hand-pollination using trispecies bridge	No seed produced. Successful. Alfalfa was hand crossed to a <i>daghestanica</i> x <i>pironae</i> hybrid that had been colchicine doubled to a tetraploid; resulted in hybrid seed.
<i>M. dzhawakhetica</i>	Mountains of Transcaucasia	Hand-pollination	Successful when using uneven ploidy levels. F ₁ were triploid and produced nonviable pollen. Backcrosses to alfalfa possible.
<i>M. glomerata</i>	Southern Europe to North Africa (Quiros and Bauchan, 1988)	Hand-pollination Natural	Successful Putative ancestor to subsp. x <i>tunetana</i>
<i>M. hybrida</i>	Corbier mountains and east Pyrenees	Ovule/embryo culture	Successful, no other data.
<i>M. lupulina</i>	Europe, most of Asia, North Africa, North America	Hand-pollination	DISPUTED/DISCOUNTED AS FALSE; Some reported hybrids, but contemporary experts contend they were selfed [also see Turkington and Cavers (1979)].
<i>M. marina</i>	Mediterranean and Black Sea shores, Atlantic coast of Iberia and France	Hand-pollination Ovule/embryo culture	Unsuccessful. Weak hybrids that did not produce flowers.
<i>M. papillosa</i>	Pontus mountains of north-eastern Anatolia to adjacent Caucasus mountains	Hand-pollination	Successful when using uneven ploidy levels.
<i>M. pironae</i>	Eastern Alps in northeast Italy	Ovule/embryo culture; Trispecies bridges	As for <i>daghestanica</i> , viz. ovule/embryo culture worked directly, but for hand-pollination, a trispecies bridge was required.
<i>M. prostrata</i>	Eastern Austria and Italy, eastern Adriatic coast to Greece	Hand-pollination	Successful, especially when <i>prostrata</i> is female
<i>M. rhodopea</i>	Mountain ranges of Bulgaria	Hand-pollination Ovule/embryo culture	Successful, but aberrant ploidies in progeny. Successful with normal chromosome complements.
<i>M. rugosa</i>	Mediterranean Region	Hand-pollination with embryo rescue	Single sterile plant only, no progeny produced (Piccirilli and Arcioni, 1992)
<i>M. rupestris</i>	Crimean mountains	Hand-pollination Ovule/embryo culture	Not successful. Successful, but F ₁ plants had very low fertility and backcross progeny were only produced using ovule/embryo culture.
<i>M. saxatilis</i>	Crimean mountains	Hand-pollination	Successful, particularly when alfalfa was maternal parent.
<i>M. scutellata</i>	Mediterranean region	Hand-pollination	Single plant only, no progeny produced; never replicated (Sangduen et al., 1982).

¹All data is taken from Lesins and Lesins (1979) or McCoy and Bingham (1988) unless otherwise noted. Table excludes all references to natural cross-pollination among subspecies in the *M. sativa* complex (see main text for further information).

Table I-4. Members of the Genus *Medicago* Found in North America as Listed by NatureServe Explorer.

<i>Medicago</i> sp. in North America	Evidence for Natural Hybridization to <i>Medicago sativa</i> Complex	Range of Occurrence
<i>M. arabica</i> Spotted Medic	No	CAN: BC, NB USA: AL, AR, CA, CT, DC, FL, GA, IL, LA, MA, ME, MO, MS, NC, NJ, OK, OR, PA, RI, SC, TX, VA, VT, WA
<i>M. laciniata</i> Cut-leaf Medic	No	CAN: ON USA: MA, ME
<i>M. littoralis</i> Water Medic	No	USA: NJ
<i>M. lupulina</i> Black Medic	No. Reports of hand-cross hybrids are disputed and discounted as false hybrids by numerous experts.	CAN: AB, BC, MB, NB, NF, NS, ON, PE, QC, SK USA: AK, AL, AR, AZ, CA, CO, CT, DC, DE, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV, WY
<i>M. minima</i> Small Medic-grass	No	USA: AL, AR, AZ, CA, CT, FL, HI, KS, LA, MA, MD, MI, MO, NC, NJ, NY, OK, OR, TN, TX, VA, WA
<i>M. monspeliaca</i> Hairy Medic	No	USA: AL, ME, MD, NY
<i>M. orbicularis</i> Button Medic	No	CAN: BC, ON USA: AL, CA, FL, GA, IL, LA, MD, MS, NC, NJ, OK, TN, TX
<i>M. polymorpha</i> Toothed Medic	No	CAN: BC, NB, ON, QC, SK USA: AK, AL, AR, AZ, CA, CT, FL, GA, HI, ID, LA, MA, ME, MI, MO, MS, MT, NC, NE, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, TN, TX, UT, VA, VT, WA, WY
<i>M. praecox</i> Mediterranean Medic	No	USA: CA, MA
<i>M. rugosa</i> Wrinkled Medic	No. A single hybrid plant was produced via hand-pollination and embryo rescue; no viable progeny produced..	USA: HI
<i>M. sativa</i> Alfalfac	Yes, Conspecific	CAN: AB, BC, MB, NB, NF, NS, ON, PE, QC, SK, YT USA: AK, AL, AR, AZ, CA, CO, CT, DC, DE, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV, WY
<i>M. sativa</i> ssp. <i>falcate</i> Yellow Alfalfa	Yes, Conspecific	CAN: AB, BC, MB, NS, ON, PE, QC, SK USA: AK, DE, IA, IL, KS, MA, MD, MI, MN, MS, MT, ND, NE, NJ, NV, PA, SD, UT, VA, WA, WY

Note: All data presented in NatureServe Explorer at <http://www.natureserve.org/explorer> were updated to be current with NatureServe's central databases as of October 6, 2007.

Note: This report was printed on November 11, 2007

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Appendix I-2. Literature Search

1.0 Literature Search on Interspecific Hybridization within the *Medicago* Complex

Literature databases were searched (AGRICOLA, BIOSIS, CAB, Chemical Abstracts, Chemical Engineering and Biotechnology Abstracts, Life Science Abstracts, MEDLINE) to reveal any additional recent or historical natural cross hybridization information for alfalfa. Literature search results as well as the search terms used are listed in Appendix X. The literature search confirmed that there are no sexually compatible relatives of *Medicago sativa* in North America. Thus, the risk for cross pollination and subsequent transgene introgression is limited to cultivated and feral alfalfa populations growing in North America. This information was reviewed by APHIS in Petition Number 04-110-01p, Section II (Subsection C), and Section VII (Subsection E.1).

1.1 Databases Searched

TOPIC/TITLE: SEARCH ON INTERSPECIFIC, HYBRID, AND ALFALFA TERMS

SOURCES USED:

CAB Abstracts

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FILE COVERS 1973 TO 2 Aug 2007

AGRICOLA

FILE COVERS 1970 TO 5 Jul 2007

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MEDLINE

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FILE COVERS 1907 - 7 Aug 2007 VOL 147 ISS 7

FILE LAST UPDATED: 6 Aug 2007

1.2 Search Strategy

L1 146304 ALFALFA OR LUCERNE OR MEDICAGO OR M(W) SATIVA
L2 15129 OUTCROSS? OR OUT(W) CROSS? OR INTERSPECIFI?(3A)(BREED? OR HYBRID?
OR CROSS?)
L3 60195 OUTCROSS? OR OUT(W) CROSS? OR INTERSPECIFI?(3A)(BREED? OR HYBRID
? OR CROSS?)
L4 45074 L3 NOT L2
L5 90163 CROSSBREED? OR CROSSBRED? OR (CROSS(3A)(BREED? OR BRED? OR POLLI
NAT?))
L6 1109 L5 AND INTERSPECIFI?
L7 44089 L4 NOT L6
L8 130 L1 AND (L2 OR L6)
L9 137147 ALFALFA OR LUCERNE OR (MEDICAGO OR M)(W) SATIVA
L10 100 L9 AND (L2 OR L6)
L11 365 L9 AND L4
L12 350 L11 NOT L10
L13 82470 (RELATE?)(3A) SPECIES
L14 268 L13 AND L9
L15 8033 L9 AND (CROSS? OR HYBRID?)
L16 57 L14 AND L15
L17 56 L16 NOT L10
Answer set saved and duplicates removed at a later date
L11 29 DUP REM L10 (27 DUPLICATES REMOVED)

L18 342 L12 NOT L17
L19 342 L18 NOT P/DT
L20 245 L19 AND ENGLISH/LA
Answer set saved and duplicates removed at a later date
L29 157 DUP REM L28 (88 DUPLICATES REMOVED)

L21 97 L19 NOT L20
Answer set saved and duplicates removed at a later date

L48 95 DUP REM L47 (2 DUPLICATES REMOVED)

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Appendix I-3. Alfalfa Terms

1.0 Related species as a phrase, hybrid & alfalfa terms

L11 ANSWER 1 OF 29 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 1

Title

Rhizobium lusitanum sp. nov. a bacterium that nodulates *Phaseolus vulgaris*

Source

International Journal of Systematic and Evolutionary Microbiology, (2006) Vol. 56, No. 11, pp. 2631-2637. 49 ref. Publisher: Society for General Microbiology. Reading ISSN: 1466-5026 URL: <http://ijs.sgmjournals.org> DOI: 10.1099/ijs.0.64402-0

Abstract

The species *Phaseolus vulgaris* is a promiscuous legume nodulated by several species of the family Rhizobiaceae. During a study of rhizobia nodulating this legume in Portugal, we isolated several strains that nodulate *P. vulgaris* effectively and also *Macroptilium atropurpureum* and *Leucaena leucocephala*, but they form ineffective nodules in *Medicago sativa*. According to phylogenetic analysis of the 16S rRNA gene sequence, the strains from this study belong to the genus *Rhizobium*, with *Rhizobium rhizogenes* and *Rhizobium tropici* as the closest related species, with 99.9 and 99.2% similarity, respectively, between the type strains of these species and strain P1-7T. The *nodD* and *nifH* genes carried by strain P1-7T are phylogenetically related to those of other species nodulating *Phaseolus*. This strain does not carry virulence genes present in the type strain of *R. rhizogenes*, ATCC 11325T. Analysis of the *recA* and *atpD* genes confirms this phylogenetic arrangement, showing low similarity with respect to those of *R. rhizogenes* ATCC 11325T (91.9 and 94.1% similarity, respectively) and *R. tropici* IIB CIAT 899T (90.6% and 91.8% similarity, respectively). The intergenic spacer of the strains from this study is phylogenetically divergent from those of *R. rhizogenes* ATCC 11235T and *R. tropici* CIAT 899T, with 85.9 and 82.8% similarity, respectively, with respect to strain P1-7T. The tRNA profile and two-primer random amplified polymorphic DNA pattern of strain P1-7T are also different from those of *R. rhizogenes* ATCC 11235T and *R. tropici* CIAT 899T. The strains isolated in this study can be also differentiated from *R. rhizogenes* and *R. tropici* by several phenotypic characteristics. The results of DNA-DNA hybridization showed means of 28 and 25% similarity between strain P1-7T and *R. rhizogenes* ATCC 11235T and *R. tropici* CIAT 899T, respectively. All these data showed that the strains isolated in this study belong to a novel species of the genus *Rhizobium*, for which we propose the name *Rhizobium lusitanum* sp. nov.; the type strain is P1-7T (=LMG 22705T=CECT 7016T).

Language

English

L11 ANSWER 2 OF 29 LIFESCI COPYRIGHT 2007 CSA on STN

Title

Rhizobium daejeonense sp. nov. isolated from a cyanide treatment bioreactor

Source

International Journal of Systematic and Evolutionary Microbiology [Int. J. Syst. Evol.

Microbiol.], (20051100) vol. 55, no. 6, pp. 2543-2549. ISSN: 1466-5026.

Abstract

A polyphasic study was carried out to determine the taxonomic position of two aerobic, cyanide-degrading bacterial strains, designated L61 super(T) and L22, which had been isolated from a bioreactor for the treatment of nickel-complexed cyanide. The two isolates exhibited almost identical taxonomic characteristics. Phylogenetic analysis inferred from comparative 16S rRNA gene sequences indicated that the isolates fall in a sublineage of the genus *Rhizobium* comprising the type strains of *Rhizobium giardinii*, *Rhizobium radiobacter*, *Rhizobium rubi*, *Rhizobium larrymoorei*, *Rhizobium vitis*, *Rhizobium undicola*, *Rhizobium loessense*, *Rhizobium galegae* and *Rhizobium huautlense*. Cells of the two isolates are Gram-negative, aerobic, motile and non-spore-forming rods (0 super(.)6-0 super(.)7x1 super(.)1-1 super(.)3 μ m), with peritrichous flagella. The DNA G+C content is 60 super(.)1-60 super(.)9 mol%. Cellular fatty acids are C sub(16 : 0) (2 super(.)2-3 super(.)3 %), C sub(18 : 0) (2 super(.)1-3 super(.)2 %), C sub(19 : 0) cyclo [omega]8c (9 super(.)9-16 super(.)8 %), C sub(20 : 3)[omega]6,9,12c (2 super(.)7-3 super(.)3 %), summed feature 3 (7 super(.)2-7 super(.)7 %) and summed feature 7 (67 super(.)8- 73 super(.)7 %). The strains formed nodules on a legume plant, *Medicago sativa*. A *nifH* gene encoding denitrogenase reductase, the key component of the nitrogenase enzyme complex, was detected in L61 super(T) by PCR amplification by using a *nifH*-specific primer system. Strains L61 super(T) and L22 were distinguished from the type strains of recognized *Rhizobium* species in the same sublineage based on low DNA-DNA hybridization values (2-4 %) and/or a 16S rRNA gene sequence similarity value of less than 96 %. Moreover, some phenotypic properties with respect to substrate utilization as a carbon or nitrogen source, antibiotic resistance and growth conditions could be used to discriminate L61 super(T) and L22 from *Rhizobium* species in the same sublineage. Based on the results obtained in this study, L61 super(T) and L22 are considered to be representatives of a novel species of *Rhizobium*, for which the name *Rhizobium daejeonense* sp. nov. is proposed. The type strain is L61 super(T) (=KCTC 12121 super(T)=IAM 15042 super(T)=CCBAU 10050 super(T)). Published online ahead of print on 12 August 2005 as DOI 10.1099/ijs.0.63667-0. The GenBank/EMBL/DDBJ accession numbers for the 16S rRNA gene sequences of strains L61 super(T) and L22 are AY341343 and DQ089696, respectively. The GenBank/EMBL/DDBJ accession number for the partial *nifH* gene sequence of strain L61 super(T) is AY428644. A transmission electron micrograph of cells of strain L61 super(T), a minimum- evolution phylogenetic tree and a table detailing the fatty acid compositions of L61 super(T), L22 and related *Rhizobium* species are available as supplementary material in IJSEM Online.

Language

English

L11 ANSWER 3 OF 29 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 2

Title

Variation in rDNA locus number and position among legume species and detection of 2 linked rDNA loci in the model *Medicago truncatula* by FISH

Source

Genome, (2005) Vol. 48, No. 3, pp. 556-561. 37 ref. Publisher: National Research

Abstract

Within Fabaceae, legume species have a variable genome size, chromosome number, and ploidy level. The genome distribution of ribosomal genes, easily detectable by fluorescent in situ hybridization (FISH), is a good tool for anchoring physical and genetic comparative maps. The organization of 45S rDNA and 5S loci was analysed by FISH in the 4 closely related species : *Pisum sativum*, *Medicago truncatula*, *Medicago sativa* (2 diploid taxa), and *Lathyrus sativus*. The 2 types of rDNA arrays displayed interspecific variation in locus number and location, but little intraspecific variation was detected. In the model legume, *M. truncatula*, the presence of 2 adjacent 45S rDNA loci was demonstrated, and the location of the rDNA loci was independent of the general evolution of the genome DNA. The different parameters relative to clustering of the rDNA loci in specific chromosome regions and the possible basis of rDNA instability are discussed.

Language

English

L11 ANSWER 4 OF 29 HCAPLUS COPYRIGHT 2007 ACS on STN

Title

Methods of transforming plants and identifying parental origin of a chromosome in those plants

Source

PCT Int. Appl., 79 pp. CODEN: PIXXD2

Abstract

Methods for plant transformation, for improving transformation efficiency, and for producing transgenic plants are provided. The methods comprise crossing a recipient plant from a genetic line of a plant species of interest with a donor plant selected from a transformation competent genetic line of the same plant species or of another closely related plant species to obtain a hybrid plant. Tissues obtained from the hybrid plant are transformation competent. These tissues can then be transformed with one or more nucleotide sequences of interest and selected for transgenic events having the nucleotide sequence of interest integrated within a chromosome derived from the recipient plant. Transformed cells can be selected and transgenic hybrid plants regenerated. The nucleotide sequence of interest can be introgressed into the genetic line from which the original recipient parent was derived, or into other genetic lines. Transformed plants and seeds are addnl. provided.

Table I-5. Patent Information

Patent Number	Kind	Date	Application Number	Date
WO 2002006500	A2	20020124	WO 2001-US22377	20010717
(1) WO 2002006500	A3	20021227		
US 2003046724	A1	20030306	US 2001-907411	20010717
US 2004194161	A1	20040930	US 2004-784418	20040223
US 7022894	B2	20060404		
US 2006101540	A1	20060511	US 2005-280890	20051116

- (1) **W:** AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW **RW:** GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW, AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR, BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG

Language

English

L11 ANSWER 5 OF 29 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 3

Title

Development of S-SAP markers based on an LTR-like sequence from *Medicago sativa* L

Source

Molecular Genetics and Genomics, (2002) Vol. 267, No. 1, pp. 107-114. 31 ref.
Publisher: Springer-Verlag. Berlin ISSN: 1617-4615

Abstract

The Sequence-Specific Amplification Polymorphism (S-SAP) method, recently derived from the Amplified Fragment Length Polymorphism (AFLP) technique, produces amplified fragments containing a retrotransposon long terminal repeat (LTR) sequence at one end and a host restriction site at the other. We report the application of this procedure to the LTR of the Tms1 element from *M. sativa*. Genomic dot-blot analysis indicated that Tms1 LTRs represent about 0.056% of the *M. sativa* genome, corresponding to 16x10³ copies per haploid genome. An average of 66 markers were amplified for each primer combination. Overall 49 polymorphic fragments were reliably scored and mapped in a F1 population obtained by crossing diploid *M. falcata* with *M. coerulea*. The utility of the LTR S-SAP markers was higher than that of AFLP or SAMPL (Selective Amplification of Microsatellite Polymorphic Loci) markers. The efficiency index of the LTR S-SAP assay was 28.3, whereas the corresponding values for AFLP and SAMPL markers were 21.1 and 16.7, respectively. The marker index for S-SAP was 13.1, compared to 8.8 for AFLP and 9.5 for SAMPL. Application of the Tms1 LTR-based S-SAP to double-stranded cDNA resulted in a complex banding pattern, demonstrating the presence of Tms1 LTRs within exons. As the technique was successfully applied to other species of the genus *Medicago*, it should prove suitable for studying genetic diversity within, and relatedness among lucerne species.

Language

English

L11 ANSWER 6 OF 29 HCAPLUS COPYRIGHT 2007 ACS on STN

Title

Molecular marker analyses in alfalfa and related species

Source

Advances in Cellular and Molecular Biology of Plants (2001), 6(DNA-Based Markers in

Plants (2nd Edition)), 169-180 CODEN: ACMBEF; ISSN: 1381-1932

Abstract

A review on the use of genetic markers to analyze the evolution, breeding, and genetics of alfalfa. The main application areas of mol. markers include anal. of interspecific hybridization, evaluation of genetic variation within and among populations, development of genetic linkage maps, and correspondence of parental genetic similarity with hybrid or synthetic yield.

Language

English

L11 ANSWER 7 OF 29 MEDLINE on STN

Title

Rapid identification of Medicago nodulating strains by using two oligonucleotide probes complementary to 16S rDNA sequences.

Source

Canadian journal of microbiology, (1997 Sep) Vol. 43, No. 9, pp. 854-61. Journal code: 0372707. ISSN: 0008-4166.

Abstract

Symbiotic bacteria associated with the Medicago genus are separated into two closely related species named Sinorhizobium meliloti and Sinorhizobium medicae. To discriminate rapidly between these two bacterial species, two 15-base DNA probes, 16Smfs and 16Smed, were designed from the alignment of 16S rDNA sequences to differentiate S. meliloti from S. medicae. Their specificities were evaluated by dot-blot hybridization experiments on 25 reference strains representing 13 species of Rhizobium and Sinorhizobium, and by comparison with all 16S rDNA sequences available in the GenBank data base. No cross-reaction was found with 16Smed, which was thus considered species specific for S. medicae. By contrast, as expected according to the 16S rDNA sequence alignment, the labeled 16Smfs probe cross-hybridized with the DNAs of S. meliloti, Sinorhizobium fredii, and Sinorhizobium saheli but not with the DNA of S. medicae. Since S. saheli and S. fredii do not nodulate Medicago, 16Smed and 16Smfs can be routinely used to characterize the two Sinorhizobium species nodulating Medicago from pure cultures or from Medicago root nodules. Fifty strains isolated from eight annual Medicago species were then characterized by using colony hybridizations. Sinorhizobium meliloti was more frequently obtained (> 80% isolates) than was S. medicae. Both Sinorhizobium species seemed to be trapped by annual Medicago and no plant-host specificity was detected.

Language

English

L11 ANSWER 8 OF 29 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

Evolutionary rate variation within Mus APRT.

Source

Genome, Oct 1996. Vol. 39, No. 5. p. 914-920 Publisher: Ottawa, Ontario, Canada : National Research Council of Canada. CODEN: GENOE3; ISSN: 0831-2796

Abstract

Rodents are thought to have relatively high rates of evolution, twice as fast as the rates for mammals in other orders. However, the uniformly high rates of evolution inferred for the order Rodentia from *Mus musculus* and *Rattus norvegicus* are not consistently found for other rodent species. Using a maximum likelihood phylogenetic algorithm (DNAML), we show here that *Mus spicilegus* has a fivefold different rate of evolution in 1100 bp around the adenine phosphoribosyltransferase gene (APRT) since its divergence from a common ancestor with *Mus musculus*. A greater than threefold difference in rates is also found in a comparison of the number of evolutionary events directly detected from the APRT sequences of these two closely related *Mus* species. The evolutionary events can be directly detected, since *M. spicilegus*, *M. musculus*, and the four rodent outgroup species used to determine the ancestral sequence are so closely related. One of the major differences between *M. spicilegus* and *M. musculus* that might affect evolutionary rate is the degree of commensalism with man. The *Mus* species therefore provide a useful model for testing various hypotheses for the causes of rate variations between genes, and possibly, between lineages.

Language

English

L11 ANSWER 9 OF 29 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 4

Title

Somatic hybrid plants between the forage legumes *Medicago sativa* L. and *Medicago arborea* L

Source

Theoretical and Applied Genetics, (1996) Vol. 93, No. 1/2, pp. 183-189. 30 ref. ISSN: 0040-5752

Abstract

Interspecific somatic hybrid plants were obtained by symmetrical electrofusion of mesophyll protoplasts of *Medicago sativa* with callus protoplasts of *M. arborea*. Somatic hybrid calli were picked manually from semi-solid culture medium after they were identified by their dual colour in fluorescent light. Twelve putative hybrid calli were selected and one of them regenerated plants. The morphogenesis of the somatic hybrid calli was induced by the synthetic growth regulator 1,2-benzisoxazole-3-acetic acid. Somatic hybrid plants showed intensive genome rearrangements, as evidenced by isozyme and RFLP analysis. The morphology of somatic hybrid plants was in general intermediate between the parents. The production of hybrids by protoplast fusion between sexually incompatible *Medicago* species is related to the in vitro responsiveness of the parental protoplasts. The possibility of using somatic hybrid plants in lucerne breeding is discussed.

Language

English

L11 ANSWER 10 OF 29 MEDLINE on STN

Title

Use of RAPD analysis for in situ identification of *Ascosphaera aggregata* and *Ascosphaera larvis* in larval cadavers of the alfalfa leafcutting bee, *Megachile rotundata*.

Source

Journal of invertebrate pathology, (1996 Jul) Vol. 68, No. 1, pp. 78-83. Journal code: 0014067. ISSN: 0022-2011.

Abstract

Chalkbrood of the alfalfa leafcutting bee, *Megachile rotundata*, is caused by the fungus *Ascosphaera aggregata*. We used random amplified polymorphic DNA (RAPD) analysis for the in situ identification of *A. aggregata* and a related species, *Ascosphaera larvis*, in larval cadavers of *M. rotundata*. A simple DNA extraction method was developed to preferentially isolate DNA from fungal spores on the cadaver surface, or from ascocysts beneath the cuticle. Similar banding patterns were obtained in *A. aggregata*-infected larval cadavers from different sources and geographic areas. The RAPD banding pattern of cadavers infected with *A. aggregata* differed from that of healthy leafcutting bee prepupae. RAPD analyses of cadavers infected with *A. aggregata* and *A. larvis* resulted in similar banding profiles as those obtained from corresponding pure fungal cultures of the two species. This suggests that the RAPD bands of infected cadavers were amplified from fungal DNA, rather than from other DNA associated with the leafcutting bee cadaver. The banding patterns of "sporulating" and "non-sporulating" chalkbrood cadavers exhibited no differences; this provides the first definitive evidence that both forms of the disease result from infection with *A. aggregata*.

Language

English

L11 ANSWER 11 OF 29 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 5

Title

The comparative phosphorus requirements of some temperate perennial legumes

Source

Plant and Soil, (1991) Vol. 133, No. 1, pp. 17-30. 37 ref. ISSN: 0032-079X

Abstract

P responses of *Lupinus polyphyllus*, *L. arboreus* and 7 temperate perennial pasture legumes were compared in a field trial over a range of 9 P rates, from 0 to 800 kg/ha. *Lupinus* spp. produced more than 5 t DM/ha in the absence of added P and showed no response to fertilizer. In contrast, the pasture legumes initially failed to grow without added P and responded to applications of between 200 and 800 kg/ha. At the higher P rates, DM production of pasture legumes was equivalent to that of *Lupinus* spp. In the first 2 years of the trial, the most productive pasture legume species at the higher rates of added P were also the most productive at the lower rates. P requirements for 90% of maximum yield varied greatly between species, but were closely related to maximum yield. Thus species with low P requirements for maximum yield were not necessarily P-efficient species. In the third and subsequent years of the trial *Lotus corniculatus* performed better than the other pasture legumes at the lower rates of added P. In contrast to other studies *Lotus pedunculatus* [*L. uliginosus*] showed no ability to outyield

Trifolium repens at low rates of P. Critical P concn of the pasture species for the late spring-early summer period declined in the order *T. repens* (0.34%) > *L. pedunculatus* (0.30%) > *T. pratense* (0.28%) > *T. hybridum* (0.27%) > *T. ambiguum* (0.26%) > *L. corniculatus* (0.23%). Mineralizable N levels were determined in soils under 3 species in the 7th year of the trial. At the lowest rates of added P, mineralizable N levels were much higher under *L. polyphyllus* than under *T. repens* or *L. corniculatus*. With increasing P rate, levels under the latter species increased, and at 100 kg P/ha were equivalent to those under *L. polyphyllus* with no added P.

Language

English

L11 ANSWER 12 OF 29 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 6

Title

Potential use of PCR-amplified ribosomal intergenic sequences in the detection and differentiation of *Verticillium* wilt pathogens

Source

Physiological and Molecular Plant Pathology, (1991) Vol. 39, No. 1, pp. 1-11. 28 ref. ISSN: 0885-5765

Abstract

The ribosomal genes from the 2 major pathogenic species, *V. albo-atrum* and *V. dahliae*, are essentially identical, but small differences were identified in the internal transcribed spacers (ITS 1 and ITS 2) of the 2 species. A cluster of 3 non-homologous nucleotides was observed in ITS 1 and a cluster of 2 in ITS 2. These differences permitted the synthesis of oligonucleotides that hybridized differentially with the rDNA of the 2 species and allowed for an efficient, fungus-specific amplification of either DNA sequence by a polymerase chain reaction (PCR). The results illustrate the effective use of intergenic sequences for the detection of fungus in a crop such as lucerne and also suggest that PCR-amplified intergenic sequences may provide sensitive probes for the differentiation of closely related species even when the mature rRNAs are too homologous or contain no exploitable sequence differences.

Language

English

L11 ANSWER 13 OF 29 HCAPLUS COPYRIGHT 2007 ACS on STN

Title

Immunotaxonomy of nodule-specific proteins

Source

Cytobios (1990), 61(244), 7-19 CODEN: CYTBAI; ISSN: 0011-4529

Abstract

Polyclonal antisera were prepared sep. from soluble protein exts. of nodules from 2 ureide-transporting legumes, *Glycine max* and *Sesbania exaltata*. The antisera were used to probe nodule exts. from 11 species from 6 Papilionaceae (Fabaceae) tribes. Comparison of nodule and root exts. by Ouchterlony double-diffusion, rocket immunoelectrophoresis, and Western blotting were used to identify nodule-specific

proteins (the so-called nodulins) among the species surveyed. The number of precipitin lines formed during double diffusion and rocket immunoelectrophoresis and the number of bands on Western blots of lithium dodecyl sulfate-solubilized polypeptides increased with commonality in nodule metabolism (ureide or amide transport) and similarity in nodule morphol. (determinate or indeterminate meristem). The number of precipitin lines and bands on Western blots did not necessarily increase among species considered to be taxonomically similar. LegHb, the only protein (a combination of both plant and rhizobial gene products) generally identified as common among the tribes, exhibited considerable variation in immunol. cross -reaction among the species. Very few, if any, nodule-specific proteins are common to all species nor are there any that are completely species-specific. A number of nodulins appear to be shared among metabolically similar species which are taxonomically related.

Language

English

L11 ANSWER 14 OF 29 CABA COPYRIGHT 2007 CABI on STN

Title

Dispersed repeats and structural reorganization in subclover chloroplast DNA

Source

Molecular Biology and Evolution, (1989) Vol. 6, No. 4, pp. 355-368. 44 ref. ISSN: 0737-4038

Abstract

Gene mapping was carried out on the chloroplast DNA (ctDNA) of *Trifolium subterraneum* varieties Tallarook and Woogenellup by hybridization of cloned restriction fragments with various probes, including cloned fragments of lucerne ctDNA. The results revealed that the chloroplast genome of *T. subterraneum* contains 10 rearranged gene clusters. Eight large inversions were sufficient to explain this reorganization; however, the actual evolutionary divergence between *Trifolium* and *Medicago* may have been more complex. A fine-scale analysis of a set of ribosomal protein genes revealed insertions, deletions and transpositions. Associated with this unusually unstable genome were 2 structural features potentially involved in the rearrangements. A dispersed family of repeats, with each element about 1 kb in length, was present in at least 6 copies. A previous survey of a wide taxonomic range of species indicated that these elements are unique to the ctDNA of *T. subterraneum* and 2 closely related species. Several of the repeated elements were associated with genomic rearrangements, and 1 repeat was inserted within a normally highly conserved series of genes. It is suggested that this set of dispersed repeats may be the first family of transposable elements found in any organelle genome. In addition, the *T. subterraneum* chloroplast genome is much larger than those in other closely related legumes, even when account is taken of the presence of the repeated elements. Some of the extra DNA had no sequence similarity to other chloroplast genomes and is thought to represent insertion of DNA from another genome. These unusual features may be implicated in the rapid and major reorganization of the ctDNA in *T. subterraneum*.

Language

English

Title

Effect of variation within and between *Medicago* and *Melilotus* species on the composition and dynamics of indigenous populations of *Rhizobium meliloti*

Source

Soil Biology & Biochemistry, (1988) Vol. 20, No. 1, pp. 31-38. 4 tab. 28 ref. ISSN: 0038-0717

Abstract

The effect of variation within and between legume species of the *Medicago* cross-inoculation group on the composition of populations of indigenous *Rhizobium meliloti* inhabiting nodules was evaluated with *Melilotus alba*, *Medicago lupulina* and *Medicago sativa* grown on three soils each collected from a site occupied by a long established population of one of these legumes (homologous species). Characterization of over 1400 nodule isolates on the basis of phage sensitivity revealed totals of 37, 75 and 87 distinct phage types of indigenous *R. meliloti* from the three soils, respectively. The distributions of phage types differed markedly between soils and on one soil an individual type dominated the nodule population accounting for over 60% of the isolates. The incidence and variety of phage types differed significantly between legume species grown on two of three soils indicating species variation in nodulation preferences for indigenous *R. meliloti*. Individual plants within each legume species were heterogeneous with respect to preferences for phage types although, overall, the extent of this variation differed between species and appeared related to pollination characteristics. The data indicate that the homologous legume species for a particular soil, irrespective of its pollination characteristics, consistently tended towards greater inter-plant homogeneity of nodulation preferences for indigenous *R. meliloti* than heterologous species grown on the same soil. On the basis of the evidence presented it is suggested that the legume host is an important factor determining the composition of its associated *Rhizobium* population. The implications of the results are discussed in relation to agricultural practice.

Language

English

Title

Tissue culture of legumes for crop improvement

Source

Plant Breeding Reviews, (1984) Vol. 2, pp. 215-264. 16pp. of ref. ISSN: 0730-2207

Abstract

Information is reviewed with respect to the following crop species (or genera) and species related to them which have potential breeding value: *Arachis hypogaea*, *Cajanus cajan*, *Cicer arietinum*, *Glycine max*, *Lotus corniculatus*, *Medicago sativa*, *Phaseolus vulgaris*, *P. acutifolius*, *P. coccineus*, *Pisum sativum*, *Psophocarpus tetragonolobus*, *Stylosanthes*, *Trifolium*, *Vicia faba*, *Vigna unguiculata*, *V. mungo*, *V. radiata*, *Ornithopus* and *Crotalaria juncea*. For many of the species the topics considered include all or some of the following: callus, cell-suspension, protoplast, anther, embryo, ovule, and shoot apical-meristem culture. A short section is devoted to somatic hybridization involving

legume + legume and legume + nonlegume combinations.

Language

English

L11 ANSWER 17 OF 29 CABA COPYRIGHT 2007 CABI on STN

Title

Interbreeding of *Lygus elisus* Van Duzee and *L. desertinus* Knight in the field

Source

Southwestern Entomologist, (1982) Vol. 7, No. 1, pp. 60-64. 3 ref. ISSN: 0147-1724

Abstract

The closely related species *Lygus elisus* Van D. and *L. desertinus* Knight occur on a variety of food-plants throughout western North America and are frequently found together. Studies were carried out in Arizona in 1980-81 on examples of the 2 species collected from nettleleaf goosefoot (*Chenopodium murale*) and lucerne to determine whether interbreeding occurs in the field. A high proportion (81%) of females of *L. desertinus* collected near Yuma, where the species coexists with *L. elisus*, produced offspring of both *L. desertinus* and *L. elisus* types. At Marana, near Tucson, where *L. elisus* is rare, only 17% of *L. desertinus* females produced mixed offspring. The results indicated that the 2 species are interbreeding in the Yuma area.

Language

English

L11 ANSWER 18 OF 29 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 8

Title

Peroxidase and leucine-aminopeptidase in diploid *Medicago* species closely related to alfalfa : multiple gene loci, multiple allelism, and linkage

Source

Theoretical and Applied Genetics, (1981) Vol. 60, No. 4, pp. 221-228. 23 ref. ISSN: 0040-5752

Abstract

Gel electrophoresis of leaf and root tissue of seedlings of selfed and crossed accessions of *M. sativa* and *M. falcata* revealed three anodal sets and one cathodal set of peroxidase isozymes which indicated the existence of four linked multiallelic loci (Prx1, Prx2, Prx3 and Prx4). In addition, two anodal sets of leucine aminopeptidase isozymes indicated the existence of two multiallelic loci (Lap1 and Lap2) that may be linked.

Language

English

L11 ANSWER 19 OF 29 CABA COPYRIGHT 2007 CABI on STN

Title

Enzyme electrophoresis as an aid for alfalfa breeding

Source

Agricultural Reviews and Manuals, Science and Education Administration, USDA,

(1981) No. ARM-NC-19, pp. 61. also Report of the twenty-seventh alfalfa improvement conference. July 8-10, 1980, University of Wisconsin, Madison. 4 ref. Price: Journal article; Conference paper .

Abstract

The uses of enzyme electrophoresis in *Medicago sativa* breeding are discussed under the following headings: (1) the identification of mother plants of breeding lines preserved in nursery plots, (2) the detection of natural cross pollination and hybridization , (3) the determination of genetic variability of accessions in a germplasm collection, (4) the detection of possible centres of diversity of *Medicago* species closely related to *M. sativa* , (5) the testing of maximum heterozygosity, and (6) the construction of linkage groups.

Language

English

L11 ANSWER 20 OF 29 CABA COPYRIGHT 2007 CABI on STN

Title

Development of procedures for detection and inheritance of resistance to *Phytophthora megasperma* Drechs. in diploid and tetraploid *Medicago* spp

Source

Dissertation Abstracts International, B, (1980) Vol. 41, No. 5, pp. 1589B. Order No: 8015208.

Abstract

Part of this work has been summarized elsewhere [see PBA 50, 7324]. For 58 S0 plants the correlation between mature root reaction and stem reaction to inoculation was highly significant. A similar correlation was seen in the S1 plants and F1 plants of a resistant X susceptible cross. Of 25 *Medicago* species accessions, all closely related to *M. sativa* , the most resistant were *M. coerulea* 'PI299046' and *M. falcata* 'PI377727'. The inheritance of resistance in diploid *M. sativa* 'CADL' was controlled by two dominant complementary genes, Pm1 and Pm2, while inheritance in *M. coerula* 'PI299046' was complex. In tetraploid *M. sativa* , two genetic systems conditioned resistance, viz. one in which susceptibility was incompletely dominant and the other in which the dominant complementary Pm1 and Pm2 were present. All plants from a cross of two resistant tetraploid *M. sativa* clones were resistant and this synthetic was designated WAPRS.

Language

English

L11 ANSWER 21 OF 29 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 9

Title

Aphidius eadyi n.sp. (Hymenoptera: Aphidiidae), a widely distributed parasitoid of the pea aphid, *Acyrtosiphon pisum* (Harris) in the Palearctic

Source

Entomologica Scandinavica, (1980) Vol. 11, No. 4, pp. 473-480. 5 fig. 11 ref. ISSN: 0013-8711

Abstract

Aphidius eadyi sp.n., a parasite of *Acyrtosiphon pisum* (Harris) (a pest of lucerne, peas and other leguminous crops) in the West Palearctic Region, is described. Its distribution and interspecific relations (crossing experiments) to the related species *Aphidius smithi* Sharma & Subba Rao are elucidated. The new species has been found to be a promising agent for the biological control of *Acyrtosiphon pisum*, but does not parasitise the lucerne pest *A. kondoi* Shinji [see next abstract].

Language

English

L11 ANSWER 22 OF 29 BIOSIS COPYRIGHT (c) 2007 The Thomson Corporation on STN

Title

CYTOLOGICAL AND FERTILITY RELATIONSHIPS OF DIFFERENT MEDICAGO SPECIES AND CYTO GENETIC BEHAVIOR OF THEIR HYBRIDS.

Source

Genetica Agraria, (1979) Vol. 33, No. 2-4, pp. 245-268. CODEN: GEAGAC. ISSN: 0016-6685.

Abstract

Crosses ($2x \cdot 2x$, $4x \cdot 4x$ and $2x \cdot 4x$) between different *M.* species [*M. hemicycla*, *M. coerulea*, *M. falcata*, *M. sativa*, *M. gaetula*, *M. glutinosa*] were made with the purpose of studying the relationship among the species through cytogenetic analysis, the extent of homology between their chromosomes and the possible origin of the tetraploid forms. Different ploidy level was the major obstacle to successful hybridization in interspecific crosses. In fact, an induced autotetraploid showed a higher crossability with the tetraploid species than the correspondent diploid species from which it originated. All the species used, once the difference in ploidy level was eliminated, crossed rather easily and the F1 hybrids showed a good degree of fertility both as seed production by self-pollination and inter-crossing and as pollen viability; diploid species had regular meiosis, tetraploid species showed some pairing abnormalities which were also observed in the F1 hybrids, especially those from $2x \cdot 4x$ and $4x \cdot 2x$ crosses. In general, the genomes of the species examined had a good chromosome homology. The multivalent frequencies were roughly the same in *M. sativa* and *M. glutinosa*. They were higher in the other tetraploid species and in the induced autotetraploid of *M. hemicycla*. Some F1 hybrids showed much higher multivalent frequencies; the values observed were always lower than the theoretical ones; the presence of quadrivalents even with low frequency, suggests an autotetraploid origin of *M. sativa* and of the other tetraploid species studied. The results also indicate that all these species are closely related and therefore may be considered variants of 7 original species.

Language

ENGLISH

L11 ANSWER 23 OF 29 BIOSIS COPYRIGHT (c) 2007 The Thomson Corporation on STN

Title

Evaluation of a nondestructive acetylene reduction assay of nitrogen fixation for pasture legumes grown in pots.

Source

New Zealand Journal of Experimental Agriculture, (1978) Vol. 6, No. 1, pp. 65-68.
CODEN: NZJEA3. ISSN: 0301-5521.

Abstract

Plants of *Trifolium repens* L. 'Grasslands Huia' (white clover), *T. pratense* L. 'Grasslands Turoa' (Montgomery red clover), *T. hybridum* L. (alsike clover), *T. pratense* L. 'Grasslands Pawera' (broad red clover), *T. subterraneum* L. 'Tallarook' (subterranean clover), *Medicago sativa* L. 'Grasslands Wairau' (lucerne) and *Lotus pedunculatus* Cav. (synonym: *L. uliginosus* Schkuhr, *L. major* Sm) 'Grasslands Maku' (lotus) were grown in pots with adequate moisture at day/night temperatures of 15° C/10° C and 23° C/10° C, and under moisture stress at 23° C/10° C. At weekly intervals during 5 and 6 wk growth periods successive non-destructive acetylene reduction (AR) assays were performed by incubating potted plants in 5 liter plastic containers for 2 h with 200 ml acetylene. N₂ fixation over the same periods was calculated from chemical analysis of plant tissue. AR and N₂ fixation rates were closely related within species and treatments, but the molar ratio of C₂H₂ reduced: N₂ fixed differed between clovers (mean ratio 2.8:1), lucerne (3.4:1) and lotus (4.3:1). Moisture stress increased the AR:N₂ fixed ratio, but temperature had no consistent effect. Repeated assays had no effect on herbage DM [dry matter] accumulation and herbage percent N.

Language

ENGLISH

L11 ANSWER 24 OF 29 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 10

Title

Pachytene chromosomes of perennial *Medicago* species. II. Distantly related species whose karyotypes resemble *M. sativa*

Source

Hereditas, (1972) Vol. 72, No. 2, pp. 289-302. 20 ref. Meeting Info.: Gillies, C. B. : Pachytene chromosomes of perennial *Medicago* species. I. Species closely related to *M. sativa*.

Abstract

M. daghestanica, *M. pironae* and their sterile hybrid had similar idiograms and the two species are probably closely related. The idiograms differed from those of the *M. sativa* -*falcata*-*glutinosa* complex only in proportional lengths of the chromosomes, hence the two groups may have a common ancestor. *M. rhodopea* and *M. rhodopea* X *M. rupestris* had almost identical idiograms, leading to the conclusion that *M. rhodopea* and *M. rupestris* are closely related. The idiogram of *M. rhodopea* was very similar to that of *M. sativa*, and in a triploid hybrid between diploid *M. sativa* and autotetraploid *M. rhodopea*, trivalent pairing was observed, confirming some homology between chromosomes of the two species. The *M. sativa* group and *M. rhodopea* group may have diverged only relatively recently. "In pachytene cells of *M. rhodopea* and two of the *M. rhodopea* X *M. rupestris* hybrids, a large darkly staining body was observed in the nucleoplasm. This was shown by pyronine/methyl green staining to contain RNA, and in behaviour resembled an accessory nucleolus".

Language

English

L11 ANSWER 25 OF 29 CABA COPYRIGHT 2007 CABI on STN

Title

Pachytene chromosomes of perennial *Medicago* species. I. Species closely related to *M. sativa*

Source

Hereditas, (1972) Vol. 72, No. 2, pp. 277-287. 26 ref.

Abstract

Pachytene chromosome complements of three diploid and one tetraploid species of perennial *Medicago* are illustrated. Caryotypic data and pachytene idiograms are presented for the diploids *Medicago coerulea*, *M. glandulosa* and *M. prostrata*. The chromosome-arm ratios and proportional lengths of the diploids are similar to published data for diploid *M. sativa*. Absolute length differences of pachytene chromosomes which occur between these species may be the result of differences in chromosome contraction. Tetraploid *M. glutinosa* has pachytene chromosomes similar in morphology to those of *M. sativa*. The presence of quadrivalents at pachytene suggested that *M. glutinosa* might be of autotetraploid origin."It is suggested that the standard pachytene idiogram for diploid *M. sativa* can be extended in use to cover all diploid species included in the *M. sativa* -*falcata*-*glutinosa* complex. Published genetic and hybridization data to support this suggestion are mentioned.

Language

English

L11 ANSWER 26 OF 29 CABA COPYRIGHT 2007 CABI on STN

Title

Taxonomy and cytogenetics of *Medicago*

Source

Agronomy, (1972) No. 15, pp. 53-86. 58 ref. Meeting Info.: Alfalfa science and technology. ISSN: 0065-4663

Abstract

A taxonomic key comprising 62 *Medicago* taxa is given with photographs of pods and other characteristic plant parts. Special consideration is given to the *M. sativa* -*falcata*-*glutinosa* complex. Based on morphological characters of diploid *M. sativa* and *M. falcata* an attempt is made to distinguish basic taxa from those which are of hybrid origin. Chromosome numbers are listed for 60 of the taxa considered in the key. Idiograms and caryotype data based on somatic chromosome studies are given for 22 annual and two perennial species and idiograms based on pachytene chromosome studies are shown for eight perennial and five annual species. A key is given for the identification of chromosomes of an *n* set of diploid *M. sativa*. Pachytene chromosomes corresponding to this *M. sativa* complement can be recognized in species related to *M. sativa*.

Language

English

L11 ANSWER 27 OF 29 BIOSIS COPYRIGHT (c) 2007 The Thomson Corporation on STN

Title

Trisomics in diploid alfalfa : L Production, fertility and transmission.

Source

CHROMOSOMA, (1967) Vol. 21, No. 3, pp. 232-242.

Abstract

Eight triploids were produced by pollinating male sterile alfalfa tetraploids with diploid lines of closely related "species " involving *Medicago sativa* , *M. falcata* and *M. coerulea*. Seeds were produced on all but one of the triploids by crossing them with diploid and tetraploid lines. Primary trisomic plants were obtained from the crosses with diploid lines and studies on their fertility and trisomic transmission are reported A brief review of the cytogenetic evidence indicates that the closely related "species " involved in these trisomics appear to be forms of a single polymorphic species and that cultivated tetraploid alfalfa behaves essentially as an autotetraploid. Thus, it is proposed that linkage groups established with these diploid trisomics will also represent the linkage groups of cultivated alfalfa. ABSTRACT AUTHORS: Authors

Language

Unavailable

L11 ANSWER 28 OF 29 BIOSIS COPYRIGHT (c) 2007 The Thomson Corporation on STN

Title

Cytological studies in alfalfa polyploids.

Source

CANADIAN JOUR BOT, (1954) Vol. 32, No. 4, pp. 531-542.

Abstract

Normal tetraploid alfalfa , *Medicago sativa* L., is characterized by meiotic irregularities consisting of a low percentage of univalents, trivalents, and quadrivalents. While these irregularities might suggest an autoploid origin, their frequency is too low to be conclusive. Cytological studies of the induced octoploid and of the hexaploid, obtained from crossing tetraploid and octoploid, indicate that the two genomes in the tetraploid are only partially homologous. The partial homology is established by the meiotic behavior in the hexaploid in which a low univalent frequency indicates a correspondingly low chiasma frequency at pachytene. Nevertheless this quadrivalent frequency in the octoploid is more than three times as high as in the tetraploid which suggests a lack of complete homology between the two genomes. The theory is advanced that tetraploid species of *Medicago* originated from crosses between a series of diploid species fairly similar cytologically out differing in well marked, morphological characters. This affords an explanation for the inheritance of some characters in a disomic and others in a tetrasomic manner. Cytological and genetic evidence thus points to tetraploid alfalfa as originating as an allopolyploid from closely related diploid species. ABSTRACT AUTHORS: Auth. abst

Language

Unavailable

L11 ANSWER 29 OF 29 HCAPLUS COPYRIGHT 2007 ACS on STN

Title

The production of tyrosinase among species of *Rhizobium* and related organisms

Source

Zentr. Bakt. Parasitenk (1933), II Abt. 88, 302-4

Abstract

Of the root-nodule bacteria, some cross inoculation groups, notably the bean, alfalfa and soy-bean groups, showed a higher percentage of cultures producing tyrosinase than did others.

Language

Unavailable

2.0 Interspecific, hybrid, & alfalfa terms in English – title only

L29 ANSWER 1 OF 157 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

Interspecific hybrids between *Medicago sativa* L. and annual *Medicago* containing Alfalfa weevil resistance.

L29 ANSWER 2 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 1

Title

Interspecific hybrids between *Medicago sativa* L. and annual *Medicago* containing Alfalfa weevil resistance.

L29 ANSWER 3 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 2

Title

Potential to increase yield in lucerne (*Medicago sativa* subsp. *sativa*) through introgression of *Medicago sativa* subsp. *falcata* into Australian adapted material.

L29 ANSWER 4 OF 157 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

White clover (*Trifolium repens*) and associated viruses in the subalpine region of south-eastern Australia: implications for GMO risk assessment.

L29 ANSWER 5 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 3

Title

New mitochondrial genome organization in three interspecific somatic hybrids of *Medicago sativa* including the parent-specific amplification of substoichiometric mitochondrial DNA units.

L29 ANSWER 6 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Compounds and genes for enhanced protein assimilation and digestibility in forage legumes: altering condensed tannins content in the leaves of forage legumes.

L29 ANSWER 7 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

A study of the mitochondrial DNA rearrangements in three interspecific somatic hybrids of *Medicago sativa*.

L29 ANSWER 8 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 4

Title

Molecular analysis of genetic variation among alfalfa (*Medicago sativa* L.) and *Medicago ruthenica* clones.

L29 ANSWER 9 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Inheritance and mapping of 2n-egg production in diploid alfalfa.

L29 ANSWER 10 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Molecular tagging of the Am gene from *Lycopersicon hirsutum* f. *glabratum* PI 134417 using AFLP markers.

L29 ANSWER 11 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 5

Title

Estimation of host-strain compatibility for symbiotic N-fixation between *Rhizobium meliloti*, several annual species of *Medicago* and *Medicago sativa*.

L29 ANSWER 12 OF 157 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

AFLP fingerprinting in *Medicago* spp.: its development and application in linkage mapping.

L29 ANSWER 13 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Chloroplast-transgenic plants are not a gene flow panacea.

L29 ANSWER 14 OF 157 BIOSIS COPYRIGHT (c) 2007 The Thomson Corporation on STN

Title

Breeding methods for forage legumes.

L29 ANSWER 15 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 6

Title

Chromosomal and molecular rearrangements in somatic hybrids between tetraploid *Medicago sativa* and diploid *Medicago falcata*.

L29 ANSWER 16 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 7

Title

A repetitive and species-specific sequence as a tool for detecting the genome contribution in somatic hybrids of the genus *Medicago*.

L29 ANSWER 17 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Karyotypic analysis of C-banded chromosomes of diploid alfalfa : *Medicago sativa* ssp. *caerulea* and ssp. *falcata* and their hybrid.

L29 ANSWER 18 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

The incidence of alfalfa mosaic virus in breeding material of *Medicago* spp. and its transmission by seeds.

L29 ANSWER 19 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 8

Title

Quantitative comparison of volatile compounds among seven *Medicago* spp. accessions.

L29 ANSWER 20 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 9

Title

The fate of ribosomal genes in three interspecific somatic hybrids of *Medicago sativa* : three different outcomes including the rapid amplification of new spacer-length variants.

L29 ANSWER 21 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 10

Title

Transgenic plantlets of 'Chancellor' grapevine (*Vitis* sp.) from biolistic transformation of embryogenic cell suspensions.

L29 ANSWER 22 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Cytogeography of *Medicago falcata* L. and *M. sativa* L. in Switzerland.

L29 ANSWER 23 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Ten years of research on *Medicago* at 'Istituto di Ricerche sul Miglioramento Genetico delle Pianta Foraggere del CNR di Perugia'.

L29 ANSWER 24 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 11

Title

A chromosome atlas and interspecific-intergenic index for *Lotus* and *Tetragonolobus* (Fabaceae).

L29 ANSWER 25 OF 157 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

Cytological, morphological and molecular analysis of controlled progenies from meiotic mutants of alfalfa producing unreduced gametes.

L29 ANSWER 26 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 12

Title

Molecular, cytological and morpho-agronomical characterization of hexaploid somatic hybrids in *Medicago*.

L29 ANSWER 27 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 13

Title

Registration of C-25, C-26, and C-27 alfalfa germplasms.

L29 ANSWER 28 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 14

Title

Registration of C-28, C-29, C-30, and C-31 alfalfa germplasms.

L29 ANSWER 29 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 15

Title

Unreduced gametes in ball clover and its relevance in white clover breeding.

L29 ANSWER 30 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Forage variety performance tests 1992-1993.

L29 ANSWER 31 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

ENOD12 gene expression as a molecular marker for comparing Rhizobium-dependent and -independent nodulation in alfalfa.

L29 ANSWER 32 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Registration of KS224 glandular-haired alfalfa germplasm with multiple pest resistance.

L29 ANSWER 33 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Identification of meiotic mutants producing 2n pollen in the *Medicago sativa* complex.

L29 ANSWER 34 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Evaluation of perennial pasture legumes for a central Victorian hill environment.

L29 ANSWER 35 OF 157 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

Diapause dynamics and host plant utilization of *Colias philodice*, *Colias interior* and their hybrids (Lepidoptera: Pieridae).

L29 ANSWER 36 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Forage variety performance tests 1991-1992.

L29 ANSWER 37 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 16

Title

Potential of trispecies bridge crosses and random amplified polymorphic DNA markers for introgression of *Medicago daghestanica* and *M. pironae* germplasm into alfalfa (*M. sativa*).

L29 ANSWER 38 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Pollen morphology as a tool for determining interspecific relationships in the genus *Medicago*.

L29 ANSWER 39 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 17

Title

Karyotype and C-banding in *Medicago noeana* Boiss., Leguminosae.

L29 ANSWER 40 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

New interspecific hybrids in the genus *Medicago* through in vitro culture of fertilized ovules.

L29 ANSWER 41 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 18

Title

Production of interspecific somatic hybrid plants in the genus *Medicago* through protoplast fusion.

L29 ANSWER 42 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 19

Title

Accumulation of potato virus Y is enhanced in *Solanum brevidens* also infected with tobacco mosaic virus or potato spindle tuber viroid.

L29 ANSWER 43 OF 157 MEDLINE on STN

Title

A PCR-based method of identifying species-specific repeated DNAs.

L29 ANSWER 44 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Production of interspecific hybrid plants in the genus *Medicago* through embryo rescue.

L29 ANSWER 45 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

The possibility of hybridization [between] *Medicago varia* Mart. and annual species of lucerne.

L29 ANSWER 46 OF 157 BIOSIS COPYRIGHT (c) 2007 The Thomson Corporation on STN

Title

Chromosome manipulations and genetic analysis in *Medicago*.

L29 ANSWER 47 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Performance of induced polyploids in North American forages.

L29 ANSWER 48 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 20

Title

The importance of endosperm balance number in potato breeding and the evolution of tuber-bearing *Solanum* species.

L29 ANSWER 49 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Genome manipulation and molecular genetic analysis of alfalfa (*Medicago sativa* L.).

L29 ANSWER 50 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 21

Title

Somatic hybrids of the forage legumes *Medicago sativa* L. and *M. falcata* L.

L29 ANSWER 51 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 22

Title

Segregation of molecular markers supports an allotetraploid structure for *Medicago sativa* X *Medicago papillosa* interspecific hybrid.

L29 ANSWER 52 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 23

Title

Protoplast fusion in the genus *Medicago* and isoenzyme analysis of parental and somatic hybrid cell lines.

L29 ANSWER 53 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 24

Title

Use of northern alfalfa as donor of valuable properties.

L29 ANSWER 54 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Interspecific somatic hybrid plants in the genus *Medicago* developed through protoplast fusion.

L29 ANSWER 55 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 25

Title

Comparison of pod-wall characteristics with seed damage and resistance to the alfalfa seed chalcid (Hymenoptera: Eurytomidae) in *Medicago* species.

L29 ANSWER 56 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Backcrossing tetraploidy into diploid *Medicago falcata* L. using 2n eggs.

L29 ANSWER 57 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Paternal inheritance of plastids in the genus *Daucus*.

L29 ANSWER 58 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Survival and growth of globemallow [*Sphaeralcea*] species in dryland spaced-plant nurseries.

L29 ANSWER 59 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Forage breeding in Taiwan.

L29 ANSWER 60 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Recurrent phenotypic selection for low grasshopper food preference in rangeland alfalfa.

L29 ANSWER 61 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 26

Title

Selection of interspecific somatic hybrids of *Medicago* by using *Agrobacterium*-transformed tissues.

L29 ANSWER 62 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Field resistance of perennial glandular-haired *Medicago* strains and alfalfa cultivars to the alfalfa weevil.

L29 ANSWER 63 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Identification of 2n and 4n gamete producers in an experimental population of diploid

Medicago.

L29 ANSWER 64 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 27

Title

Resistance to viruses in *Trifolium* interspecific hybrids related to white clover.

L29 ANSWER 65 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 28

Title

A potential solution to the chromosome instability problem in hexaploid alfalfa ,
Medicago sativa L.

L29 ANSWER 66 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Transfer of genes for aphid resistance from *Medicago truncatula* (barrel medic) via *M. littoralis* (strand medic) to *M. tornata* (disc medic).

L29 ANSWER 67 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Potential uses of embryo culture derived interspecific hybrids of alfalfa (*Medicago sativa* L.).

L29 ANSWER 68 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 29

Title

Allotetraploid behavior of hybrids of *Medicago sativa* L. and *M. papillosa* Boiss.

L29 ANSWER 69 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Cytology and cytogenetics of alfalfa.

L29 ANSWER 70 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Alfalfa and alfalfa improvement.

L29 ANSWER 71 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 30

Title

Tissue culture selection for disease resistant plants.

L29 ANSWER 72 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 31

Title

Electric field mediated fusion of protoplasts of *Medicago sativa* L. and *Medicago arborea* L.

L29 ANSWER 73 OF 157 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

Interspecific hybrid lines of *M. sativa* and *M. arborea* by protoplast electrofusion.

L29 ANSWER 74 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 32

Title

Dominant expression of a gene amplification-related herbicide resistance in *Medicago* cell hybrids.

L29 ANSWER 75 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Electrofusion of protoplasts and heterokaryon survival in the genus *Medicago*.

L29 ANSWER 76 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Methods for the selection of interspecific somatic hybrids in the genus *Medicago*.

L29 ANSWER 77 OF 157 LIFESCI COPYRIGHT 2007 CSA on STN

Title

Cytology and cytogenetics of alfalfa. ALFALFA AND ALFALFA IMPROVEMENT.

L29 ANSWER 78 OF 157 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

Forage breeding to improve yield and quality.

L29 ANSWER 79 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Preliminary analysis of chromosome stability in hexaploid hybrids of *Medicago sativa* X *M. papillosa*.

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Title

Independent inheritance of genes conditioning resistance to Phytophthora root rot from diploid and tetraploid alfalfa.

L29 ANSWER 81 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 33

Title

Cytogenetic analysis of interspecific hybrids between alfalfa (*Medicago sativa* L.) and *M. rhodopea* Velen.

L29 ANSWER 82 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 34

Title

Mitochondrial and chloroplast DNA analysis of interspecific somatic hybrids of a Leguminosae: *Medicago* (alfalfa).

L29 ANSWER 83 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Plant regeneration from cotyledon protoplasts of wild *Medicago* species.

L29 ANSWER 84 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Xerophytism in *Medicago*.

L29 ANSWER 85 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Selection for improved nutritional quality of alfalfa forage.

L29 ANSWER 86 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 35

Title

Interspecific hybridization of perennial *Medicago* species using ovule-embryo culture.

L29 ANSWER 87 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 36

Title

Interspecific relations and the breeding of pasture plants for semiarid regions.

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Title

FORAGE DRY MATTER ACCUMULATION AND QUALITY OF TURNIP
BRASSICA-RAPA SWEDE RAPE BRASSICA-NAPUS CHINESE CABBAGE

BRASSICA-CAMPESTRIS HYBRIDS AND KALE BRASSICA-OLERACEA IN THE
EASTERN USA.

L29 ANSWER 89 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Registration of 81IND-2 glandular-haired alfalfa germplasm.

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Library of the Department of Agriculture of the United States

Title

Hybrids between *Medicago taxa* in lucerne breeding.

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Title

Unreduced gametes in diploid *Medicago* and their importance in alfalfa breeding.

L29 ANSWER 92 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Unreduced gametes production in *Medicago* spp.: analysis of morphological and
cytological behaviour of F1 hybrids from 2x.4x and 4x.2x crosses.

L29 ANSWER 93 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Inheritance of density of erect glandular trichomes in the genus *Medicago*.

L29 ANSWER 94 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Alfalfa seed chalcid (Hymenoptera: Eurytomidae) infestation trials in annual *Medicago*.

L29 ANSWER 95 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 37

Title

Interspecific hybridization of *Medicago sativa* L. and *M. rupestris* M. B. using ovule-
embryo culture.

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Title

Verticillium wilt of alfalfa , background and current research.

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Title

Analytic breeding of alfalfa for resistance to Phytophthora root rot.

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Title

Registration of A169, A224, A603, A604, N.S. 31, N.S. 33, N.S. 46, and N.S. 47 broad-crowned or creeping-rooted alfalfa germplasms.

L29 ANSWER 99 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Use of meiotic analysis to describe genomic affinities in Medicago.

L29 ANSWER 100 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 38

Title

Uneven ploidy levels and a reproductive mutant required for interspecific hybridization of Medicago sativa L. X Medicago dzhawakhetica Bordz.

L29 ANSWER 101 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Influence of drought stress on genetic variances of alfalfa and wheatgrass seedlings.

L29 ANSWER 102 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 39

Title

Laboratory evaluation of medics for resistance to lucerne weevil.

L29 ANSWER 103 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Screening of Medicago species for resistance to alfalfa weevil.

L29 ANSWER 104 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Reproductive characteristics of hexaploid alfalfa derived from 3x X 6x crosses.

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Title

IN-VITRO CULTURE OF PODS FROM ANNUAL AND PERENNIAL MEDICAGO

SPECIES.

L29 ANSWER 106 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Interspecific hybrids of perennial *Medicago* species produced via ovule-embryo culture.

L29 ANSWER 107 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Analytic breeding of alfalfa : selection and breeding at the diploid level for resistance to *Phytophthora megasperma* f. sp. *medicaginis*.

L29 ANSWER 108 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 40

Title

Sources of resistance to spotted alfalfa aphid (*Therioaphis maculata* Buckton) in medics.

L29 ANSWER 109 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Genetic variances of alfalfa and wheatgrass populations grown under water application gradients.

L29 ANSWER 110 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Interspecific hybridization of alfalfa (*Medicago sativa*) and *M. rupestris*.

L29 ANSWER 111 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 41

Title

Light and electron microscopy of embryo development in an annual X perennial *Medicago* species cross.

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Title

Pollen germination and pollen tube growth following self-pollination and intra-and interspecific pollination of *Medicago* species [Includes *Medicago sativa*, alfalfa, fertilization, interspecific crosses].

L29 ANSWER 113 OF 157 BIOSIS COPYRIGHT (c) 2007 The Thomson Corporation on STN DUPLICATE 42

Title

GENETICS CYTOLOGY AND CROSSING BEHAVIOR OF AN ALFALFA
MEDICAGO -SATIVA MUTANT RESULTING IN FAILURE OF THE POST
MEIOTIC CYTOKINESIS.

L29 ANSWER 114 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Breeding alfalfa for tolerance to multiple cutting.

L29 ANSWER 115 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Description of several variants observed in plant introductions being increased at Reno,
Nevada.

L29 ANSWER 116 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Efficient hybridization of *Medicago dzhawakhetica* and *M. sativa* using a *M. sativa*
mutant lacking post-meiotic cytokinesis.

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Title

Hexaploid alfalfa derived from 3x X 6x crosses: a status report.

L29 ANSWER 118 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Testing a heterozygous block concept in advanced generations of *Medicago sativa* - *M.*
falcata hybrids.

L29 ANSWER 119 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Hybrids from diploid X tetraploid crosses in *Medicago* studied at two ploidy levels.

L29 ANSWER 120 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Studies on the breeding behavior of alfalfa, *Medicago sativa* L.: I. Selection in two
allele populations of tetraploid alfalfa. II. Mechanism of 2n egg production. III. Test of a
heterozygous block hypothesis in *M. sativa* - *M. falcata* hybrids.

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Title

Heinrichs alfalfa.

L29 ANSWER 122 OF 157 LIFESCI COPYRIGHT 2007 CSA on STN

Title

A perennial x annual *Medicago* cross.

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Title

The inheritance of 2n pollen formation in diploid alfalfa *Medicago sativa*.

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Title

Tetrasomic segregation for multiple alleles in alfalfa.

L29 ANSWER 125 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Transfer of glandular hairs from diploid *Medicago prostrata* to tetraploid *M. sativa*.

L29 ANSWER 126 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Hybridization of crop plants.

L29 ANSWER 127 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 43

Title

Production of two species and two interspecific hybrids of *phalaris* under irrigation in south-west New South Wales.

L29 ANSWER 128 OF 157 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 44

Title

Mating between *Pratylenchus penetrans* and *P. fallax* in sterile culture.

L29 ANSWER 129 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Genus *Medicago* (Leguminosae): a taxogenetic study.

L29 ANSWER 130 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Cytology and breeding of hexaploid alfalfa. I. Stability of chromosome number.

L29 ANSWER 131 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Influence of genetical and non-genetical sources of variability on number of eggs in lucerne ovaries.

L29 ANSWER 132 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Cultivated alfalfa at the diploid level: origin, reproductive stability, and yield of seed and forage.

L29 ANSWER 133 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Disease and insect resistance in cultivated grapes.

L29 ANSWER 134 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Saponins of the genus *Medicago*.

L29 ANSWER 135 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Classified list of herbage varieties England and Wales 1977/78.

L29 ANSWER 136 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Cytological analysis and electrophoretic patterns of seed proteins in *Medicago sativa*, *Medicago glutinosa* and their hybrids.

L29 ANSWER 137 OF 157 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

Interspecific crosses between *Rhizobium leguminosarum* and *Rhizobium melioli*: Formation of haploid recombinants and of R-primes [Nodule bacteria, inoculation tests with peas and lucerne]

L29 ANSWER 138 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Attempted interspecific hybridization of *Medicago scutellata* and *M. sativa*.

L29 ANSWER 139 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Alfalfa germplasm in the United States: genetic vulnerability, use, improvement, and maintenance.

L29 ANSWER 140 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Classified list of herbage varieties in England and Wales 1976/77.

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Title

Medicago falcata L. X *M. sativa* L. (lucerne) Cv. Walkabout (Reg. Number B-8b-2).

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Title

Some factors affecting production of two species and two interspecific hybrids of *Phalaris* under irrigation.

L29 ANSWER 143 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Registration of alfalfa germplasm from cultivated X wild hybrids.

L29 ANSWER 144 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Fodder improvement in *Pennisetums*.

L29 ANSWER 145 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Polyploidy in alfalfa breeding.

L29 ANSWER 146 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Breeding lucerne (*Medicago sativa* L.) with higher tolerance to water logging.

L29 ANSWER 147 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Reduction of chromosome number in root tip cells of *Medicago*.

L29 ANSWER 148 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Lucerne.

L29 ANSWER 149 OF 157 CABA COPYRIGHT 2007 CABI on STN

Title

Inheritance of the level of substances inhibiting *Trichoderma viridis* development in local populations of alfalfa.

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Title

Chromosome homology at pachytene in diploid *Medicago sativa*, *M. falcata* and their hybrids.

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Title

Interspecific crosses involving alfalfa. VII. *Medicago sativa* X *M. rhodopea*.

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Title

Cytology and evolution of the *Medicago sativa*-*falcata* complex.

L29 ANSWER 153 OF 157 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

Interspecific crosses involving alfalfa. VII. *Medicago sativa* X *Medicago rhodopea*

L29 ANSWER 154 OF 157 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

Interspecific hybrids involving alfalfa. VI. Ineffectiveness of allopolyploidy in induction fertility in *Medicago pironae* x *Medicago daghestanica* hybrids

L29 ANSWER 155 OF 157 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

Interspecific crosses involving alfalfa. V. *Medicago saxatilis* x *Medicago sativa* with reference to *Medicago cancellata* and *Medicago rhodopaea*

L29 ANSWER 156 OF 157 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

First generation crosses between two alfalfa species.

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Title

Pollen morphology as a tool for determining interspecific relationships in the genus *Medicago*.

3.0 Interspecific, hybrid, & alfalfa terms not in English – title only

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Title

[Genome analysis by molecular markers: III. Analysis of gene expression]. Analisi del genoma mediante marcatori molecolari: III. Studio dell'espressione genica.

L48 ANSWER 2 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

[Forage crops: 1998 varietal list]. Colture foraggere: liste varietali 1998.

L48 ANSWER 3 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Inter-species hybridization of alfalfa as the means to develop new species for the conditions of Ukrainian Polissya News of agrarian science..

L48 ANSWER 4 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

[National catalogue of varieties]. Catalogo nacional de variedades.

L48 ANSWER 5 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Kinetics of cell polyploidization in primary callus of different lucerne genotypes.

L48 ANSWER 6 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

[Resistance of interspecific hybrids of *Medicago* spp. and *Trifolium* spp. to some virus pathogens]. Rezistence mezidruhových hybridu *Medicago* spp. a *Trifolium* spp. k některým virovým patogenům.

L48 ANSWER 7 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

[Trials of herbage plants, root crops, maize, green fodder plants and potatoes 1994]. Afprøvnings af græsmarks- og bælgeplanter, rodfrugter, majs, grønne foderplanter og kartofler 1994.

L48 ANSWER 8 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Cytokaryological characterization of the lucerne species *Medicago lupulina* L., *Medicago borealis* Grossch. and their somatic hybrid, as an evaluation of source material for breeding for fodder value.

L48 ANSWER 9 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

[Varieties of herbage plants, root crops, maize, green fodder plants and potatoes 1993]. Sorter af græsmarksplanter, rodfrugter, majs, grønne foderplanter og kartofler 1993.

L48 ANSWER 10 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

[Interspecific crossing in lucerne]. Krzyżowanie międzygatunkowe lucerny.

L48 ANSWER 11 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Production of lucerne breeding material of the cutting type by means of distant hybridization.

L48 ANSWER 12 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

[Annual report, July 1988 - end 1990]. Rapport d'activité scientifique, juillet 1988 - fin

1990.

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Title

OBTAINING ASYMMETRICAL SOMATIC HYBRIDS IN THE GENUS
MEDICAGO.

L48 ANSWER 14 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Use of Medicago borealis as a donor of useful traits.

L48 ANSWER 15 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

[New lucerne variety NS-Novosaanka H11]. Nova sorta lucerke NS-Novosaanka H11.

L48 ANSWER 16 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

New varieties of perennial herbage crops.

L48 ANSWER 17 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Ecological and genetic parameters of survival and shoot production in lucerne plants.

L48 ANSWER 18 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Biotechnological methods of producing valuable forms of perennial fodder legumes.

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Title

Results of using interspecific and intergeneric hybridization in breeding perennial
herbage crops.

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Title

Sources of disease resistance in lucerne.

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Title

Evaluation of the combining ability of varieties and heterosis effects in lucerne hybrids produced using cytoplasmic male sterility (CMS).

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Title

Patterns in the expression of heterosis and the gene pool of fodder crops.

L48 ANSWER 23 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

[Prerequisites for the use of heterosis and synthetic populations in fodder crops].
Predpoklady vyuzivani heteroze a syntetickych populaci u picnin.

L48 ANSWER 24 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Comparative evaluation of hybrid lucerne varieties.

L48 ANSWER 25 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Heritability and variation in content of amino acids and protein in lucerne hybrids.

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Title

Tests with promising lucerne cultivars on solonetzic soils.

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Title

POLLEN FERTILITY IN ALFALFA PARENTS AND INTERSPECIFIC HYBRIDS.

L48 ANSWER 28 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Promising source material of perennial leguminous crops for breeding in the steppe zone of northern Kazakhstan.

L48 ANSWER 29 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Using induced polyploidy in breeding lucerne species of different chromosome numbers.

L48 ANSWER 30 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Primary problems in studying and utilizing the gene pool of fodder crops.

L48 ANSWER 31 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Producing single and complex lucerne hybrids.

L48 ANSWER 32 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Root rot pathogens in lucerne and crop resistance to them.

L48 ANSWER 33 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Breeding lucerne for resistance to diseases and high yield.

L48 ANSWER 34 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Polyploidy and interspecific hybrids of lucerne.

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Title

USE OF IN-VITRO METHODS IN BREEDING PROGRAMS FOR DISEASE
RESISTANCE IN PLANTS.

L48 ANSWER 36 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Results and methods of breeding lucerne for increased seed production.

L48 ANSWER 37 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Breeding perennial herbage crops in the Ukraine.

L48 ANSWER 38 OF 95 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 1

Title

Use of induced polyploidy and interspecific hybridization in producing lucerne
breeding material.

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Title

Evaluation of lucerne species and varieties for pod and seed set using the topcross method.

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Title

Somatic hybridization between *Medicago sativa* L. and *Medicago falcata* L.

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Title

Main results and prospects in genetical studies with perennial herbage crops.

L48 ANSWER 42 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Breeding lucerne for yield and quality. Methods of producing and evaluating hybrids for pastures.

L48 ANSWER 43 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Polyploidy and distant hybridization in breeding lucerne.

L48 ANSWER 44 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Breeding lucerne for quality.

L48 ANSWER 45 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Lucerne Donskaya 1.

L48 ANSWER 46 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Results of breeding perennial leguminous herbage crops for flood plains.

L48 ANSWER 47 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Fodder yield of synthetic lucerne populations.

L48 ANSWER 48 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Culture of cells, tissues and reproductive organs in breeding herbage crops.

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Title

Mobilization of fodder plant resources in Kazakhstan.

L48 ANSWER 50 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Evaluation of pasture-type lucerne hybrids in pasturage and simulated grazing.

L48 ANSWER 51 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

[Morphological and biological features of lucerne in relation to seed yield].
Morfologicko-biologicka charakteristika vojtesky ve vztahu k vynosu semene.

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Title

Initial material for producing heterotic lucerne hybrids.

L48 ANSWER 53 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Pod and seed set in top crosses of different varieties and hybrids of lucerne.

L48 ANSWER 54 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Some characteristics of seed set following intervarietal crosses of lucerne.

L48 ANSWER 55 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Production and evaluation of lucerne hybrids of the pasture type.

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Title

Results of studies of interspecific hybrids of alfalfa.

L48 ANSWER 57 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Polyploidy in interspecific crosses of lucerne species differing in ploidy.

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Title

Polyploidy in interspecific crossings of alfalfa species of different ploidy.

L48 ANSWER 59 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Content and composition of aminoacids in the protein of hybrid lucerne.

L48 ANSWER 60 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Breeding lucerne for resistance to frequent cutting during early stages of development.

L48 ANSWER 61 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Breeding lucerne for the Nonchernozem Zone.

L48 ANSWER 62 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Production of lucerne with branched inflorescence and intermediate falcate pods following the interspecific hybridization of *Medicago sativa* with *M. falcata*.

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Title

Interspecific crosses of lucerne.

L48 ANSWER 64 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Results of the collection and study of genetic resources of fodder plants.

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Title

Main results of work in the field of genetics at the Institute of Cytology and Genetics of the Siberian Branch of the Soviet Academy of Sciences during 1971-75.

L48 ANSWER 66 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Breeding lucerne for increased protein yield.

L48 ANSWER 67 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

New initial material of lucerne.

L48 ANSWER 68 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Features of the use of pollen-sterile lucerne plants in back crosses.

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Title

INVESTIGATIONS ON FACTORS INFLUENCING SEED SET IN MEDICAGO-FALCATA AND INTERSPECIFIC HYBRIDS OF MEDICAGO-FALCATA X MEDICAGO -SATIVA.

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Title

Genetic resources of wild Medicago falcata in the USSR and their importance for breeding and production.

L48 ANSWER 71 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Some results of breeding and seed-production work with lucerne in Azerbaijan.

L48 ANSWER 72 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Initial material for the production of high-yielding varieties and heterotic hybrids of lucerne.

L48 ANSWER 73 OF 95 AGRICOLA Compiled and distributed by the National Agricultural Library of the Department of Agriculture of the United States

Title

Investigations on factors influencing seed set in Medicago falcata and interspecific hybrids of Medicago falcata X Medicago sativa [Alfalfa] Untersuchungen uber den samenansatz beeinflussende faktoren bei Medicago falcata und artbastarden M. falcata X M. Sativa

L48 ANSWER 74 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

[Experiments in lucerne breeding in the USSR]. Erfahrungen bei der Luzernezüchtung in der UdSSR.

L48 ANSWER 75 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Importance for breeding of wild species of lucerne. (Brief review).

L48 ANSWER 76 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Resources of perennial forage plants in eastern Kazakhstan.

L48 ANSWER 77 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

[Species crosses in lucerne breeding at the Swedish Seed Association's Ultuna branch station]. Artkorsningar i lusernförädlingen vid Sveriges Utsädesförenings Ultunafilial.

L48 ANSWER 78 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Lucerne hybrids displaying heterosis.

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Title

INTERSPECIFIC CROSSES INVOLVING ALFALFA PART 7 MEDICAGO - SATIVA MEDICAGO-RHODOPEA HYBRID.

L48 ANSWER 80 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Breeding and seed production of perennial herbage crops for the Far East.

L48 ANSWER 81 OF 95 CABA COPYRIGHT 2007 CABI on STN DUPLICATE 2

Title

Agronomic evaluation of interspecific crosses of Medicago spp.

L48 ANSWER 82 OF 95 CABA COPYRIGHT 2007 CABI on STN

Title

Initial material for breeding lucerne for frost resistance.

L48 ANSWER 83 OF 95 BIOSIS COPYRIGHT (c) 2007 The Thomson Corporation on STN
Title

INTERSPECIFIC HYBRIDS INVOLVING ALFALFA -D PART 6
INEFFECTIVENESS OF ALLO PLOIDY IN INDUCTION FERTILITY IN
MEDICAGO-PIRONAE-D MEDICAGO DAGHESTANICA-D HYBRIDS.

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Title

INTERSPECIFIC CROSSES INVOLVING ALFALFA -D PART 5 MEDICAGO-
SAXATILIS-D X MEDICAGO -SATIVA -D WITH REFERENCE TO MEDICAGO-
CANCELLATA-D AND MEDICAGO-RHODOPAEA-D.

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Title

INTERSPECIFIC CROSSES INVOLVING ALFALFA -D IV MEDICAGO-
GLOMERATA-D MEDICAGO -SATIVA -D WITH REFERENCE TO MEDICAGO-
PROSTRATA-D.

L48 ANSWER 86 OF 95 BIOSIS COPYRIGHT (c) 2007 The Thomson Corporation on STN
Title

Intra- and intervarety crosses of *Medicago sativa* L. and *Medicago falcata* L.

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Title

INTERSPECIFIC CROSSES FOR THE IMPROVEMENT OF LUCERNE -D
MEDICAGO -SATIVA -D.

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Title

Interspecific crosses involving alfalfa. III. *Medicago sativa* L. x *M. prostrata* Jacq.

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Title

Interspecific crosses involving alfalfa. II. *Medicago cancellata* M. B. X *Medicago sativa* L.

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Interspecific crosses involving alfalfa. I. *Medicago dzhawakhetica* (Bordz.) Vass. X *M.*

sativa L. and its peculiarities.

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Title

Uchet entomofil'nosti pri vyvedenii sortov lyutsern Use of insect attraction in breeding lucerne varieties Number 80881. (Translation).

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Title

Important wild forage plants of the northern Caucasus. Original Title: Vazheishie dikorastushchie kormovye rasteniya severnogo Kavkaza.

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Cytogenetics of forage crops.

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Interspecific hybridization in Medicago.

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Title

Flower colour inheritance in diploid and tetraploid alfalfa.

Appendix I-4. Communication

1.0 Communication from E. Charles Brummer, Iowa State University, on Potential Natural Hybridization between Annual and Perennial Medics

From: ecbrummer@gmail.com [mailto:ecbrummer@gmail.com] **On Behalf Of** Charles Brummer
Sent: Tuesday, November 27, 2007 4:27 PM
To: Fitzpatrick, Sharie
Subject: Re: Annual medic X alfalfa, contd.
Hi Sharie,

You have my permission to use this letter as personal communication.

I have reviewed the Skalska et al. manuscript regarding hybridization of alfalfa with annual *Medicago* species. The limitations of the paper are significant as you describe below. I concur with all your statements below.

The major reservations I have about the paper, reiterating many that you have, are as follows:

1. Control self fertilization of the male sterile alfalfa plant to assess the potential for selfed seed production was not done--that is, the male sterility may not be complete.
2. Control hybridizations to other alfalfa (i.e., tetraploid *Medicago sativa*) plants was not done, so the potential hybridization efficiency is not noted.
3. No evidence is presented that the putative hybrids are actually hybrids and not selfs.
4. No evidence is presented that the putative hybrid seeds were viable and could germinate.

Therefore, I see no evidence in this paper that producing viable hybrids between tetraploid *M. sativa* and the annual species is possible, congruent with all previously published results that hybridization is not successful (with the exception of the Sangduen et al. paper, in which one *sativa* x *scutellata* plant was allegedly produced, but it was sterile and never replicated).

Let me know if you have other questions regarding this paper.

Best regards,

Charlie

On 11/28/07, **Fitzpatrick, Sharie** <SFitzpatrick@foragegenetics.com> wrote:

Dear Dr. Brummer:

Attached for your review are the original Skalska et al paper and the Polish to English translation of the main text. Please review in detail.

With your permission, I would intend to use your reply letter to me as a "personal communication" citation as an expert's review of this publication.

My review of the data lead me to the conclusions stated below. Please reply with your agreement, edits or other comments regarding whether or not you view the data sufficient to determine whether or not there is evidence that *Medicago sativa* produced viable hybrid progeny with any of the annual species listed and whether in your view, any other data in the literature would support these findings or discount them.

There is no evidence that seeds were viable or an attempt to germinate them; in fact "most were of dark color" and "most embryos died out" which indicate that the developed seeds were non-viable seeds. All of the data are only measurements of seed development, count, size and color.

There is no genetic evidence that putative hybrid seeds were interspecific hybrids.

There was no proper negative control (i.e., no attempt to self pollinate the *M. sativa* seed-parent plants to determine if they were fully pollen-sterile; it is known that most male sterile plants leak some viable pollen that can result in a low frequency of selfed seed of low vigor). The putative hybrid seeds may have been the result of *M. sativa* self pollination; there is no proof that they were cross-pollinated.

For all annual species, this would be the only account of interspecific hybridization between annual medics and *M. sativa* by hand pollination (with the exception of those already noted in Table II-1 from the 2004 Roundup Ready alfalfa Petition (see excerpt attached for your convenience; table summarized from published data).

Inferring from the author's closing statement that, 'the results indicate the usefulness of future research into tissue culture and cytological and biochemical methods to eliminate embryo lethality, the author's do not use their data to state that hand-crossing or natural crossing is a viable method of *M. sativa* X annual species hybridization.

Authors specifically state that hand crosses to *M. lupulina* were unsuccessful. This data supports that *M. sativa* and *M. lupulina* do not form hybrids. This supports statements made in Petition Appendix 4: "Expert Testimony of *M. sativa* with *M. lupulina*".

For perennial "species": All successful crosses were to other members of the *M. sativa* complex which is in agreement with Petition statements: i.e., *M. hemicycla*; *M. coerula*; *M. falcata*; *M. glutinosa* are synonyms for members of subspecies grouped within the *M. sativa* complex.

For the annual species listed below, this is the only account (except as noted for *M. scutellata*). Based on lack of evidence of viable hybrids, these putative hybridizations are unproven, in direct conflict with other literature, and should be discounted until proven.

M. aculeata
M. aculeata intermis
M. blanchiana
M. coronata
M. hispida

M. intertexta
M. lacininata
M. murex
M. nigra
M. orbicularus
M. rotata
M. scutellata-- previously noted by Sangduen et al., 1982; single hybrid not fertile, died out
M. truncatula

Thank you for your time.

Sharie Fitzpatrick

~~~~~  
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--

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## **Appendix J. Effects of Changes in Farming Practices on Water, Soil and Air Due to Use of Glyphosate-Tolerant Alfalfa**

# **Effects of Changes in Farming Practices on Water, Soil and Air Due to Use of Glyphosate-Tolerant Alfalfa**

## **Executive Summary**

Glyphosate-tolerant (GT) crops came on the market in 1996 and have been widely adopted since then. The primary selling feature of GT crops is the ability to apply the broad spectrum herbicide, glyphosate, directly on plants, which provides excellent weed control. Glyphosate is an attractive herbicide for farmers because it does not have restrictions regarding which crops can be planted in the field following the GT crop rotation.

### **Herbicide use associated with GT crops**

As anticipated by the developers of GT crops, the adoption of GT crops has shifted herbicide use away from many other herbicides to glyphosate and herbicide use has declined. Several analyses of pesticide use concluded that herbicide use has been reduced due to the adoption of herbicide-tolerant crops. (Brimner et al., 2005; Fernandez-Cornejo, 2006; Gianessi and Reigner, 2006; Kleter et al., 2007; Sankula, 2006; Johnson et al., 2008). One analysis of pesticide use concluded that herbicide use has increased due to herbicide-tolerant crops (Benbrook, 2004). All the studies agreed that herbicide use has shifted towards glyphosate. Using standardized methods for ranking environmental impact, researchers have concluded that glyphosate is less harmful to the environment than many other herbicides and that the shift of herbicide use has resulted in a net lower environmental impact from herbicides (Kleter et al., 2007).

### **Glyphosate occurrence in water, soil, and air**

Glyphosate adsorbs strongly to soil so doesn't generally move vertically below six inches. Glyphosate is rapidly degraded by soil microbes in the environment. The major degradate of glyphosate is aminomethyl phosphonic acid (AMPA), which degrades in the soil to form carbon dioxide. The half-life of glyphosate in soil laboratory studies is two days. In agricultural soils, the half-life of glyphosate ranges from 1.7 to 197.3 days, but is typically less than 60 days. Although glyphosate and AMPA have been detected in surface water and ground water, the concentrations are many times lower than levels where toxic effects might occur. Glyphosate has low volatility and has not been detected in air, other than possibly adhered to dust particles.

### **Non-glyphosate-tolerant, glyphosate-tolerant, and organic alfalfa**

Non-GT and GT alfalfa can be treated similarly regarding cultivation techniques and most herbicide applications. The difference between non-GT and GT alfalfa is glyphosate usage. Glyphosate can be used to remove non-GT stands, but can not be used for whole field weed control. Glyphosate can be used for in crop weed control in GT alfalfa but can not be used for stand removal. Organic farming practices do not permit the use of any herbicides. Cultivation weed control practices are permitted in organic farming.

## Herbicides associated with alfalfa farming

Herbicides related to alfalfa farming can be divided into two major groups, herbicides that do not kill alfalfa, so can be used to control weeds in alfalfa, and herbicides that kill alfalfa, so are used for stand removal. Adoption of GT alfalfa decreases the number of herbicides used to control weeds in alfalfa because glyphosate is the preferred herbicide for GT alfalfa. Adoption of GT alfalfa may increase use of some herbicides used for stand removal. For stand removal adoption of GT alfalfa may result in a shift from glyphosate to other herbicides. Herbicide shifts due to stand removal would be smaller in magnitude than herbicide shifts due to weeds control.

## Crop Rotations with alfalfa

Alfalfa is used in crop rotation because it provides nitrogen to the soil, which decreases fertilizer inputs in other rotations. Perennials and annuals promote and restrict different weeds, so rotating perennials with annuals helps control weeds in general.

Adoption of GT alfalfa affects crop rotations because glyphosate cannot be used for stand removal or volunteer alfalfa control. Therefore other herbicides, which may have rotation restrictions, may need to be used along with tillage to remove GT alfalfa stands. GT alfalfa stands may also last longer than non-GT alfalfa stands, therefore adoption of GT alfalfa may influence the number of years that alfalfa is in a rotation. It is recommended that rotations not consist of all GT crops. Because several of the crops that are popular in rotation with alfalfa (corn, soybeans) have GT varieties farmers may have to decide which GT crop provides the most benefit to the rotation plan and overall farm production.

## Companion crops

There are several types of companion cropping practices. These include crops that are interseeded with alfalfa and provide protection from wind and harsh weather or outcompete weeds in the stand establishment year, crops that are planted to cover the soil and prevent erosion between growing seasons, and barrier crops along side fields that serve as a refuge for beneficial insects and distract pests. Interseeded companion crops are not likely to be used with GT alfalfa. Mechanical and cultural methods for weed control (e.g. tillage and companion crops) were used for ~80% of the spring planted alfalfa and 18% of the fall planted alfalfa (Hower et al., 1999).

## Soil conservation

Soil conservation practices include, chiseling and subsoiling, conservation cover, conservation tillage (no-till, ridge-till, mulch till), contour farming, cover or green manure (legumes), critical area planting (erosion zones), crop residue use, filter strips, grade-stabilization structures, grass and legume in rotation, grassed waterways, strip cropping, and terracing. GT alfalfa is compatible with all soil conservation practices. GT crops are known to enhance the adoption of conservation tillage.

The cultural practices associated with GT crops and GT alfalfa have a net benefit on soil conservation and quality.

## 1.0 Introduction

Glyphosate-tolerant (GT) alfalfa is cultivated in a similar manner to conventional alfalfa, except that glyphosate can be applied “in crop” on GT alfalfa and glyphosate cannot be used for stand removal for GT alfalfa. Alfalfa, a perennial crop, can be grown for forage, seed or sprouts. This technical report discusses mainly forage (hay) alfalfa. Alfalfa grown for seed is noted where cultivation is different, for example, herbicide use is more common in seed crops than hay crops. Seed for alfalfa sprouts is not within the scope of this technical report. For a discussion of alfalfa sprouts, refer to the technical report *Glyphosate-Tolerant Alfalfa Presence in Human Food and Animal Feed* (appendix Q).

The life cycle of an alfalfa hay field includes field preparation, planting, stand establishment (first year), established stand maintenance (2-8 years), and stand termination (Orloff et al., 1997). If a crop is being harvested for hay, it is harvested multiple times per growing season, from 2-11 times depending on region. Seed crops are harvested once at the end of each growing season (Putnam et al., 2001). There are varying management practices that depend on the preference of the grower, such as harvest time, weed control method (herbicides or mowing), crop rotation, companion crop choice, insect and other pest control measures, and stand removal techniques. In general, the choice of methods can depend on the region, climate, weed spectrum, and intended market. Growers are assumed to fall into three broad categories of farming practices, conventional, GT, and organic. This technical report discusses herbicide use, tillage practices (during field preparation and stand removal), crop rotations, and companion crops for each of the three categories of farming and the effect these practices have on water, soil, and air. Insect pests and other pests (e.g., small mammals, nematodes, and diseases) may be controlled differently in organic farming versus conventional farming. However, because the use of GT alfalfa does not influence these control measures, they are not discussed in this technical report. Weed control is the only pest control for which GT alfalfa and conventional alfalfa differ.

### 1.1 Conventional Farming

Conventional farming includes any farming system where synthetic pesticides or fertilizers may be used. The definition of conventional farming usually includes the use of genetically engineered crops, but genetically engineered GT alfalfa is considered separately for this report (Harker et al., 2005). Conventional farming covers a broad scope of farming practices, ranging from farmers who only occasionally use synthetic pesticides and fertilizers to those farmers whose harvest depends on regular pesticide and fertilizer inputs.

### 1.2 GT Farming

GT alfalfa can be integrated into conventional farming practices. Farming GT alfalfa is mostly the same as farming conventional alfalfa, with a few important exceptions. Weeds can be controlled by the application of glyphosate directly on top of growing alfalfa, and, when alfalfa stands reach the end of their life cycle (typically after 3-8 years depending on growing region), glyphosate cannot be used to kill the stand to prepare for another rotation (Miller et al., 2006). In GT alfalfa, herbicides other than glyphosate, combined with tillage, are required to obtain 100 percent removal of an unwanted stand. Glyphosate can be used to prepare a field for alfalfa in

the stand establishment year. Several of the recommended GT alfalfa stand removal herbicides result in restrictions regarding what crops can be planted next, so careful crop rotation plans are necessary when using GT alfalfa.

Companion crops (usually annual grasses) are sometimes interseeded with alfalfa to provide benefits such as erosion control, protection of alfalfa seedlings from wind and frost, and reduced weed germination. The density of companion crops needs to be carefully managed, so the alfalfa seedlings do not suffer from too much competition (Orloff et al., 1997). For some farmers another important difference is that non-GT crops cannot be used as companion crops for GT alfalfa. For farmers that plant pure alfalfa stands this difference does not matter. For farmers that traditionally use companion crops, this difference is important. Companion crops can increase overall forage yield but decrease hay quality (McCordick et al., 2008).

Monsanto's Stewardship Program for GT alfalfa varieties includes the following features: 1) provides users of GT alfalfa with appropriate crop rotation practices, thereby enabling a smooth transition in and out of GT alfalfa; 2) provides vegetation control personnel (e.g., highway department personnel) with control options for feral alfalfa; 3) uses grower agreements to prevent unauthorized seed production; 4) provides the alfalfa seed production industry with gene flow information and analytical tools that will be used in the production of conventional and GT alfalfa varieties; and 5) provides Monsanto field personnel with ongoing training to address anticipated and unforeseen issues that may arise because of the introduction of the technology (Rogan and Fitzpatrick, 2004)

### 1.3 Organic Farming

For this report, organic production is only those cropping systems that fall under the USDA National Organic Program (NOP) definition of organic farming and are certified organic production systems. In organic systems, the use of synthetic pesticides, fertilizers, and genetically engineered crops is strictly limited. NOP publishes a list of approved substances for organic farming inputs (<http://www.ams.usda.gov/AMSV1.0/ams.fetchTemplateData.do?template=TemplateN&navID=NationalListLinkNOPNationalOrganicProgramHome&rightNav1=NationalListLinkNOPNationalOrganicProgramHome&topNav=&leftNav=NationalOrganicProgram&page=NOPNationalList&resultType=&acct=nopgeninfo>). GT alfalfa is not approved for use in organic systems because it is genetically engineered and because glyphosate application is not permitted in organic systems.

### 1.4 Methodology

A literature search was designed to identify peer review articles and grey literature (e.g., government reports, State Agricultural Extension Office publications) on cultivation practices in alfalfa and their effects on water, soil, and air (appendix J-2 of this technical report). Several DIALOG databases were searched. Google, Google Scholar, and Yahoo search engines supplemented the DIALOG search. Calculations for percentages of harvest were done with Microsoft Excel. Alfalfa harvest statistics were obtained from USDA's National Agricultural Statistics Service (<http://www.nass.usda.gov/index.asp>). In addition, USDA's Economics, Statistics and Market Information System (ESMIS), which is a collaborative project between

Albert R. Mann Library at Cornell University and USDA, provided information on alfalfa harvesting (<http://usda.mannlib.cornell.edu/MannUsda/homepage.do>). USDA's Agricultural Marketing Service also provided information on harvests (<http://www.ams.usda.gov>).

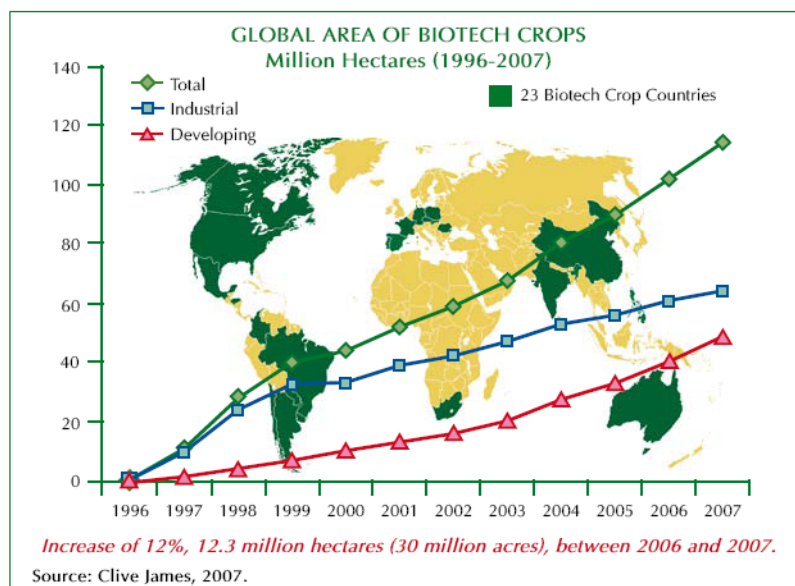


## 2.0 Herbicide Use in Alfalfa and GT Crops

This section discusses herbicide use on GT crops in general and in GT alfalfa. It does not discuss insecticides or genetically modified crops with traits other than glyphosate tolerance.

### 2.1 Current and Historical Herbicide Usage on GT Crops

The first GT crops were introduced in 1996. In 2007, the U.S. had the most biotech crops (herbicide and pest resistant combined) of any country (57.7 million hectares; James, 2007). Each year the International Service for the Acquisition of Agri-biotech Applications (ISAAA) publishes a report tracking global adoption of biotech crops. Figure J-1 presents the most current data. Brookes and Barfoot (2006) determined that on a global level, pesticide use has been reduced by 224 million kg of active ingredient (6.9% reduction) from 1996 to 2005.



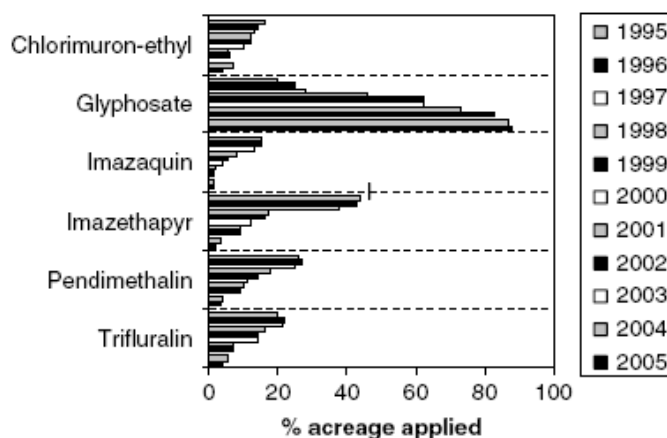
**Figure J-1: Global biotech crop adoption (James 2007)**

USDA Economic Research Service (ERS) evaluates U.S. statistics on biotech crops and herbicide use. The primary source of data for agricultural statistics in the United States is USDA's National Agricultural Statistics Service (NASS). This report focuses on herbicide-tolerant biotech crops only. Insect resistant crops are not explicitly included. United States adoption of herbicide resistant crops in 2005 was as follows (Sankula 2006):

- Herbicide resistant canola – 93% of national acreage (62% of national acreage was GT canola, 31% was glufosinate-tolerant)
- Herbicide resistant soybean – 88% of national acreage
- Herbicide resistant cotton – 80% of national acreage
- Herbicide resistant corn – 35% of national acreage

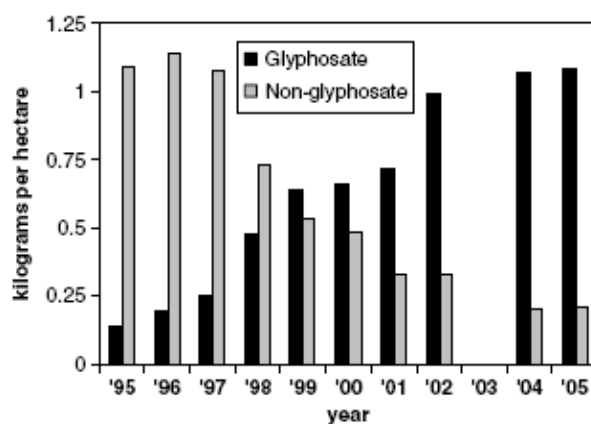
One of the anticipated benefits of GT crops was an herbicide shift to glyphosate, which is one of the less hazardous herbicides compared to the range of herbicides that are available for weed

control. In fact this herbicide shift has been observed. Herbicide use in soybean has a high percentage of adoption (>85 % of soybeans in the U.S. in 2007 were herbicide-tolerant) and serves as an example to illustrate the shift in herbicide use (Kleter et al., 2007). Figure J-2 presents the acreage for glyphosate application and five other herbicides on soybean fields. Figure J-3 presents the change in herbicide active ingredient per hectare.



**Figure J-2: Herbicide use in soybeans, percent of total acres, 1995-2005 (Kleter, 2007)**

Use of selected herbicides on soybeans in the USA, percentage of total acreage treated with herbicides. Data from NASS,<sup>-35</sup> herbicides selected with minimally 10% acreage in 1995; no survey was carried out in 2003.



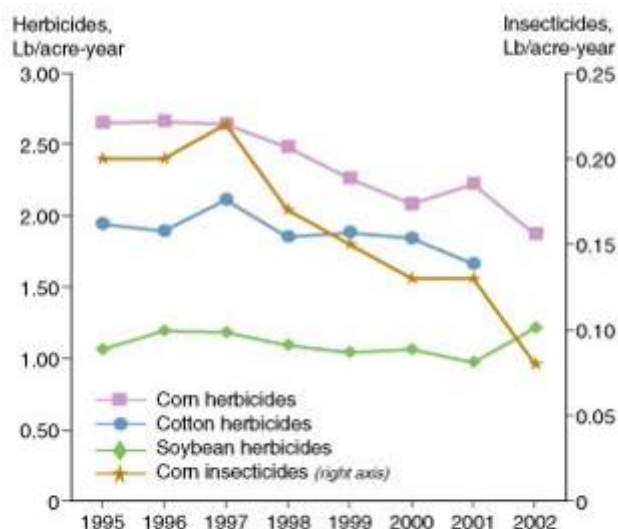
**Figure J-3: Herbicide use in soybeans, active ingredient per hectare, 1995-2005 (Kleter, 2007)**

Herbicide use on soybeans in the USA, average active ingredient per area treated with herbicides, 1995-2005. Data from NASS,<sup>-35</sup> no survey was carried out in 2003; data have been

converted to metric values employing a conversion factor of  $1 \text{ lb acre}^{-1} = 1.121 \text{ kg ha}^{-1}$ .

Overall, herbicide use in the United States shows a downward trend between 1995 and 2002, especially in corn (Fernandez-Cornejo, 2006). Figure J-4 from the USDA ERS Agricultural

Resources and Environmental Indicators (AREI) report presents herbicide application rates in corn, cotton, and soybean from 1995 to 2002.

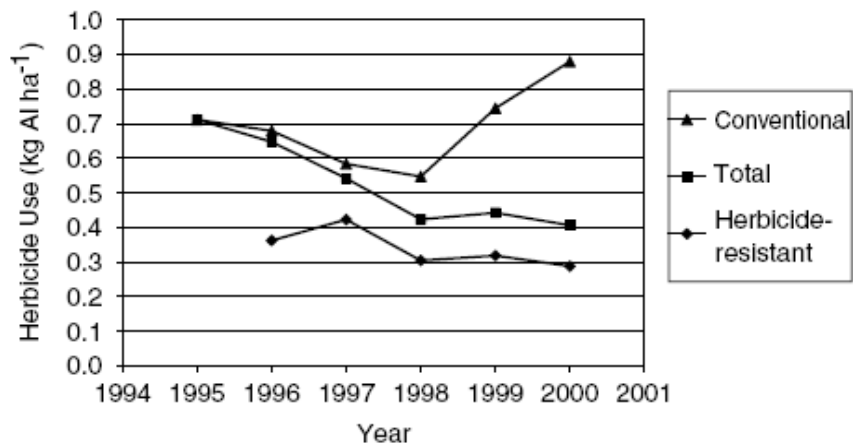


Source: USDA, NASS surveys.

**Figure J-4: Pesticide use in major field crops  
(Fernandez-Cornejo, 2006)**

Brimner et al. (2005) evaluated herbicide use in Canada on canola from 1995 to 2000. The amount of herbicide used in conventional canola fluctuated and increased by 29.5% from 1995 to 2000. In contrast, herbicide use in herbicide resistant canola declined by 20.4% (Brimner et al., 2005).<sup>37</sup>

<sup>37</sup> Herbicide resistant canola includes imidazolinone tolerant, glufosinate tolerant, and glyphosate tolerant varieties of canola.



**Figure J-5: Herbicide active ingredient use per hectare of canola (Brimner et al., 2005)**

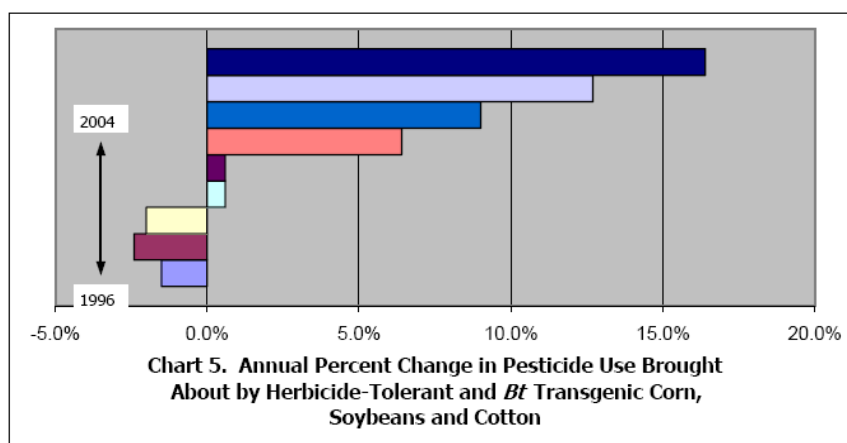
Benbrook (2004) evaluated the USDA NASS data on genetically modified crop acreage along with data on pesticide volumes used, from 1996 to 2004, and determined that genetically modified corn, soybeans and cotton have led to a 138 million pound increase in herbicide use since 1996, which is a 5% increase. Benbrook (2004) attributes this increase to increasing weed resistance to glyphosate and reduction in glyphosate prices after the patent expired. Benbrook (2004) concluded that across all crops, genetically modified crops reduced pesticide use from 1996 to 1998, but from 1999 to 2004, pesticide use increased. The USDA NASS data does not directly report amount of herbicide applied based on conventional versus GT varieties. NASS pesticide surveys report the percent of acres treated with a given pesticide, the average rate of application (for each distinct application), the average number of applications, the rate per crop year (average one-time rate multiplied by the number of applications), and the total pounds applied. NASS also reports total acres planted to corn, soybeans, and cotton by year, and the percent of acres planted to various genetically modified crops. Using these two sources of data, Benbrook (2004), estimated herbicide use on conventional versus herbicide resistant crops using the following equation:

$$\frac{\left[ \begin{array}{c} \text{Average herbicide rate (pounds per acre) for all acres of crop X} \\ - \\ \left[ \begin{array}{c} \% \text{ acres HT varieties for crop X} \\ \times \\ \begin{array}{c} \text{Rate herbicide application (pounds per acre) on HT crop X} \end{array} \end{array} \right] \end{array} \right]}{\begin{array}{c} \% \text{ acres non-HT varieties of crop X} \end{array}} = \begin{array}{c} \text{Herbicide Pounds Applied per Acre of Non-HT Variety of Crop X} \end{array}$$

The “rate of herbicide application in herbicide-tolerant acres” was estimated using NASS pesticide use data, coupled with information from herbicide manufacturers and universities.

At the request of Benbrook Consulting Services, USDA ERS reported for only 1998, both the percent of total soybean acreage by category (conventional varieties, no glyphosate applied; conventional varieties, glyphosate applied (mostly on no-till acreage); Roundup Ready® varieties; and other herbicide-tolerant varieties), as well as the average number of herbicides and

pounds of herbicides applied in each category. The average acre of herbicide-tolerant soybeans in 1998 was treated with 0.07 pounds more herbicide than conventional acres. Benbrook's (2004) summary is presented in figure J-6.



**Figure J-6: Annual percent change in pesticide use after introduction of genetically modified crops, 1996-2004 (Benbrook, 2004).**

Annual percent change in pesticide use brought about by herbicide-tolerant and *Bt* transgenic corn, soybeans and cotton.

Gianessi (2005) suggests additional factors besides increased weed resistance that could lead to increased herbicide use. The alternative explanations include: wet weather that may result in greater weed flushes, more no-till acres resulting in extra glyphosate applications, and lower cost of glyphosate resulting in growers increasing the rate of application to improve control of perennial weeds. Dill et al. (2008) indicate that GT corn shows a trend for increasing use of non-glyphosate herbicides, from 42 percent of acreage in 2002 to 55 percent of acreage grown in 2006.

Although Benbrook (2004) makes the case that there was a 138 million pound increase in herbicide use from 1996 to 2004, Gianessi and Reigner (2006) make the case that herbicide use decreased 61 million pounds (of active ingredient) between 1997 and 2002. Both studies used similar data sources, but Benbrook (2004) is based on only NASS data and Gianessi and Reigner (2006) used the National Pesticide Use Database (NPUD), which is based on the following:

- Surveys by the National Agricultural Statistics Service (NASS) [2,631 records]
- USDA Crop Profiles/Strategic Management Plans [657 records]
- State of California Department of Pesticide Regulation [1,054 records] - The State of California requires full reporting of pesticides used in agriculture.
- Survey of Extension Service Specialists [4,830 records]
- Other Sources [538 records] - Mint Industry Research Council, Cranberry Institute, U.S. Hop Plant Protection Committee, Oregon Hop Commission, and the New England Vegetable and Berry Growers Association. Estimates for statewide aggregations for Arizona and Nevada. Individual survey reports prepared at the state-level were available

for certain crops in several states: Nebraska, Washington, North Dakota, Georgia and Virginia.

- Assignments [567 records] - In cases where usage profiles for a crop in a state were not available from the above sources, usage estimates were assigned by assuming that a state's pesticide use profile for an active ingredient/crop combination is similar to that of a nearby state.

In cotton and soybeans between 1997 and 2002 the following herbicides were reduced, presumably replaced by glyphosate (Gianessi and Reigner, 2006):

- Bentazon reduced by 4.4 million pounds
- DSMA reduced by 0.8 million pounds
- Fluometuron reduced by 4.5 million pounds
- Imazethapyr reduced by 1.0 million pounds
- Metribuzin reduced by 1.5 million pounds
- MSMA reduced by 1.7 million pounds
- Paraquat reduced by 2.9 million pounds
- Pendimethalin reduced by 14 million pounds
- Sethoxydim reduced by 1.1 million pounds
- Trifluralin reduced by 13 million pounds

Other reductions in herbicides between 1997 and 2002 are attributed to the following (Gianessi and Reigner, 2006):

- Metolachlor was withdrawn from the market between 1997 and 2002 (1997 application was 67 million pounds). Corn growers switched to S-metolachlor which has a lower application rate than metolachlor.
- Glyphosate was adopted on many soybeans acres that were previously treated with metolachlor.
- Cyanazine was withdrawn from the market between 1997 and 2002 (1997 application was 20 million pounds). Cyanazine use in corn was replaced by glyphosate, mesotrione, rimsulfuron, and simazine.
- A 48 million reduction in corn herbicide was due to replacement of high rate herbicides (butylate, cyanazine, EPTC, metolachlor) with lower rate herbicides (flufenacet, mesotrione, rimsulfuron, S-metolachlor).

Sankula (2006) evaluated the impact of biotechnology-derived crops planted in the United States in 2005. A summary of the herbicide analysis follows:

- Herbicide-tolerant canola used less herbicide active ingredient per acre than conventional canola, which represented a reduction of 0.69 million pounds of herbicide use in 2005.
- Herbicide-tolerant corn reduced herbicide use in corn by 21.8 million pounds in 2005, which corresponds to a grower cost savings of \$269 million. Compared to 2004, grower returns were 94% higher and pesticide use was 18% lower due to a 67% increase in the adoption of herbicide resistant corn (due to EU approvals).

- Herbicide-tolerant cotton reduced pesticide use by 18 million pounds and reduced production costs by \$39 million.
- On average glyphosate-tolerant soybean programs used 1.03 pounds active ingredient per acre (lbs a.i./A) whereas conventional herbicide programs used an additional 0.32 lb a.i./A. This translates to a reduction of 39.4 million pounds of herbicide and a cost savings of \$134 million.

Johnson et al. (2008) evaluated the USDA NASS database and concluded that herbicide use in 2006 was reduced by 100.5 million pounds of active ingredient based on estimates of biotechnology-derived crop replacement of conventional crops.

## 2.2 Current Levels of Glyphosate in the Environment

### 2.2.1 *Current Levels of Glyphosate in Water*

In a U.S. Geological Survey (USGS) monitoring study of surface water, groundwater, and soil conducted from 2001 to 2006, the metabolite aminomethyl phosphonic acid (AMPA) was observed more frequently than the parent compound glyphosate (Scribner et al., 2007). The sample collections were from several USGS studies including the National Stream Quality Accounting Network Program, the National Water-Quality Assessment Program, and the Toxic Substances Hydrology Program. Additionally, glyphosate and its metabolite AMPA were found in surface water more frequently than groundwater. Higher occurrences of glyphosate and AMPA in ground and surface waters were observed when samples were taken from an area with greater proximity to agricultural areas with recent applications of glyphosate and with a recent rain event. During 2002, 171 samples were collected from 51 streams in 9 Midwestern states. Glyphosate was detected in 63 samples with a maximum concentration of 8.7 µg/L and AMPA was detected in 117 samples with a maximum concentration of 3.6 µg/L. From 2001 to 2003 water samples were collected twice a month from the Mississippi River at Baton Rouge, Louisiana. Out of the 35 samples collected, glyphosate was detected in none and AMPA was detected in 31, with a maximum concentration of 0.38 µg/L. In vernal pools glyphosate was detected in 31 of 76 samples with a maximum concentration of 328 µg/L and AMPA was detected in 30 samples with a maximum concentration of 41 µg/L. One area that had higher levels of contamination was the Leary Weber Ditch Basin, which is part of the White River Basin in Indiana. Of 117 ground water samples, glyphosate was detected in 40 samples with a maximum of 4.7 µg/L, and AMPA was detected in 85 samples with a maximum of 2.6 µg/L. Of 64 surface water samples, glyphosate was detected in 54 samples with a maximum concentration of 427 µg/L, and AMPA was detected in 52 samples with a maximum concentration of 29 µg/L. Glyphosate and AMPA were detected in 12 of 14 rainfall samples and concentrations ranged from 0.02 to 1.1 µg/L. However, this was due to glyphosate's association with particulate matter (dust), and not to its existence as vapor (Scribner et al., 2007).

Glyphosate dissipated from small forest ponds in southern Manitoba (half life of 3.5 to 11.2 days). Glyphosate and AMPA increased in sediment samples to day 36, suggesting that the sediments adsorption was a major sink (Goldsborough and Brown, 1993). In another study by the same researchers, a comparison of glyphosate dissipation from small forest ponds versus in

situ water microcosms, the half life in the ponds was 1.5 to 3.5 days and glyphosate remained at treatment levels in the water environments without soil (Goldsborough and Beck, 1989).

Major et al. (2003) studied sediments following application of glyphosate to control smooth cordgrass in marine bay environments. Their data indicate that glyphosate degradation is slower in estuarine habitats than in freshwater environments, and is more similar to degradation rates reported for agricultural soil.

In a study of the contribution of wastewater treatment plants (WWTP) to glyphosate and AMPA levels in surface waters, 40 samples were collected from upstream and down stream of 10 WWTPs and directly from effluent (Kolpin et al, 2006). Glyphosate and AMPA were detected in 67.5 percent of the samples. There was roughly a two-fold increase in the frequency of detection for both AMPA and glyphosate downstream of the WWTPs. The concentrations detected were generally low, but the maximum concentration of AMPA was 3.9 µg/L and the maximum concentration of glyphosate was 2.2 µg/L. The authors conclude that urban uses of glyphosate contribute to glyphosate and AMPA concentrations in streams (Kolpin et al., 2006). Although not stated by the authors, presumably the WWTPs served combined sewer systems, where street run off is sent to the WWTP along with waste water from drains in buildings.

Wauchope et al. (2001) used computer models to predict herbicide concentrations in surface water reservoirs under scenarios with different herbicide applications. To simulate GT corn versus non-GT corn, glyphosate and glufosinate were compared to atrazine and alachlor. In the monitoring data used to build the computer model, in almost all years, a single run-off event dominated the input into the reservoir. As a result annual herbicide concentrations were highly correlated with annual maximum daily values. Glyphosate and glufosinate loads in run-off were generally 1/5 to 1/10 those of atrazine and alachlor. The simulations indicate that if glyphosate and glufosinate completely or partially replace atrazine and alachlor there would be improvements in water quality.

Table J-1 presents a summary of the fate properties for glyphosate.

**Table J-1. Chemical Fate Properties of Glyphosate (EPA, 2006)**

| Property                                               | Value                                                                                       |
|--------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Common Name                                            | Glyphosate                                                                                  |
| Chemical Name                                          | <i>N</i> -(phosphonomethyl)glycine                                                          |
| Log Kow                                                | -3                                                                                          |
| Hydrolysis                                             | Stable $\geq 30$ days at pH 3, 6, and 9 at 5 and 35°C                                       |
| Photolysis                                             | Does not absorb light energy pH 5, 7, and 9                                                 |
| Metabolism in soil, half life                          | 1.85 – 2.06 day                                                                             |
| Metabolism water-sediment system, half life            | Aerobic: 7 days<br>Anaerobic: 8.1 – 199 days                                                |
| Soil Mobility, $K_{ads, Freundlich}$                   | 9.4 – 700 mL/g                                                                              |
| Soil water partition coefficient<br>$K_d$ (adsorption) | 62 Drummer silty clay loam<br>90 Ray silt<br>70 Spinks sandy loam<br>22 Lintonia sandy loam |



| Property                                                                              | Value                                                                               |
|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
|                                                                                       | 175 Cattail swamp sediment                                                          |
| Soil adsorption $K_{oc}$                                                              | 2100 (500 – 2600) (L/kg)<br>2600 – 4900 (L/kg)<br>8 to >500,000 (L/kg)<br>54 (L/kg) |
| Metabolite                                                                            | aminomethyl phosphonic acid (AMPA)                                                  |
| Field dissipation (application rate: 7.95 lb a.e./acre, 10.7 lb a.i./acre), half life | 13.9 days (median)<br>2.6 days in Texas<br>140.6 days Iowa                          |

A measure of pesticide persistence (half-life) and adsorption in soil ( $K_{OC}$ ) is the Groundwater Ubiquity Score (GUS), which can be calculated for pesticides in order to rank their potential to leach towards groundwater (Vogue et al., 1994).  $GUS = \log_{10}(\text{half-life}) \times [4 - \log_{10}(K_{OC})]$ , and values between 1 and 2 are low, 2 and 3 are moderate, 3 and 4 are high, and pesticides with a GUS greater than 4 has a very high potential to move toward groundwater. Glyphosate has a GUS of 1.17 with a half life of 13 days and a  $K_{OC}$  of 884, showing its low mobility and low risk of moving to groundwater. POEA (surfactant) has a GUS of 0.69 with a half life of 14 days and a  $K_{OC}$  of 2,500, showing that POEA also has very low potential to leach to groundwater. The GUS for other herbicides can be calculated from the values presented in table J-2. Glyphosate has a low vapor pressure and Henry's law constant; thus, it has a low potential to volatilize from soil and water (Vogue et al., 1994).

Table J-2 shows the results of a model that examined the environmental risks of various herbicides, all of which have low groundwater concentrations. These herbicides were evaluated in relation to glyphosate, and the relative risk gives an indication of which herbicides have greater impact on the environment. Relative risk is calculated by determining Risk Quotients (RQs), the estimated environmental concentration (based on environmental fate properties and application rates) divided by estimated concentrations in groundwater, and dividing the RQs by glyphosate's RQ. A relative risk less than one presents less risk than a relative risk greater than one. Glyphosate had less relative risk than most other active ingredients (Peterson and Hulting, 2004).

**Table J-2. Predicted Groundwater Concentrations of Active Ingredients Based on SCI-GROW Modeling (Peterson and Hulting, 2004)**

| Active Ingredient     | Application rate (g a.i./ha) | Groundwater value (ppb) | Relative Risk <sup>2</sup> | $K_{OC}$ <sup>3</sup> | Aerobic soil half-life (days) |
|-----------------------|------------------------------|-------------------------|----------------------------|-----------------------|-------------------------------|
| <b>Glyphosate</b>     | 840                          | 0.0005                  | 1                          | 2,100                 | 2                             |
| <b>2,4-D</b>          | 560                          | 0.005                   | 10                         | 48                    | 5.5                           |
| <b>Bromoxynil</b>     | 1,100                        | 0.0004                  | 0.8                        | 1,003                 | 2                             |
| <b>Clodinafop</b>     | 67                           | 0.00003                 | 0.06                       | 252                   | 1                             |
| <b>Clopyralid</b>     | 146                          | 0.06                    | 120                        | 36                    | 26                            |
| <b>Dicamba</b>        | 280                          | 0.1                     | 220                        | 13                    | 18                            |
| <b>Fenoxaprop</b>     | 90                           | 0.000006                | 0.01                       | 9,490                 | 1                             |
| <b>Flucarbazone</b>   | 34                           | 0.2                     | 400                        | NA                    | NA                            |
| <b>MCPA</b>           | 1,457                        | 0.26                    | 520                        | 110                   | 25                            |
| <b>Metsulfuron</b>    | 9                            | 0.004                   | 8                          | 42                    | 28                            |
| <b>Thifensulfuron</b> | 22                           | 0.0001                  | 0.2                        | 28                    | 6                             |
| <b>Tralkoxydim</b>    | 280                          | 0.001                   | 2                          | 30                    | 5                             |

| Active Ingredient | Application rate (g a.i./ha) | Groundwater value (ppb) | Relative Risk <sup>2</sup> | K <sub>oc</sub> <sup>3</sup> | Aerobic soil half-life (days) |
|-------------------|------------------------------|-------------------------|----------------------------|------------------------------|-------------------------------|
| Triallate         | 1,100                        | 0.04                    | 80                         | 1,601                        | 54                            |
| Triasulfuron      | 34                           | 0.05                    | 100                        | 105                          | 114                           |
| Tribenuron        | 16                           | 0.00003                 | 0.06                       | 52                           | 2                             |
| Trifluralin       | 1,100                        | 0.009                   | 18                         | 7,200                        | 169                           |

<sup>2</sup> Relative risk compared with glyphosate; values highlighted in grey indicate greater risk relative to glyphosate

<sup>3</sup> K<sub>OC</sub>, soil adsorption coefficient

Malone et al., (2004) tested the preferential flow of several herbicides after simulated rainfall using USDA-ARS maintained lysimeters. The lysimeters have 8.1 m<sup>2</sup> in surface area, 2.4 meters deep and wall strips to prevent side wall leakage. Collection pans collect percolate that is directed to a collection tank. The researchers found that because of preferential flow, the breakthrough time of herbicides was independent of their sorptive properties, but the transport time was dependent on the herbicide sorptive properties. Although rapid glyphosate transport occurred through preferential flow (macropore flow), glyphosate was not detected in percolate samples. None of the concentrations were close to the glyphosate EPA Maximum Contaminate Level (Malone et al., 2004).

Fomsgaard et al. (2003) also studied leaching of pesticides through soil using lysimeters. Normal till and low-till conditions were maintained for 2 years, with one initial glyphosate application corresponding to 0.8 kg active ingredient per ha. The mean yearly concentration of leached glyphosate and/or AMPA was significantly below 0.1 mg/l from both sets of lysimeters. The highest amounts of glyphosate were found in samples of leachate taken two years after spraying. The concentrations of residual AMPA in the soil were significantly higher in the in low-tillage soil than in normal-till soil. The reason for these higher concentrations could be differences in extraction efficiency and/or residuals from prior experiments that had more frequent sprayings with Round Up in the low-tillage soil (Fomsgaard et al., 2003).

Another Danish study at agricultural fields determined that leaching of glyphosate was mainly governed by pronounced macropore flow during the first months after application. Also AMPA was frequently detected more than 1.5 years after application (Kjaer et al., 2005).

Torstensson et al., (2005) glyphosate and AMPA mobility on Swedish railway embankments and found that most of the glyphosate and AMPA was found in the upper 30 cm layer of soil and the half life was less than 5 months, except for some sites where half life was longer. The experimental design also included groundwater sampling. Based on the finding that transport to groundwater is dependent on application rate, the authors concluded that Roundup Bio application rate should not exceed 3 L/ha.

In summary (Borggaard and Gimsing, 2007), groundwater and surface water contamination by glyphosate is limited because of sorption onto variable-charged soil minerals and microbial degradation. Glyphosate leaching is mainly determined by soil structure and rainfall, while leaching to drainage systems occurs due to preferential flow in macropores. In contrast, other herbicides are often found in groundwater (Kolpin et al., 1998).

## 2.2.2 Current Levels of Glyphosate in Soil

Glyphosate adsorbs strongly to soil and is not expected to move vertically below the six inch soil layer; residues are expected to be immobile in soil (Cerdeira and Duke, 2006; EPA, 2006; Vereecken, 2005). Glyphosate is primarily and rapidly degraded by soil microbes in the environment. The major degradate of this process is aminomethyl phosphonic acid (AMPA), which further degrades in the soil to form carbon dioxide. The half-life of glyphosate in soil laboratory studies is two days (EPA, 2006). In agricultural soils, the half-life of glyphosate ranges from 1.7 to 197.3 days, but is typically less than 60 days, and one study determined the disappearance time for 50 percent ( $DT_{50}$ ) to be 13 days following a single application of glyphosate (Giesy et al., 2000).  $DT_{50}$  depends on climate, weather and application rates, but in general, glyphosate will continue to degrade even after multiple applications. AMPA was found to have a longer half life than glyphosate, and it has the potential to accumulate in the soil after extensive glyphosate applications (Cerdeira and Duke, 2006).

Polyethoxylated alkyl amine (POEA) is a class of surfactants used with glyphosate to increase the plant uptake of the glyphosate. Microbial degradation is the primary degradation process for POEA as well, and the half-life for POEA in soil is estimated at 7-14 days (Giesy et al., 2000). Glyphosate and POEA have similar dissipation rates, so accumulation of POEA in the soil is not anticipated with increased glyphosate use. Both toxicity and concentration of POEA in experimental water microcosms decreases more rapidly in the presence of sediment, higher total organic carbon, clay, and microbial biomass (Wang et al., 2005).

Soil microbes readily metabolize glyphosate into AMPA and other metabolites (USDA FS, 2003). Microorganisms produce aromatic amino acids through the shikimate pathway, similar to plants. Since glyphosate inhibits this pathway, it could be expected that glyphosate would be toxic to microorganisms. However, field studies show that glyphosate has little effect on soil microorganisms, and, in some cases, field studies have shown an increase in microbial activity (USDA FS, 2003). The addition of microbes via compost made from organic solid waste did not enhance glyphosate degradation in soils (Getenga and Kengara, 2004). In one study the population size of *Pseudomonas* spp. bacteria was highly correlated with high mineralization rates of glyphosate. In addition the mineralization rates were higher in soil sampled from organically managed soils than in soil from conventional farming (Gimsing et al., 2004). In a field study on GT versus non-GT crops, soil microbial community structure based on total fatty acid methyl ester analysis indicated a significant effect of GT crop following 5 years of continuous GT crop as compared with the non-GT crop system (Locke et al., 2008). The effect of glyphosate on soil biota is discussed more in the Technical report *Potential Impacts to Wildlife, Amphibians, Plants, And Ecosystems from Increased Glyphosate and Other Chemical Usage* (appendix N).

Due to glyphosate and AMPA's strong adsorptive characteristics, they are not likely to leach to groundwater from the soil, and compared to most herbicides, leaching is very limited (Cerdeira and Duke, 2006; Grunewald et al., 2001). Studies indicate that glyphosate leaching is dominated by preferential flow mechanisms and that it is dependent on the clay particles, iron oxides and organic matter present in the soil (Vereecken, 2005). Glyphosate and its metabolite adsorb to soil particles that become suspended in runoff water and can potentially contaminate surface waters as a result of erosion of this soil. Once in surface water, glyphosate and AMPA are not

readily broken down by water or sunlight (EPA, 1993), but can be removed through standard water purification processes and disinfection processes such as ozonation and chlorination (Speth, 1994). There is also evidence that glyphosate is translocated through plants from foliar application to roots to soil (Laitinen et al., 2007).

The U.S. Geological Survey (USGS) study that monitored glyphosate and AMPA in ground water, surface water, and rainfall, also monitored soil at the Leary Weber Ditch Basin site (Scribner et al., 2007). Of 193 soil cores, glyphosate was detected in 119 with a maximum concentration of 476 µg/kg, and AMPA was detected in 154 with a maximum concentration of 956 µg/kg. For the soil samples, the maximum level of AMPA measured was 23 µg/kg, and it was detected prior to application of glyphosate (April). The authors suggest it persisted from the previous year.

Studies show that glyphosate does not move deep into the soil, it does not get transported at high levels to or through groundwater, and it does not persist long in the soil (Major, 2003; Miller et al., 1995; Torstensson, 2005). It is highly adsorptive and remains in the soil until mineralizing bacteria breaks it down into AMPA (Gimsing et al., 2004).  $K_f$  (from table J-3) is a measure of adsorption that relates the concentration of the solute on the surface to the concentration of the solute in the liquid with which it is in contact (Vereecken, 2005). It is a constant, and the higher the value of  $K_f$  is, the more immobile the glyphosate in the soil. Soil composition does have an effect on glyphosate adsorption, with presence of minerals increasing adsorption (lessening movement of the glyphosate) and the presence of soil organic matter inhibits adsorption (Getenga and Kengara, 2004; Vereecken, 2005). Table J-3 presents parameters for glyphosate adsorption in different soils. The Freundlich Equation is an adsorption isotherm, or a curve relating the concentration of a solute on the surface of an adsorbent to the concentration of the solute in the liquid with which it is in contact. The equation is defined by:

$$c_s = K_f * c^n$$

Where  $K_f$  is the Freundlich adsorption constant (a constant for a given adsorbate at a particular temperature, related to sorbent capacity) and “n” is the Freundlich exponent related to the degree of deviation from isotherm linearity (Lee et al., 2001).

**Table J-3. Freundlich Parameters of Glyphosate Adsorption in Different Soils. (Vereecken, 2005)**

| Soil Type         | C (%) | Sand (%) | Silt (%) | Clay (%) | pH   | n    | K <sub>f</sub> |
|-------------------|-------|----------|----------|----------|------|------|----------------|
| Clay Loam         | 1.56  | 9.9      | 37.5     | 52.6     | 7.5  | 0.67 | 76             |
| Silt Loam         | 2.60  | 42.29    | 44.71    | 13       | 5.96 | 0.83 | 88.97          |
| Sandy Loam        | 3.35  | 79.99    | 12.63    | 8.51     | 6.1  | 0.81 | 75.95          |
| Sandy Silt        | 3.7   | 46       | 37       | 17       | 5.8  | 0.77 | 40.64          |
| Loamy Silt        | 0.5   | 2        | 82       | 16       | 8.3  | 0.44 | 152.9          |
| Sand              | 0.94  | -        | -        | -        | 5.10 | 1    | 100641.1       |
| Clay              | 3.67  | 32.6     | 20.8     | 43.43    | 6.49 | 0.99 | 113.14         |
| Muddy Clay        | 12.6  | -        | -        | 57       | 6.9  | 0.91 | 84             |
| Organic Soil      | 26    | 78       | 13       | 9        | 5.2  | 1.14 | 303            |
| Coarse Sandy Loam | 1.7   | 65       | 17       | 15       | 7.40 | 0.83 | 35.15          |
| Sandy Soil        | 3.1   | 90       | 2.9      | 4        | 5.32 | 0.79 | 57             |

Mamy et al., (2005) studies the environmental fate of five herbicides. The main dissipation pathways were mineralization for glyphosate and sulcotrione, volatilization for trifluralin and non-extractable residues formation for metazachlor and metamitron. All five herbicides had low persistence, and glyphosate had the shortest half-life, which varied with soil type. Trifluralin had the longest half-life. Glyphosate, metazachlor and sulcotrione were degraded into persistent metabolites. At 140 days after herbicide applications, the amounts of glyphosate and AMPA in soils were the lowest in two soils, but not in the third soil, a loamy sand with low pH. The authors concluded that the environmental advantage in using glyphosate due to its rapid degradation is counterbalanced by accumulation of AMPA specifically in the context of extensive use of glyphosate (Mamy et al., 2005).

### 2.2.3 Current Levels of Glyphosate in Air

Herbicides can pollute air either through drift, the movement of herbicide through the air to unintended sites, or volatility, evaporation into the air. Glyphosate is essentially not volatile at 25°C and has not been reported as an atmospheric contaminant (Cerdeira and Duke, 2006). When glyphosate is applied directly to plant leaves, the risk of drift is low, but when glyphosate is applied broadly to a field, the risk of drift increases (Owen, 1998). Glyphosate poses very little risk of contaminating air, but as its use increases, the opportunity for drift and application to unintended sites can increase. Glyphosate concentrations found in a few rainwater samples were considered due to glyphosate's association with particulate matter in the air (dust), and not to its existence as vapor (Scribner et al., 2007). Bennett et al. (2004) performed a life-cycle assessment on the impacts of sugar beets (both conventional and GT) on the air and environment, and found that growing GT sugar beets is less harmful to the environment than growing conventional sugar beets due to the lower emissions from herbicide manufacturers, transport and field operations. The use of glyphosate as a post-emergence herbicide leads to an increase in no-till farming, which can lead to a decrease in tractor use. No-till also decreases dust, which improves air quality. Emissions related to global warming, ozone depletion, summer smog and carcinogenicity, among others, were found to be lower in GT crop systems than conventional systems (Bennett et al., 2004).

## 2.3 Environmental Effects of Herbicides Used on GT Crops

The use of herbicides impacts the environment in multiple ways. In this report, the focus is the impact of herbicides on the soil, water and air. However, a general Environmental Impact Quotient (EIQ) was devised in 1992 that gives an indication of the effect of an herbicide on the environment in general (Kovach et al., 1992). It is calculated from the following parameters and is the average of the farm worker, consumer and ecological components:

$$EIQ = \{C[(DT*5)+(DT*P)] + [(C*((S+P)/2)*SY)+(L)] + [(F*R)+(D*((S+P)/2)*3)+(Z*P*3)+(B*P*5)]\} / 3$$

DT = dermal toxicity, C = chronic toxicity, SY = systemicity, F = fish toxicity, L = leaching potential, R = surface loss potential, D = bird toxicity, S = soil half-life, Z = bee toxicity, B = beneficial arthropod toxicity, P = plant surface half-life (Kovach, 1992).

EIQs are universal indicators, updated annually, that effectively integrate various environmental impacts of individual pesticides into a single value that is consistent and comprehensive. EIQs have been calculated by Kovach for common herbicide ingredients, and table J-4 lists the herbicides relevant to alfalfa cultivation and their EIQs (Kovach, et al., 2007).

**Table J-4. Calculated EIQs for Alfalfa-Related Herbicides (Kovach et al., 2007)**

| Herbicide                     | EIQ   |
|-------------------------------|-------|
| 2,4-D*                        | 18.67 |
| Atrazine (Atrazine)*          | 22.9  |
| Bromoxynil (Buctril)          | 20.0  |
| Clethodim (Prism, Select)     | 17.0  |
| Clopyralid (Stinger)*         | 18.1  |
| Dicamba (Dicamba)*            | 28.0  |
| Diflufenzopyr (Distinct)*     | 17.5  |
| Diuron (Karmex, Direx)        | 20.5  |
| EPTC (Eptam)                  | 9.4   |
| Glufosinate-ammonium (Rely)*  | 28.25 |
| Glyphosate (Roundup)**        | 15.3  |
| Halsulfuron methyl (Sanda)*   | 17.0  |
| Hexazinone (Velpar)           | 18.0  |
| Imazamox (Raptor)             | 19.5  |
| Imazethapyr (Pursuit)         | 27.3  |
| Metribuzin (Sencor)           | 28.4  |
| Norfluzaon (Solicam)          | 18.8  |
| Paraquat (Gramoxone Inteon)   | 31.0  |
| Picloram (Pathway)*           | 18.0  |
| Primsulfuron-methyl (Beacon)* | 27.33 |
| Sethoxydim (Poast)            | 27.5  |
| Terbacil (Sinbar)             | 16.8  |
| Trifluralin (Treflan/TR-10)   | 18.8  |

\* Indicates an herbicide used for control of alfalfa, not weeds in alfalfa

**\*\* Glyphosate can be used to control alfalfa if it is non-GT and it can be used to control weeds in GT alfalfa**

The effects of GT crops other than GT alfalfa have been studied. In a study examining the Environmental Impact (EI, calculated by multiplying the EIQ of an herbicide by application rate to get an environmental impact per acre measurement) of GT canola, researchers found that on average, the environmental impact of GT canola was lower than the environmental impact of conventional canola. It appears this is the case because the herbicides used in GT canola, such as glyphosate and imazethapyrs, tend to have lower application rates than the herbicides used in conventional canola, such as ethalfluralin and trifluralin, instead of just being more environmentally benign (Brimner et al., 2005). Table J-5 presents EIQ and EI for canola in Canada.

**Table J-5. EIQ and EI per Hectare of Canola for Common Herbicides Used in 1995, 1998 or 2000<sup>1</sup> (Brimner et al., 2005)**

| Active ingredient                             | EIQ  | EI h <sup>-1</sup> |
|-----------------------------------------------|------|--------------------|
| Herbicides used in herbicide-resistant canola |      |                    |
| Glufosinate-ammonium                          | 34.3 | 10.3               |
| Glyphosate                                    | 32.4 | 8.5                |
| Imazamox                                      | 27.3 | 0.4                |
| Imazethapyr                                   | 27.3 | 0.4                |
| Herbicides used in conventional canola        |      |                    |
| Ethalfluralin                                 | 30.7 | 25.8               |
| Sethoxydim                                    | 27.5 | 4.0                |
| Trifluralin                                   | 26.8 | 21.6               |
| Clopyralid                                    | 18.0 | 2.7                |
| Ethametsulfuron-methyl                        | 16.0 | 0.2                |

<sup>1</sup> EI was determined by multiplying the EIQ for each active ingredient by the lowest recommended application rate of that ingredient in kg a.i. ha<sup>-1</sup>

Another study calculated EI for GT cotton, corn and soybean, as well as canola in the United States, and concluded that, in general, a downward trend in pesticide use was observed for transgenic crops when compared to non-transgenic crops (Kleter et al., 2007). The exception was a slight increase in herbicides applied to GT soybean, but this corresponded to an increased use of less environmentally persistent herbicides. Table J-6 shows a decrease of 25-33% in the quantities of herbicide active ingredients (a.i.) applied to GT crops versus non-GT crops in 2004 (Kleter et al., 2007).

**Table J-6. Environmental Impact of Herbicide Use in Herbicide-Resistant Transgenic Crops in the United States in 2004<sup>1</sup> (Kleter et al., 2007)**

| Item                                      | Non-transgenic | Transgenic herbicide-resistant | Difference | Difference, % |
|-------------------------------------------|----------------|--------------------------------|------------|---------------|
| <i>Herbicide-resistant canola</i>         |                |                                |            |               |
| Pesticide use (kg a.i. ha <sup>-1</sup> ) | 0.6            | 0.4                            | -0.2       | -30           |
| Total impact (EI ha <sup>-1</sup> )       | 14.8           | 8.6                            | -6.2       | -42           |
| Farm worker impact (EI ha <sup>-1</sup> ) | 8.9            | 4.1                            | -4.8       | -54           |
| Consumer impact (EI ha <sup>-1</sup> )    | 3.8            | 2.5                            | -1.3       | -35           |
| Ecology impact (EI ha <sup>-1</sup> )     | 31.8           | 19.4                           | -12.4      | -39           |
| <i>Herbicide-resistant cotton</i>         |                |                                |            |               |
| Pesticide use (kg a.i. ha <sup>-1</sup> ) | 5.4            | 3.7                            | -1.7       | -32           |
| Total impact (EI ha <sup>-1</sup> )       | 113.4          | 66.1                           | -47.4      | -42           |
| Farm worker impact (EI ha <sup>-1</sup> ) | 57.7           | 34.4                           | -23.4      | -40           |
| Consumer impact (EI ha <sup>-1</sup> )    | 33.1           | 21.7                           | -11.4      | -35           |
| Ecology impact (EI ha <sup>-1</sup> )     | 249.5          | 142.4                          | -107.1     | -43           |
| <i>Herbicide-resistant maize</i>          |                |                                |            |               |
| Pesticide use (kg a.i. ha <sup>-1</sup> ) | 3.8            | 2.5                            | -1.2       | -33           |
| Total impact (EI ha <sup>-1</sup> )       | 87.9           | 53.6                           | -34.4      | -39           |
| Farm worker impact (EI ha <sup>-1</sup> ) | 48.4           | 29.0                           | -19.3      | -40           |
| Consumer impact (EI ha <sup>-1</sup> )    | 26.2           | 16.2                           | -10.1      | -38           |
| Ecology impact (EI ha <sup>-1</sup> )     | 189.1          | 115.6                          | -73.5      | -39           |
| <i>Herbicide-resistant soybean</i>        |                |                                |            |               |
| Pesticide use (kg a.i. ha <sup>-1</sup> ) | 1.2            | 1.4                            | -0.4       | -25           |
| Total impact (EI ha <sup>-1</sup> )       | 42.8           | 17.7                           | -25.1      | -59           |
| Farm worker impact (EI ha <sup>-1</sup> ) | 29.3           | 9.2                            | -20.1      | -68           |
| Consumer impact (EI ha <sup>-1</sup> )    | 14.1           | 5.8                            | -8.4       | -59           |
| Ecology impact (EI ha <sup>-1</sup> )     | 85.0           | 38.1                           | -46.9      | -55           |

<sup>1</sup> Based on pesticide use data for 2004 from Sankula et al. (2005). Units have been converted to metric, e.g. 1 lb a.i. acre<sup>-1</sup> = 1.121 kg a.i. ha<sup>-1</sup>. The EIQ values have been multiplied by the values of the application rates expressed as kg a.i. ha<sup>-1</sup> in order to calculate the environmental impact per hectare (EI ha<sup>-1</sup>).



Researchers at Ghent University developed the pesticide occupational and environmental risk (POCER) indicator (Devos et al., 2008). POCER is a similar concept as EIQ and includes ten modules; (1) risk to pesticide operator; (2) risk to worker; (3) risk to bystander; (4) persistence in the soil; (5) risk of ground water contamination; (6) acute risk to aquatic organisms; (7) acute risk to birds; (8) acute risk to bees; (9) acute risk to earthworms; and (10) risk to beneficial arthropods. The toxicological reference values used in the effect assessment are certified endpoints defined in Annex VI of Directive 91/414/EEC. Using GT corn and non-GT corn as an example, the POCER values for glyphosate or glufosinate used alone were about one sixth less than other herbicide regimes (31 regimes were evaluated). This environmental benefit of glyphosate over other herbicides was attributed to lower potential for leaching and lower toxicity to aquatic organisms (Devos et al., 2008).

Using the above standardized methods for ranking environmental impact, researchers have concluded that glyphosate is less harmful to the environment than many other herbicides and that the shift of herbicide use has resulted in a net lower environmental impact from herbicides.

## 2.4 Herbicide Usage in Conventional Alfalfa Farming

Herbicides are used at three different phases in conventional alfalfa farming, stand establishment and established stands (to control weeds), and during stand removal to kill alfalfa.

The 16 herbicides that may be used for weed control in conventional alfalfa farming are summarized in table J-7 (based on Canevari et al., 2007; Loux et al., 2007; OMAFRA, 2008; Rogan and Fitzpatrick, 2004).

**Table J-7. Herbicides Used to Control Weeds in Conventional Alfalfa**

| Herbicide (Brand)                 | Stand Stage                                                       | Notes                                                                                                                                                             |
|-----------------------------------|-------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2,4-DB<br>(Butyrac,<br>Butoxone)  | 1-4 trifoliolate or<br>established stands                         | No harvesting or grazing allowed for 60<br>days following treatment                                                                                               |
| Benefin<br>(Balan)                | Before seeding                                                    | Not for use on soils high in organic matter                                                                                                                       |
| Bromoxynil<br>(Buctril)           | 2-4 trifoliolate                                                  | Often tank mixed with other herbicides                                                                                                                            |
| Clethodim<br>(Prism, Select)      | 2-4 trifoliolate or<br>established stands                         | Well established perennials require<br>multiple applications<br>Allow 15 days between application and<br>grazing, feeding, or harvesting of alfalfa               |
| Diuron<br>(Karmex, Direx)         | Established stands                                                | Persists in soil for one year, so cannot be<br>used in last year of stand                                                                                         |
| EPTC<br>(Eptam)                   | Established stands                                                | Applied before germination<br>Controls for 30 to 45 days so repeated<br>applications may be necessary                                                             |
| Hexazinone<br>(Velpar)            | 6 inches of root growth in<br>new stands or established<br>stands | Many crops cannot be planted for 18<br>months without yield damage                                                                                                |
| Imazamox<br>(Raptor)              | 2-4 trifoliolate or<br>established stands                         | Preharvest interval is 20 days                                                                                                                                    |
| Imazethapyr<br>(Pursuit)          | 2-4 trifoliolate or<br>established stands                         | Follow-up planting restrictions range from<br>4 to 40 months                                                                                                      |
| Metribuzin<br>(Sencor)            | Established stands                                                | No grazing or harvesting allowed for 28<br>days following application                                                                                             |
| Norfluzaon<br>(Solicam)           | Established stands                                                | Cannot be applied within 28 days of<br>harvest<br>Does not control emerged weeds<br>24 month rotation interval                                                    |
| Paraquat<br>(Gramoxone<br>Inteon) | 3, 6, or 9 trifoliolate;<br>established stands                    | Rescue treatment when weeds form a<br>canopy over alfalfa<br>No harvest or grazing until 60 days after<br>application<br>Often used in the last year of the stand |
| Pronamide<br>(Kerb)               | First trifoliolate leaf stage                                     | No grazing or harvesting allowed for 120<br>days following application                                                                                            |
| Sethoxydim<br>(Poast)             | 2-4 trifoliolate or<br>established stands                         | Well established perennials require<br>multiple applications                                                                                                      |
| Terbacil<br>(Sinbar)              | Established stands                                                | Can not plant any other crop for 2 years<br>after Sinbar application                                                                                              |

|                                |                    |                                                                                                                                                                                    |
|--------------------------------|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Trifluralin<br>(Treflan/TR-10) | Established stands | Applied before germination<br>Rainfall or sprinkler irrigation is required<br>within 3 days after irrigation to incorporate<br>the herbicide<br>Controls dodder before germination |
|--------------------------------|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Based on an extensive survey<sup>38</sup> performed from 1988 to 1992 herbicides are used much more often with seed fields (78.3% of total fields) than with hay fields (16.6% of total fields; 22% of acreage) (Hower et al., 1999). Mechanical and cultural methods for weed control (e.g. tillage and companion crops) were used for ~80% of the spring planted alfalfa and 18% of the fall planted alfalfa (Hower et al., 1999). Table J-8 presents data from Hower et al. (1999) on the acreage of alfalfa hay that is treated with herbicide versus cultural methods for weed control broken down by spring versus fall plantings and established stands.

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<sup>38</sup> Data collected in the herbicide survey represented 90.1% of the 25.6 million acres produced annually from 1988-1992 as reported by the NASS.

**Table J-8. Alfalfa Hay Acreage (in thousands) Treated with Various Herbicides and Weed Management Strategies (U.S. 1988-1992) (Hower et al., 1999)**

| Management Option                              | South | Northeast | North Central | West   | U.S. total |
|------------------------------------------------|-------|-----------|---------------|--------|------------|
| Spring Seedings (3.2 million acres annually)   |       |           |               |        |            |
| Benefin                                        | 0.8   | 5.2       | 71.0          | 3.6    | 80.6       |
| Bromoxynil                                     | 0     | 4.9       | 18.7          | 10.3   | 33.9       |
| EPTC                                           | 0.2   | 17.4      | 66.8          | 20.8   | 105.2      |
| Glyphosate                                     | 0.2   | 11.8      | 265.3         | 2.6    | 279.9      |
| Imazethapyr                                    | 0.2   | 12.9      | 148.7         | 5.4    | 167.1      |
| MCPA                                           | 0     | 0.6       | 57.2          | 0      | 57.8       |
| Paraquat                                       | 0.5   | 6.3       | 69.4          | 3.4    | 79.6       |
| Pendimethalin                                  | 0     | 0         | 2.4           | 1.3    | 3.6        |
| Sethoxydim                                     | 0.2   | 5.3       | 76.7          | 3.2    | 85.5       |
| Trifluralin                                    | 0     | 0         | 34.5          | 5.1    | 39.6       |
| 2,4-DB                                         | 1.8   | 23.7      | 117.3         | 13.2   | 156.0      |
| Pronamide                                      | 0     | 0         | 0             | 0.3    | 0.3        |
| 2,4-D                                          | 0     | 3.6       | 1.9           | 1.3    | 6.8        |
| Herbicide Total                                | 3.9   | 91.7      | 929.9         | 70.5   | 1095.9     |
| Percentage Herbicide of U.S. Acres (Spring)    | 0.12% | 2.87%     | 29.06%        | 2.20%  | 34.25%     |
| Clipping                                       | 0.6   | 162.8     | 755.4         | 48.2   | 966.9      |
| Companion crop                                 | 0     | 95.4      | 1371.0        | 107.9  | 1574.4     |
| Flash grazing                                  | 0     | 5.9       | 12.0          | 0.4    | 18.3       |
| Early harvest                                  | 0     | 3.1       | 0             | 0      | 3.1        |
| Cultural Total                                 | 0.6   | 267.2     | 2138.4        | 156.5  | 2562.7     |
| Percentage Cultural of U.S. Acres (Spring)     | 0.02% | 8.35%     | 66.83%        | 4.89%  | 80.08%     |
| Fall Seedings (1.4 million acres annually)     |       |           |               |        |            |
| Benefin                                        | 1.3   | 0.8       | 0.1           | 22.0   | 24.2       |
| Bromoxynil                                     | 0     | 1.9       | 14.3          | 20.1   | 36.2       |
| EPTC                                           | 0.3   | 3.3       | 0.4           | 54.2   | 58.1       |
| Glyphosate                                     | 0.3   | 4.4       | 16.7          | 28.2   | 49.6       |
| Imazethapyr                                    | 0     | 6.2       | 12.4          | 9.7    | 28.3       |
| MCPA                                           | 0     | 0.2       | 0             | 0      | 0.2        |
| Paraquat                                       | 0.5   | 3.4       | 68.8          | 12.1   | 84.8       |
| Sethoxydim                                     | 1.0   | 2.2       | 16.9          | 28.5   | 48.5       |
| Trifluralin                                    | 0     | 0         | 0             | 12.9   | 12.9       |
| 2,4-DB                                         | 3.8   | 5.6       | 5.4           | 66.1   | 80.9       |
| Pronamide                                      | 0.3   | 0         | 0             | 5.1    | 5.4        |
| 2,4-D                                          | 0     | 0.6       | 0             | 0      | 0.6        |
| Herbicide total                                | 7.5   | 28.6      | 135           | 258.9  | 429.7      |
| Percentage Herbicide of U.S. Acres (Fall)      | 0.54% | 2.04%     | 9.64%         | 18.49% | 30.69%     |
| Clipping                                       | 0.5   | 2.8       | 19.3          | 166.5  | 189.1      |
| Companion crop                                 | 0.1   | 5.9       | 8.8           | 21.0   | 35.7       |
| Flash grazing                                  | 0.5   | 2.4       | 4.1           | 17.4   | 24.5       |
| Cultural Total                                 | 1.1   | 11.1      | 32.2          | 204.9  | 249.3      |
| Percentage Cultural of U.S. Acres (Fall)       | 0.08% | 0.79%     | 2.30%         | 14.64% | 17.81%     |
| Established Stands (23,024,800 acres annually) |       |           |               |        |            |
| Glyphosate                                     | 0     | 0.6       | 62.0          | 53.9   | 116.4      |
| Imazethapyr                                    | 0     | 33.4      | 65.1          | 216.3  | 314.9      |
| MCPA                                           | 0     | 0         | 0             | 3.9    | 3.9        |
| Paraquat                                       | 10.6  | 95.4      | 315.1         | 373.1  | 794.3      |
| Sethoxydim                                     | 12.6  | 15.8      | 470.3         | 131.8  | 630.4      |
| Trifluralin                                    | 0     | 0         | 81.0          | 302.5  | 383.5      |

| Management Option                                | South | Northeast | North Central | West   | U.S. total |
|--------------------------------------------------|-------|-----------|---------------|--------|------------|
| Diuron                                           | 1.2   | 0         | 43.7          | 135.4  | 180.3      |
| 2,4-DB                                           | 55.4  | 6.5       | 79.3          | 26.1   | 167.3      |
| Pronamide                                        | 0.5   | 6.1       | 23.6          | 78.6   | 108.8      |
| Metribuzin                                       | 1.3   | 39.0      | 618.5         | 404.7  | 1063.5     |
| Hexazinone                                       | 0     | 53.2      | 198.3         | 749.4  | 1000.9     |
| Terbacil                                         | 1.2   | 42.4      | 72.3          | 202.4  | 318.3      |
| Herbicide total                                  | 82.8  | 292.4     | 2029.2        | 2678.1 | 5082.5     |
| Percentage Herbicide of U.S. Acres (Established) | 0.36% | 1.27%     | 8.81%         | 11.63% | 22.07%     |
| Clipping                                         | 7.6   | 0         | 237.8         | 88.4   | 333.8      |
| Companion crop                                   | 0     | 0         | 0             | 16.3   | 16.3       |
| Flash grazing                                    | 5.0   | 64.8      | 156.2         | 292.2  | 518.2      |
| Cultivation/tillage                              | 1.2   | 19.1      | 96.4          | 642.4  | 759.2      |
| Burning                                          | 0     | 0         | 158.7         | 4.6    | 163.4      |
| Cultural Total                                   | 13.8  | 83.9      | 649.1         | 1043.9 | 1790.9     |
| Percentage Cultural of U.S. Acres (Established)  | 0.06% | 0.36%     | 2.82%         | 4.53%  | 7.78%      |

The exact use of herbicide on alfalfa crops typically depends on region, weed spectrum and farmer preference, among other things. One herbicide rarely takes care of all weed control issues in a crop, and farmers usually have sequential combinations of herbicides to take care of summer and winter weeds. In California, research has shown that with the proper sequence and application rates, farmers can achieve weed-free alfalfa hay (Gianessi et al., 2002). In field experiments in southwestern Michigan, researchers found no net economic benefit to herbicide use in alfalfa establishment (Brothers and Hesterman 1991).

#### *2.4.1 Stand removal and volunteer control*

After 2-8 years alfalfa stands are usually thinning and vulnerable to weeds, so the stand is removed by killing the alfalfa by either plowing or herbicide application or both (Rogan and Fitzpatrick 2004). Herbicides that are used for stand removal or to control volunteer alfalfa (including GT alfalfa, except for glyphosate) include (Dillehay and Curran, 2006; Miller et al., 2006; Renz, 2007; Rogan and Fitzpatrick, 2004):

- 2,4-D
- Clopyralid
- Dicamba
- Dicamba and diflufenzopyr
- Glufosinate
- Glyphosate
- Primsulfuron-methyl
- Mixtures of dicamba, 2,4-D, and clopyralid
- Picloram
- Picloram and 2,4-D
- Halsulfuron and dicamba
- Acetochlor

- Acetochlor and atrazine
- Acetochlor and atrazine and dicamba
- Atrazine and dicamba
- Clopyralid and flumetsulam

See table J-11 for more detailed information on the herbicides used for alfalfa control.

## 2.5 Herbicide Usage in GT Alfalfa Farming

Glyphosate can be used for both hay and seed fields at stand establishment, in order to prepare the field for planting. The effectiveness of this first application depends on the weed species present, their germination period, and how long until the alfalfa grows big enough to compete with weeds on its own. If the application was effective, successive treatments would not be needed, but if the first application was not effective, it is possible that multiple glyphosate treatments would be needed (Canevari et al., 2007). In the technical report *Potential Impacts To Wildlife, Amphibians, Plants, And Ecosystems From Increased Glyphosate And Other Chemical Usage* (appendix N), the maximum use rate accepted for quantitative risk assessment was 1.99 lb a.e./acre for a single use, with minimum reapplication after 7 days and not to exceed 7.98 lb a.e./acre in a year. Monsanto recommends a maximum of 1.5 lb a.e./acre for a single application, with a seasonal maximum of 4.5 lb a.e./acre and a combined total of all pre-emergence and post-emergence applications of glyphosate per year of 6 lbs a.e./acre (Rogan and Fitzpatrick, 2004). Table J-9 present rates of glyphosate use on GT alfalfa based on different tillage practices (Rogan and Fitzpatrick, 2004).

**Table J-9. Typical Agronomic Practice for Glyphosate Applications to GT Alfalfa – Stand Establishment Year (Rogan and Fitzpatrick 2004)**

| Type of Application                                       | Application Rate <sup>1</sup> | Purpose                                                                                         |
|-----------------------------------------------------------|-------------------------------|-------------------------------------------------------------------------------------------------|
| No-Till Farming                                           |                               |                                                                                                 |
| Pre-plant, at planting or pre-emergence                   | Up to 1.5                     | No-till. Weed control prior to alfalfa emergence.                                               |
| Post-emergence: emergence to 4-trifoliate stage           | 0.75                          | Weed control and removal of non-Roundup Ready alfalfa seedlings (null application) <sup>2</sup> |
| Post-emergence: 5-trifoliate to 5 days prior to first cut | 0.75                          | 2 <sup>nd</sup> weed control application for heavy infestations                                 |
| <i>Combined total of all applications per year</i>        | <i>3.00</i>                   |                                                                                                 |
| Conventional Tillage                                      |                               |                                                                                                 |
| Post-emergence: emergence to 4-trifoliate stage           | 0.75                          | Weed control and removal of non-Roundup Ready alfalfa seedlings (null application) <sup>2</sup> |
| Post-emergence: 5-trifoliate to 5 days prior to first cut | 0.75                          | Weed control (annual and perennial)                                                             |
| <i>Combined total of all applications per year</i>        | <i>1.50</i>                   |                                                                                                 |

<sup>1</sup> pound per acre glyphosate acid equivalents

<sup>2</sup> Due to the biology and breeding constraints of alfalfa, up to 10% of the seedlings may not contain the Roundup Ready gene. See Appendix of Rogan and Fitzpatrick, 2004

There are specific herbicide mixtures recommended by the Roundup® label ([http://www.monsanto.com/monsanto/ag\\_products/pdf/labels\\_msds/roundup\\_orig\\_max\\_label.pdf](http://www.monsanto.com/monsanto/ag_products/pdf/labels_msds/roundup_orig_max_label.pdf)) to control various weeds of alfalfa. These weeds are either naturally resistant to glyphosate or have recently evolved resistant biotypes. For more discussion of glyphosate resistant weeds refer to the Technical report *Effects of Glyphosate-Tolerant Weeds in Agricultural Systems* (appendix G). Weeds for which mixtures are recommended include:

- Common ragweed
- Common waterhemp
- Giant ragweed
- Horseweed (Marestail)
- Italian ryegrass
- Johnsongrass
- Palmer Amaranth
- Rigid ryegrass
- Junglerice
- Burning nettle
- Cheeseweed
- Common lambsquarters
- Field bindweed
- Filaree

- Large crabgrass
- Morning glory
- Purslane
- Velvet leaf

### 2.5.1 Stand Removal and volunteer control

Glyphosate can be used to kill old stands of conventional alfalfa for crop rotations, however, GT alfalfa has to be removed through other mechanisms. Application of an herbicide (e.g., 2,4-D, dicamba (Banvel®), and clopyralid (Stinger®)) and tillage is effective. In no-till systems 2,4-D and dicamba can be applied together. However dicamba cannot be used before planting soybean (Dillehay and Curran, 2006).

Renz (2007) reported that dicamba and 2,4-D (WeedMaster®) applied at 2 pt/acre achieved zero resprouting of alfalfa in the spring following herbicide application. Lower concentrations of WeedMaster resulted in 0.3 to 2.5 percent resprouting. The other herbicides applications (dicamba or 2,4-D only) resulted in 0.5 to 26.5 percent resprouting. In another study, picloram and 2,4-D was more effective than dicamba and 2,4-D (Miller et al., 2006). Combined with plowing, clopyralid, clopyralid plus 2,4-D, dicamba plus 2,4-D, picloram, and picloram plus 2,4-D all controlled alfalfa 100 percent. Plowing alone provided 75 percent control of alfalfa (Miller et al., 2006).

Multiple other combinations of herbicides and tillage can be used for stand removal. See table J-11 for a list of these possible treatments, their effects and possible restrictions. Figure J-7 presents Monsanto's Technical User Guide stand takeout guidance.

**STAND TAKEOUT AND VOLUNTEER MANAGEMENT**

Crop rotations can be divided into two main groups, alfalfa rotated to: 1) grass crops (e.g. corn and cereal crops); and 2) broadleaf crops. More herbicide alternatives exist for management of volunteer alfalfa in grass crops. The recommended steps for controlling volunteer Roundup Ready Alfalfa are:

**Diligent Stand Takeout**

Use appropriate commercially available herbicide treatments alone for reduced tillage systems or in combination with tillage to terminate the Roundup Ready Alfalfa stand. Refer to your regional technical bulletin for specific stand takeout recommendations. NOTE: Roundup agricultural herbicides are **not** effective for terminating Roundup Ready Alfalfa stands.

**Start Clean**

If necessary, utilize tillage and/or additional herbicide application(s) after stand takeout, and before planting of the subsequent rotational crop to manage any newly emerged or surviving alfalfa.

**Plan for Success**

Rotate to crops with known and available mechanical or herbicidal methods for managing volunteer alfalfa, keeping in mind that Roundup agricultural herbicides will not terminate Roundup Ready Alfalfa stands.

- Rotations to certain broadleaf crops are not advisable if the grower is not willing to implement recommended stand termination practices.
- In the event that no known mechanical or herbicidal methods are available to manage volunteer alfalfa in the desired rotational crop, it is suggested that a crop with established volunteer alfalfa management practices be introduced into the rotation.

**Timely Execution**

Implement in-crop mechanical or herbicide treatments for managing alfalfa volunteers in a timely manner; that is, before the volunteers become too large to control or begin to compete with the rotational crop.

**Figure J-7: Monsanto technology user guide for stand removal (Monsanto, 2008)**



For stand takeout procedures, Monsanto, using information from the Crop Data Management System's (CDMS) Ag Product Label Service database, recommends 2,4-D, clopyralid (Stinger®), dicamba - dimethylamin salt (Banvel®), dicamba – diglycolamine salt (Clarity®), diflufenzopyr + dichloro-o-anisic acid (Distinct®), glufosinate (Liberty®), glyphosate (Roundup), and rimsulfuron-methyl (Beacon®) for control of alfalfa. Independent research has demonstrated that dicamba, 2,4-D, tank mixtures of dicamba and 2,4-D, and clopyralid were often more effective than glyphosate for terminating alfalfa stands (Rogan and Fitzpatrick, 2004).

In order to control volunteer alfalfa, growers currently use a combination of tillage and herbicide treatments, both prior to planting and again after crop emergence. 2,4-D, dicamba - dimethylamin salt (Banvel), dicamba - diglycolamine salt (Clarity), clopyralid (Stinger), rimsulfuron (Matrix®), primisulfuron-methyl (Beacon) and diflufenzopyr + dichloro-o-anisic acid (Distinct) are registered for in-crop use to remove volunteer alfalfa in 35 crops. They are also labeled for control of feral alfalfa in 15 non-crop settings, such as roadsides, fencerows, and ditch banks and in 22 forestry, turf or municipal settings, such as Douglas fir (*Pseudotsuga* spp.), turfgrass, or golf courses (Rogan and Fitzpatrick, 2004)

Acetochlor, acetochlor and atrazine, acetochlor, atrazine and dicamba, atrazine and dicamba, and clopyralid and flumetsulamcan herbicides and mixes can control volunteer GT alfalfa in corn (Rogan and Fitzpatrick 2004). Clopyralid is effective at controlling volunteer alfalfa in broccoli (Tickes 2002). Clopyralid or 2,4-D provide control of volunteer alfalfa in 33 different crops. Exceptions include potatoes and popcorn (Rogan and Fitzpatrick 2004).

Feral alfalfa (alfalfa not in fields) is discussed in more depth in the *technical report Effects of Glyphosate-Tolerant Weeds in Non-agricultural Ecosystems* (appendix H).

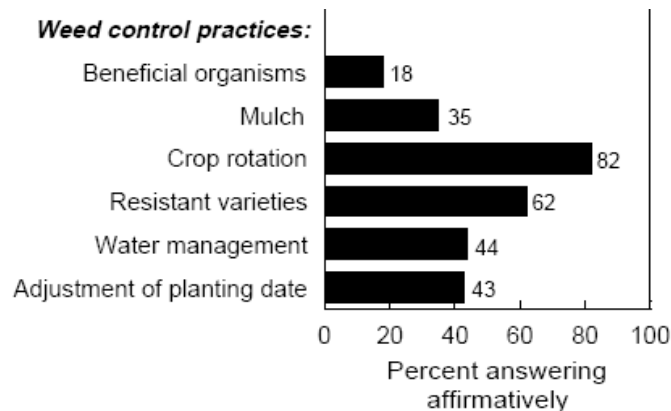
Adoption of GT alfalfa decreases the number of herbicides used to control weeds in alfalfa because glyphosate is the preferred herbicide for GT alfalfa. Adoption of GT alfalfa may increase use of some herbicides used for stand removal. For stand removal adoption of GT alfalfa may result in a shift from glyphosate to other herbicides. Herbicide use to control weeds occurs mainly in the first year during stand establishment and as needed during subsequent years of stand life. Herbicide use for stand removal occurs once during stand life-cycle, which is 2-8 years. Herbicide shifts due to stand removal would be smaller in magnitude than herbicide shifts due to weeds control.

## 2.6 Herbicide Usage in Organic Alfalfa Farming

In organic systems, where synthetic herbicides are not permitted, the area to be seeded with alfalfa is tilled and allowed to sit for seven to ten days. Two or more disking passes may be necessary if weed germination is observed. The field should also be treated with nutrients, such as compost and boron, and left for a week to check for further weed germination. Planting can occur once weed growth potential is minimized (Guerena and Sullivan, 2003). Manure fertilizer should be composted to kill weed seeds (Canevari et al., 2007). The USDA NOP standards list the following approved inputs to control weeds (<http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5068682&acct=nopgeninfo>):

- a) As herbicides, weed barriers, as applicable.
  - i) Herbicides, soap-based—for use in farmstead maintenance (roadways, ditches, right of ways, building perimeters) and ornamental crops.
  - ii) Mulches.
    - (1) Newspaper or other recycled paper, without glossy or colored inks.
    - (2) Plastic mulch and covers (petroleum-based other than polyvinyl chloride (PVC)).

In 1994 organic farmers used several weed control practices that are presented in figure J-8.



**Figure J-8: Weed control practices used by organic farmers to produce vegetables, 1994 (Padgitt et al., 2000)**

## 2.7 Summary of Findings

GT crops, which were introduced in 1996, have been widely adopted in the United States and their adoption in the United States and globally is on an upward trend (James, 2007).

Several analyses of pesticide use concluded that herbicide use has been reduced due to the adoption of herbicide-tolerant crops. (Brimner et al., 2005; Fernandez-Cornejo, 2006; Gianessi and Reigner, 2006; Kleter et al., 2007; Sankula, 2006; Johnson et al., 2008). One analysis of pesticide use concluded that herbicide use has increased due to herbicide-tolerant crops (Benbrook, 2004). All the studies agreed that herbicide use has shifted towards glyphosate. Using standardized methods for ranking environmental impact, researchers have concluded that glyphosate is less harmful to the environment than many other herbicides and that the shift of herbicide use has resulted in a net lower environmental impact from herbicides (Kleter et al., 2007).

Glyphosate adsorbs strongly to soil so doesn't generally move vertically below six inches. Glyphosate is rapidly degraded by soil microbes in the environment. The major degradate of glyphosate is aminomethyl phosphonic acid (AMPA), which degrades in the soil to form carbon dioxide. The half-life of glyphosate in soil laboratory studies is two days. In agricultural soils, the half-life of glyphosate ranges from 1.7 to 197.3 days, but is typically less than 60 days. Although glyphosate and AMPA have been detected in surface water and ground water, the

concentrations are many times lower than levels where toxic effects might occur. Glyphosate has low volatility and has not been detected in air, other than possibly adhered to dust particles.

Herbicides are used much more often with alfalfa seed fields (78.3% of total fields) than with hay fields (16.6% of total fields; 22% of acreage). Mechanical and cultural methods for weed control (e.g. tillage and companion crops) were used for ~80% of the spring planted alfalfa and 18% of the fall planted alfalfa (Hower et al., 1999).

Non-GT and GT alfalfa can be treated similarly regarding cultivation techniques and most herbicide applications. The difference between non-GT and GT alfalfa is glyphosate usage. Glyphosate can be used to remove non-GT stands, but can not be used for whole field weed control. Glyphosate can be used for in crop weed control in GT alfalfa but can not be used for stand removal. Organic farming practices do not permit the use of any herbicides. Cultivation weed control practices are permitted in organic farming.

Herbicides related to alfalfa farming can be divided into two major groups, herbicides that do not kill alfalfa, so can be used to control weeds in alfalfa, and herbicides that kill alfalfa, so are used for stand removal. Adoption of GT alfalfa decreases the number of herbicides used to control weeds in alfalfa because glyphosate is the preferred herbicide for GT alfalfa. Adoption of GT alfalfa may increase use of some herbicides used for stand removal. For stand removal adoption of GT alfalfa may result in a shift from glyphosate to other herbicides. Herbicide shifts due to stand removal would be smaller in magnitude than herbicide shifts due to weeds control.

### 3.0 Cultural Farming Practices in Alfalfa

Cultural farming practices include all the methods farmers use to control weeds without the application of herbicides. There are usually multiple benefits of cultural practices beyond weed control. Examples include crop rotation, companion crops, mowing, grazing, burning, tillage, and no-tillage.

#### 3.1 Crop Rotation

For weed, insect, and disease management, it is recommended that alfalfa be used in rotation with other crops (Orloff et al., 1997; Padgitt et al., 2000). Alfalfa is also used in crop rotation because it provides nitrogen to the soil, which decreases fertilizer inputs in other rotations. It can be economically advantageous to include alfalfa in rotations (Mends and Dobbs, 1991).

Perennials and annuals promote and restrict different weeds, so rotating perennials with annuals helps control weeds in general. It is also advisable to rotate alfalfa because mature alfalfa is auto toxic to seedling alfalfa (Xuan et al., 2005). Monsanto recommends that alfalfa can be rotated to grass crops (corn and cereal crops) or broadleaf crops, and that alfalfa should not be rotated with other GT crops (Monsanto, 2008). This limits some options for farmers, as GT corn and GT soybean are both popular rotation crops for alfalfa. Typical rotation crops include wheat, oats, barley, potato (*Solanum tuberosum* L.), sugar beet (*Beta vulgaris* L.), and corn. These are expected to continue as currently practiced because non-glyphosate herbicides are available to manage alfalfa volunteers in each crop. Alfalfa rotation with soybean will remain uncommon because of the lack of nitrogen benefit from alternating between consecutive plantings of legumes. Although the success of rotation with cotton will depend largely on mechanical control of volunteer alfalfa, the number of acres is expected to be low (Rogan and Fitzpatrick, 2004).

The crops that are rotated with alfalfa must have known and available mechanical or herbicidal methods for controlling volunteer alfalfa (Monsanto, 2008). Table J-10 gives an indication of typically recommended crop rotations for alfalfa. These could change as plants and weeds become resistant to glyphosate, or as GT volunteer alfalfa becomes a problem. Crop rotations can help maintain soil fertility, reduce soil erosion, avoid pathogen and pest buildup, adapt to weather changes, avoid allelopathic effects and increase profits (Peel, 1998).

Herbicides that can be used to remove either conventional or GT alfalfa have rotation restrictions. For example, following clopyralid (Curtail® or Stinger®), pea, lentil, potato, and dry bean cannot be planted for 18 months. Picloram (Tordon®) can only be followed by grasses for the year following application. Sunflower, dry bean, and potato should not be planted for several years following picloram (Miller et al., 2006). Dicamba (Banvel®) should not be used prior to soybean and is also limited seasonally in California (Dillehay and Curran, 2006). Because of these restrictions, alfalfa stand removal and rotation schedules should be closely coordinated. Non-glyphosate herbicides are available to manage alfalfa volunteers in wheat, oats, barley, sugar beet, and corn. Therefore rotations from GT alfalfa to those crops should be similar to rotations with non-GT alfalfa (Rogan and Fitzpatrick, 2004). However, if a farmer cultivates another GT crop that would impact crop rotations, and might discourage the use of GT alfalfa as glyphosate could not be used in other crop rotations to control for volunteer alfalfa.

**Table J-10. Recommended Rotations for Pest Reduction (Goodell 2006)**

| <b>Pest</b>                                                                                       | <b>Recommended Rotation</b>                                                                                                                                                                                                  |
|---------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Root knot nematode                                                                                | 1 year rotation with cotton                                                                                                                                                                                                  |
| Stem nematode                                                                                     | 3-4 year rotation with small grains, beans, cotton, corn, sorghum, lettuce, carrots, tomatoes, or forage grasses.*                                                                                                           |
| Diseases:<br>Bacterial wilt<br>Anthracnose<br>Spring blackstem<br>Common leafspot<br>Stagonospora | 3-4 year rotation with small grains, beans, corn, sorghum, forage grasses.*                                                                                                                                                  |
| Winter weeds                                                                                      | A minimum of 1 year (preferably longer) in crops such as small grains, wheat, oats, winter forage grasses that allow the use of selective herbicides that are not registered in alfalfa.                                     |
| Summer weeds                                                                                      | A minimum of 1 year (preferably longer) in crops such as small grains, beans, cotton, corn, sorghum, summer forage grasses that allow the use of selective herbicides that are not registered in alfalfa.                    |
| Dodder                                                                                            | At least 2 years with cotton or other nonhost crops such as small grains, beans, corn, sorghum, or forage grasses. Avoid rotations with crops such as tomatoes, onions, and carrots that also serve as a host for this weed. |
| Nutsedge                                                                                          | Two year rotation with corn or sorghum rotation that includes application of herbicide to control nutsedge.                                                                                                                  |

\* Three to four-year rotations give satisfactory results. A rotation for fewer years will provide minimal suppression.

Adoption of GT alfalfa does affect crop rotations because glyphosate cannot be used for stand removal or volunteer alfalfa control. Therefore other herbicides, which may have rotation restrictions, may need to be used along with tillage to remove GT alfalfa stands. GT alfalfa stands may also last longer than non-GT alfalfa stands (Rogan and Fitzpatrick 2004), therefore adoption of GT alfalfa may influence the number of years that alfalfa is in a rotation. No data was found that quantifies actual differences in herbicide use throughout stand life comparing GT alfalfa with non-GT alfalfa. No data was found that indicates if rotation differences are observed with the adoption of GT alfalfa.

### 3.2 Companion Cropping in Alfalfa

Alfalfa grown for hay is sometimes grown with a companion crop. Companion crops planted with alfalfa are crops that act as weed control and prevent soil erosion, such as oats, spring wheat or peas. They tend to grow much quicker than alfalfa, and out-compete any weeds while alfalfa is becoming established. Once the companion crop begins to compete with the alfalfa for nutrients, water and space, the companion crop can be harvested, and serves as extra profit for the farmer (Smith et al., 1998). At this point, the alfalfa is established enough to compete against any weeds on its own. Oats are the most popular companion crop to alfalfa because they are the least competitive, with alternatives such as peas also in wide use, but exact companion crop habits depend on farmer preference and region (McCordick et al., 2008; Smith et al., 1998). Studies have found that companion cropping in alfalfa can suppress weed growth more than herbicide treatments, but that the crop then competes with the alfalfa, reducing yield (McCordick et al., 2008). As noted in table J-8, companion cropping is more prevalent in the North Central U.S. (Hower et al., 1999).

Companion crops are different from nurse crops in that nurse crops are a specific type of companion crop. Nurse crops do not compete with alfalfa for nutrients, but rather are removed

or killed with herbicide early in development. This can result in both effective weed control and little impact on alfalfa yield (McCordick et al., 2008). Nurse crops can also help reduce wind, water and soil erosion and provide early groundcover like other companion crops (Hall et al., 2004). Other types of companion cropping include using a cover crop, used during dormant seasons to protect the soil, or a barrier crop, used as pest control by serving as a refuge and distraction for pests.

With the development of GT alfalfa, companion cropping options and methods have the opportunity to change. A study by McCordick et al. (2008) looked at the effect of establishment method (companion crops and herbicide interactions) on GT alfalfa establishment. The study found that the highest alfalfa yield came from plots treated with glyphosate, either with or without a companion crop, and that the treatment without herbicide and with a companion crop had the lowest yield, but the system did reduce weed biomass. Also, plots without a companion crop experienced higher dry matter yields than that of plots seeded with a companion crop, indicating that establishing GT alfalfa without a companion crop can maximize production. They also studied the effect of imazamox, another herbicide, on the crops, and found more damage to the alfalfa and lower first harvest yields with use of this herbicide, indicating that the weed control used before the first harvest can significantly impact the crop. Because glyphosate is less damaging to the GT alfalfa, but normal herbicides are still toxic, the results suggest that farmers who grow GT alfalfa can move away from companion cropping and solely use glyphosate for weed control. This would not only reduce potential herbicide damage to the alfalfa, but it could also decrease costs by removing harvesting of the companion crop and increase profits by having more pure alfalfa hay. Exact establishment methods would depend on the goal of the farmer as well as weed presence. Companion crops can decrease weed biomass, but can also decrease yield, and the study concludes that companion crops are not needed with GT alfalfa (McCordick et al., 2008).

### 3.3 Tillage

Tillage fits into the broader context of soil conservation practices. Some soil conservation practices include, chiseling and subsoiling, conservation cover, conservation tillage (no-till, ridge-till, mulch till), contour farming, cover or green manure (legumes), critical area planting (erosion zones), crop residue use, filter strips, grade-stabilization structures, grass and legume in rotation, grassed waterways, strip cropping, and terracing (Caswell et al., 2001).

Tillage practices during cultivation of crops impact the soil and water, and can influence such factors as weed control, crop rotations and yields. Tillage is most often used between crops in order to remove the traces of the previous crop and as weed control in preparation for the next crop. Excessive tillage causes soil erosion. For example, in 100 years half of Iowa's original topsoil eroded (Fawcett and Towery, 2002). Soil degradation has been cited as the most frequent cause of historical cultural decline and civilization collapse (Ragnarsdottir, 2006). Conventional till agriculture fields average one to two orders of magnitude greater soil erosion than natural rates, which is considered unsustainable (Montgomery, 2007). There are multiple types of tillage methods, including conventional tillage, reduced tillage and no tillage. These types of tillage, their uses and their effects are elaborated in table J-11.

Conservation tillage benefits the environment in the following ways (Fawcett and Towery, 2002):

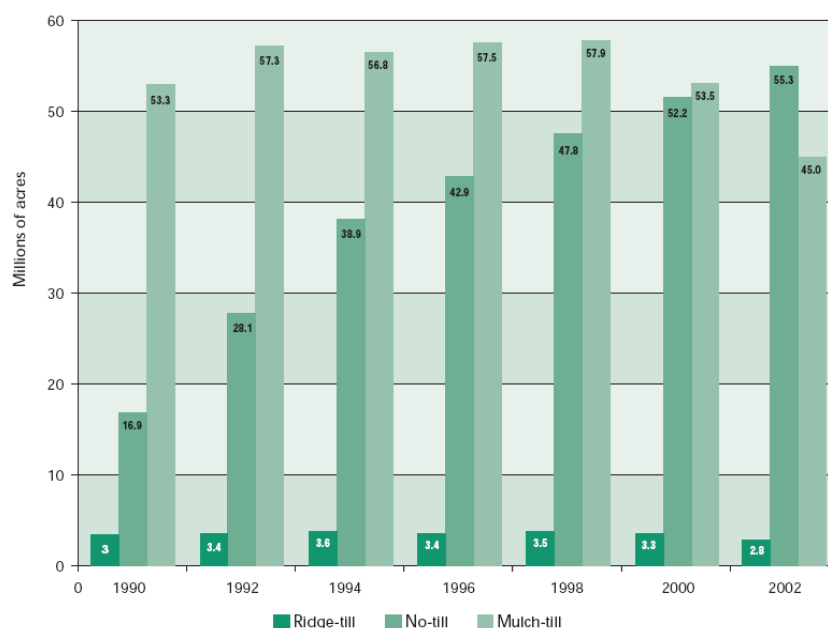
- Reduced soil erosion
- Improved moisture content in soil
- Healthier, more nutrient-enriched soil
- More earthworms and beneficial soil microbes
- Reduced consumption of fuel to operate equipment
- Return of beneficial insects, birds, and other wildlife in and around fields
- Less sediment and chemical runoff entering streams
- Reduced potential for flooding
- Less dust and smoke to pollute the air
- Less carbon dioxide released into the atmosphere

No-till agriculture requires less fossil fuels than conventional agriculture due to decreased use of fertilizers, pesticides, and fuel (Gregory et al., 2005). Both fossil fuel energy consumption and soil compaction (at 15 cm) can be half as much with no-till compared to conventional (Gregory et al., 2005).

Tillage effects cone index, which is a measure of soil strength and soil moisture. Higher cone indexes may lead to reduced crop growth, although cone index effects have not been determined for alfalfa. Preparation of alfalfa seed bed commonly includes deep tillage. Huhnke et al. (1993) measured the effects of different primary tillage practices in alfalfa stand establishment, light disking had the highest cone index and deep primary tillage had the lowest cone index. After the first year cone indexes were not related to primary tillage type. The researchers also concluded that tillage treatment did not significantly affect initial alfalfa population or first year yield. Tillage treatments did have a significant effect on cool-season grass emergence (weeds) within the first month after planting (Huhnke et al., 1993). In another study, forage yield was greater the first year after no-tillage compared to conventional tillage, but there were no differences in yield in the following two years (Malhi et al., 2007). In experimental fields rotated from corn to alfalfa, simulated rainfall and tillage treatments did not strongly affect soil properties, presumably due to a stable soil structure (Karunatilake and van Es, 2002). Forney et al. (1985) found that in experimental sites no-till alfalfa establishment was compromised by factors other than weeds, which is consistent with the concept that reduced-tillage systems generally require more careful management than conventional systems.

No-till farming has grown in popularity since 1996, specifically in crops that since then have had herbicide-tolerant crops introduced. Because the primary purpose of tillage is weed control, farmers can now use and trust herbicide to serve as weed control in its place. Farmers will choose to reduce tillage if they are assured of weed control without disturbing the fields, such as in the case of GT alfalfa where over-the-top glyphosate application is effective (Fawcett and Towery, 2002). Fifty-two percent of GT soybean farmers increased no-till acres after adopting GT soybeans, between 1996 and 2002, while only 21% of non-GT soybean farmers increased no-till acres, indicating a correlation between GT soybeans and decreasing tillage (Fawcett and Towery, 2002). A USDA survey showed that in 1997, 60 percent of GT soybean acres were under conservation tillage while only 40 percent of conventional soybeans were under conservation tillage (Wiebe and Gollehon, 2006). See figure J-9 for the change in tillage

practices from 1990-2002, before and after adoption of GT crops (Fawcett and Towery, 2002). GT crops came on the market in 1996. While use of GT crops encourage reduced tillage, reduced tillage, in turn, encourages increased reliance on herbicide use as weed control. Farmers need methods to manage weeds, and when using GT crops, they will be encouraged to use herbicides (glyphosate) in conjunction with the GT crops. A USDA ERS study from 1994 examined pesticide use based on tillage practices in corn and soybeans, and determined that while herbicide use did increase slightly when tillage was decreased, the biggest difference between tillage methods was the type of herbicides used, not the amount of herbicides total.



**Figure J-9: Conservation tillage adoption in the U.S., 1990-2002**  
(Fawcett and Towery, 2002)

Studies have been performed that look at the impact of GT crops on tillage practices, and also the impact of tillage practices on glyphosate residues in soil and water. The American Soybean Association examined changes in tillage practices once farmers began using GT soybeans, and they found that farmers increasingly used conservation tillage as opposed to conventional tillage (ASA, 2001; Cerdeira and Duke, 2006). When asked why this was the case, 63% of responders stated the GT technology was responsible, as it made cultivation with conservation tillage as effective as conventional tillage. Their reasons included that it reduced weeds, lowered production costs related to fuel and maintenance, decreased the number of labor hours needed for a given field, extended equipment life, and increased yield. The same amount of labor can cover more area elsewhere, leading to increased income. The decreased costs in production might be offset by the increased crop protection costs and the amount of fertilizers needed (Wiebe and Gollehon, 2006).

Tillage can be used in conjunction with GT crops as a form of weed control prior to establishing a stand or for stand removal. If used prior to establishing a stand of alfalfa in order to prepare the land, then this would reduce the amount of herbicide needed for stand establishment (Shukla, 2003).



Sankula (2006) evaluated the impact of biotechnology-derived crops planted in the United States in 2005. A summary of the tillage analysis follows:

- As of 2004 no-till acreage in corn has increased 20 % compared to 1996.
- No till cotton acres increased 371% in 2004 (the most recent year for which information is available) compared to 1996.
- In 2004 about 36% of the total soybean acreage was planted using no-tillage, which represents a 64% increase since 1996.

One study examined the levels of AMPA, a glyphosate residue, in the soil after either low or normal tillage, and found that residues were at higher levels in the low tillage treatment than in the normal tillage treatment, due to increased leaching in the low till treatment (Fomsgaard, 2003). No-till practices can lead to nutrient stratification in the soil because the soil is never mechanically disturbed, and repeated applications of herbicides are made to the surface (Wiebe and Gollehon, 2006). Herbicides that adsorb strongly, such as glyphosate, will be protected from degradation and volatilization, and will not readily leach to ground water. They will only be found in surface water runoff when erosion conditions lead to the loss of surface particles, like in conventional tillage when the soil is highly prone to erosion. Switching to a conservation tillage system, and thus increasing herbicide use, does not increase the likelihood of degradation of water quality through chemical contamination. In general, tillage systems that incorporate low mobility and short persistence herbicides will be better for water-quality standards, with less chance of entering nearby water (Wiebe and Gollehon, 2006). Adopting GT crops would indirectly benefit the environment through the soil conservation practices of conservation tillage, which would increase in popularity (Wiebe and Gollehon, 2006).

Locke et al., (2008) conducted a 6 year conservation tillage field study from 2000 to 2005 at the USDA-ARS Southern Weeds Science Research Unit farm in Stoneville, Mississippi. GT crop rotations were only done from 2003 to 2005. Rotations included continuous GT cotton, continuous non-GT cotton, continuous GT maize, continuous non-GT maize, GT rotation 1 (cotton-maize-cotton), non-GT rotation 1 (cotton-maize-cotton), GT rotation 2 (maize-cotton-maize), and non-GT rotation 2 (maize-cotton-maize). Under continuous GT maize, soils maintained greater soil organic carbon and nitrogen as compared with continuous non-GT maize, but no differences were measured in continuous cotton or in cotton rotated with maize. Soil organisms also showed differences based on fatty acid methyl ester analysis. Locke et al. (2008) concluded that glyphosate use may result in minor effects on soil biological/chemical properties. However, enhanced organic carbon and plant residues in surface soils under conservation practices may buffer potential effects of glyphosate.

Table J-11. Effectiveness of and Restrictions for Herbicides Used for Alfalfa Control

| Herbicide                 | Effect/Efficiency/<br>Resprouting Level                                                                                                                                                                                                                                                                                                 | Tillage                                  | Crop Restrictions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Effect as<br>Volunteer<br>Alfalfa Control<br>(after 2,4-D<br>stand take-out) | Source  |
|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|---------|
| 2,4-D                     | Alfalfa was controlled in tilled and non-tilled treatments at 51% and 55%, respectively. Thirty-six days after stand take-out herbicide treatment, 22 days after tillage, and seven days after irrigation, the same treatment provided 100% and 18% control of Roundup Ready alfalfa in tilled and non-tilled treatments, respectively. | Both tilled and non-tilled fields tested | Only the low rate (0.5 L/acre) should be used in the spring. Only field corn or spring cereals can be planted after a spring application, however a 14 day interval between application and planting is required. No specific crop restrictions when applied alone or with glyphosate in the fall. To be safe the following is recommended: If applied alone or with glyphosate before September 1st, then field corn, soybean, spring cereals and canola can be planted in the spring. If applied after September 1st or in the spring, then only field corn can be planted after application.<br>There must be a 60-day harvest interval in new seedlings and 30 days in established alfalfa. | 95%                                                                          | 1, 2, 3 |
| Clopyralid                | When Stinger (clopyralid) was applied to crops at a rate of 3 oz/A, alfalfa was controlled at 84%, 100%, and 96% in no-tillage, plow, and chisel plow conditions, respectively. At a rate of 4 oz/acre, 91%, 100%, and 99%, respectively; and at 6 oz/acre, 93%, 100%, and 100%, respectively                                           | Both tilled and non-tilled fields tested | Rotational restrictions: peas, lentil, potato, and dry bean cannot be planted until 18 months following clopyralid application.<br><br>Application time: in spring before boot stage and/or as a postharvest fall treatment. To control late-emerging Canada thistle, treat preharvest after grass seed is fully developed; apply after most basal leaves emerge but before bud stage.                                                                                                                                                                                                                                                                                                          | 95%                                                                          | 1, 2, 3 |
| Dicamba                   | When Clarity (Dicamba-diglycolamine salt) was applied to crops at a rate of 4 oz/ acre, alfalfa was controlled at 32%, 90%, and 85% with no-tillage, plow, and chisel plow, respectively. When applied at a rate of 8 oz/ acre, effectiveness ranges from 37% (no-tillage), 91% (plow), and 89% (chisel plow).                          | Both tilled and non-tilled fields tested | Can be applied in the fall or spring prior to corn, but should be applied to alfalfa that is actively growing with at least 10 inches of spring growth or 5 inches of post-harvest regrowth. Dicamba should not be used prior to planting soybean or other susceptible crops.<br>It may severely stunt brome grass.<br>Trees, legumes, and broadleaved plants are sensitive to drift and soil residues.                                                                                                                                                                                                                                                                                         | 25%                                                                          | 1, 2, 3 |
| Dicamba and diflufenzopyr | When Distinct (dicamba and diflufenzopyr) was applied to alfalfa at a rate of 4 oz/ acre, 25% of alfalfa was controlled under no-tillage conditions; 88% under plow; and 82% under the chisel plow. When 8 oz/ acre was applied, 34% control                                                                                            | Both tilled and non-tilled               | Acceptable control of alfalfa can better be reached in a competitive cropping system involving small grains.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 75%                                                                          | 3       |

| Herbicide           | Effect/Efficiency/<br>Resprouting Level                                                                                                                                                | Tillage                    | Crop Restrictions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Effect as<br>Volunteer<br>Alfalfa Control<br>(after 2,4-D<br>stand take-out) | Source     |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|------------|
|                     | was achieved under no-tillage; 90% under plow; and 87% under the chisel plow.                                                                                                          |                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                              |            |
| Glufosinate         | In tilled land after 36 days, glufosinate took out 98% of Roundup Ready alfalfa. In non-tilled land, after 36 days, it controlled 35% control alfalfa.                                 | Both tilled and non-tilled | Canola, corn, and soybean best tolerate glufosinate.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 95%                                                                          | 1, 4       |
| Primsulfuron-methyl |                                                                                                                                                                                        |                            | Primsulfuron-methyl recropping restrictions: corn: 0.5 months; sorghum: 8 months; wheat: 3 months; oats: 8 months; rye: 3 months; alfalfa: 8 months; clover: 18 months; soybeans: 8 months.<br>If a field was previously treated with primsulfuron-methyl, sorghum is not a recrop option.                                                                                                                                                                                                                                                                                                                                                                                                                                                | 95%                                                                          | 5          |
| Picloram            | After Tordon (Picloram) application to Roundup Ready alfalfa at a rate of 8 oz/ acre, 98% of alfalfa was controlled under no-tillage, 100% under plow, and 100% under the chisel plow. | Both tilled and non-tilled | Should be applied when the plant is at least 12 inches tall and actively growing. If applied from late June until mid August, there is better residual control the following growing season than either spring or fall treatments. The plants should be mowed in early to mid summer to promote active regrowth prior to a fall treatment. Can be used in pastures, rangeland, and noncropland only. Fields previously treated with Tordon 202C Liquid Herbicide may be seeded to rapeseed, (including canola) mustard, flax, wheat, oats, barley or may be summer fallowed. These crops are tolerant to residues of picloram remaining in the soil. Sunflower, soybean, dry edible bean, and potato are especially susceptible to Tordon |                                                                              | 1, 3, 6, 7 |
| Acetochlor          |                                                                                                                                                                                        |                            | Corn herbicide recropping restrictions: corn: the next year; sorghum: the next year; wheat: 4 months; oats: 2 <sup>nd</sup> year; rye: 2 <sup>nd</sup> year; alfalfa: 2 <sup>nd</sup> year; clover: 2 <sup>nd</sup> year; soybeans: next year. Rotational options: four months for wheat and to next spring (nine months) for soybean, oats, barley, rye, dry beans, sugar beets and potatoes                                                                                                                                                                                                                                                                                                                                             |                                                                              | 5          |

1-Rogan and Fitzpatrick, 2004

2-[http://plantsci.sdstate.edu/weeds/weed\\_description.cfm?weed=Leafy%20spurge](http://plantsci.sdstate.edu/weeds/weed_description.cfm?weed=Leafy%20spurge)

3-Miller et al., 2006

4-[http://www.bayercropscienceus.com/products\\_and\\_seeds/herbicides/liberty.html](http://www.bayercropscienceus.com/products_and_seeds/herbicides/liberty.html)

5-[www.ipm.uiuc.edu/bulletin/pastpest/articles](http://www.ipm.uiuc.edu/bulletin/pastpest/articles)

6-[http://pr-rp.pmra-arla.gc.ca/PR\\_SOL/pr\\_web.v1?p\\_ukid=9905](http://pr-rp.pmra-arla.gc.ca/PR_SOL/pr_web.v1?p_ukid=9905)

7-Zollinger, 2008

Table J-12. Benefits and Consequences of Various Tillage Systems

| Tillage Types     | Defined                                                                                                                                                                                                                                                                                                                                                                                                                                            | Use                             | Benefits                                                                                                                                                                                                                                                                                                                                                                                                                   | Consequences                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Conventional Till | Full width tillage which disturbs all of the soil surface and is performed prior to and/or during planting. Leaves <b>less than 15 percent residue cover</b> after planting, or less than 500 pounds per acre of small grain residue equivalent throughout the critical wind erosion period. It typically involves plowing or intensive tillage. Weed control is accomplished with herbicides and/or row cultivation.                              | Weed control, field preparation | Highly effective weed control, stand removal, loosens compacted soil                                                                                                                                                                                                                                                                                                                                                       | Causes soil erosion, reduces soil quality and productivity by destroying soil structure, reduces organic matter content and harms beneficial invertebrates such as earthworms, fouls aquatic systems, runoff water contributes to flooding, destroys wildlife food sources, reduces surface crop residues that serve as wildlife cover.                                                                                                                                                                                                       |
| Reduced Till      | Full-width tillage involving one or more tillage trips which disturbs all of the soil surface and is performed prior to and/or during planting. Leaves <b>15 to 30 percent residue cover</b> after planting or 500 to 1,000 pounds per acre of small grain residue equivalent throughout the critical wind erosion period. Weed control is accomplished with crop protection products and/or row cultivation.                                      |                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Conservation Till | Any tillage and planting system that leaves <b>more than 30 percent residue cover</b> on the soil surface, after planting, to reduce soil erosion by water. Where soil erosion by wind is the primary concern, any system that maintains at least 1,000 pounds per acre of flat, small grain residue equivalent on the surface throughout the critical wind erosion period. No-till, ridge-till, and mulch-till are types of conservation tillage. | Weed control, field preparation | Reduces soil erosion, consumption of fuel to operate equipment, labor cost/hours, improves moisture content in soil, results in healthier, more nutrient-enriched soil, more earthworms and beneficial soil microbes, the return of beneficial insects, birds and other wildlife in and around fields, lessens sediment and chemical runoff entering streams, reduces potential for flooding, decreases amount of dust and | Dependence on herbicides, weed spectrum shifts to perennial weeds, increases herbicide resistant weeds, increases herbicide use, increases danger of crop injury due to reduced tolerance to herbicides or presence of herbicides in the soil affecting crop rotations, inconsistent yields based on climate or soils, complex nutrient management due to higher residue levels and reduced options with regard to method and timing of nutrient applications, nutrient stratification, need to supplement nitrogen in soil for some crops, , |
| Mulch Till        | Full-width tillage involving one or more tillage trips which disturbs all of the soil surface and is done prior to and/or during planting. Tillage tools such as chisels, field cultivators, disks, sweeps, and blades are used. Weed control is accomplished with herbicides and/or mechanical cultivation.                                                                                                                                       |                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Ridge Till        | Tillage on ridges with sweeps, disk openers, coulters or row cleaners along with nutrient injection. Residue is left on the surface between the ridges. Weed control is accomplished with herbicides and/or mechanical cultivation. Ridges are rebuilt during cultivation.                                                                                                                                                                         |                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

| <b>Tillage Types</b> | <b>Defined</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>Use</b> | <b>Benefits</b>                                                                | <b>Consequences</b>                                                                     |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|--------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| No Till              | The soil is left undisturbed from harvest to planting except for planting and nutrient injection. Planting or drilling is accomplished in a narrow seedbed or slots created by coulters, row cleaners, disk openers, in-row chisels or rotary tillers. Weed control is accomplished primarily by herbicides. Cultivation may be used for emergency weed control. Other common terms used to describe no-till include direct seeding, slot planting, zero-till, row-till, and slot-till. |            | smoke to pollute the air, lessens carbon dioxide released into the atmosphere. | high residue cover prevents soil from warming quickly, so plants emerge and grow slowly |

Sources: Fawcett and Towery, 2002; Conservation for Agriculture's Future, Wiebe and Gollehon, 2006, Johnson, 2005

### 3.4 Summary of Findings

Cultural practices such as crop rotation, companion crops, mowing, grazing, burning, tillage, and no-tillage provide multiple benefits to crop production.

Alfalfa is used in crop rotation because it provides nitrogen to the soil, which decreases fertilizer inputs in other rotations. Perennials and annuals promote and restrict different weeds, so rotating perennials with annuals helps control weeds in general.

Adoption of GT alfalfa affects crop rotations because glyphosate cannot be used for stand removal or volunteer alfalfa control. Therefore other herbicides, which may have rotation restrictions, may need to be used along with tillage to remove GT alfalfa stands. GT alfalfa stands may also last longer than non-GT alfalfa stands, therefore adoption of GT alfalfa may influence the number of years that alfalfa is in a rotation. It is recommended that rotations not consist of all GT crops. Because several of the crops that are popular in rotation with alfalfa (corn, soybeans) have GT varieties farmers may have to decide which GT crop provides the most benefit to the rotation plan and overall farm production.

There are several types of companion cropping practices. These include crops that are interseeded with alfalfa and provide protection from wind and harsh weather or outcompete weeds in the stand establishment year, crops that are planted to cover the soil and prevent erosion between growing seasons, and barrier crops along side fields that serve as a refuge for beneficial insects and distract pests. Interseeded companion crops are not likely to be used with GT alfalfa.

Soil conservation practices include, chiseling and subsoiling, conservation cover, conservation tillage (no-till, ridge-till, mulch till), contour farming, cover or green manure (legumes), critical area planting (erosion zones), crop residue use, filter strips, grade-stabilization structures, grass and legume in rotation, grassed waterways, strip cropping, and terracing. GT alfalfa is compatible with all soil conservation practices. GT crops are known to enhance the adoption of conservation tillage.

The cultural practices associated with GT crops and GT alfalfa have a net benefit on soil conservation and quality.

## Appendix J-1.

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<http://www.ag.ndsu.edu/weeds/w253/w253-3f.htm>.

## Appendix J-2.

## Literature Search

### 1.0 Literature Search Strategy

#### 1.1 Purpose

The purpose of this literature search is to locate references about the potential impacts of glyphosate-tolerant alfalfa cultivation practices on water, soil, and air.

#### 1.2 Retrieval criteria

Titles were used to indicate the subject of the paper. If the paper was not in English or indicated a geographic region outside of the U.S., it was not retrieved. Over 90 pages of titles were generated by the searches (see Results below). All titles were reviewed and approximately 50 titles were deemed relevant to provide information on cultivation practices in alfalfa (highlighted in gray in the Results below). The selected titles were searched for online by a professional librarian. Titles that were obtained for free and were cited include the URL in the citation. Titles that were not free access were obtained through online purchase or the use of a copy vendor, who regularly visits National Institutes of Health and National Agricultural Library to obtain references. Not all of the articles were retrieved due to availability. Books that were of marginal interest were not purchased.

#### 1.3 Databases

File 10:AGRICOLA 70-2008/Jun  
(c) format only 2008 Dialog  
File 156:ToxFile 1965-2008/Jun W2  
(c) format only 2008 Dialog  
File 266:FEDRIP 2008/Feb  
Comp & dist by NTIS, Intl Copyright All Rights Res  
File 245:WATERNET(TM) 1971-2008Apr  
(c) 2008 American Water Works Association  
File 5:Biosis Previews(R) 1926-2008/Jun W2  
(c) 2008 The Thomson Corporation  
File 6:NTIS 1964-2008/Jun W4  
(c) 2008 NTIS, Intl Cpyrght All Rights Res  
File 41:Pollution Abstracts 1966-2008/May  
(c) 2008 CSA.  
File 40:Enviroline(R) 1975-2008/Apr  
(c) 2008 Congressional Information Service  
File 76:Environmental Sciences 1966-2008/Jun  
(c) 2008 CSA.  
File 24:CSA Life Sciences Abstracts 1966-2008/Mar  
(c) 2008 CSA.  
File 117:Water Resources Abstracts 1966-2008/Mar

(c) 2008 CSA.  
File 144:Pascal 1973-2008/Jun W2  
(c) 2008 INIST/CNRS  
File 50:CAB Abstracts 1973-2008/May W4  
(c) 2008 CAB International  
File 44:Aquatic Science & Fisheries Abstracts 1966-2008/Mar  
(c) 2008 CSA.  
File 71:ELSEVIER BIOBASE 1994-2008/Jun W2  
(c) 2008 Elsevier B.V.  
File 143:Biol. & Agric. Index 1983-2008/Apr  
(c) 2008 The HW Wilson Co  
File 203:AGRIS 1974-2008/Feb  
Dist by NAL, Intl Copr. All rights reserved

Descriptions of these files are available at <http://library.dialog.com/bluesheets/>.

## 1.4 Scope of Search

The search focused on any published references between 1990 and the present. A list of titles (below) was screened followed by screening of abstracts for relevant titles. There were no limits on language for titles but only English language publications were retrieved for evaluation.

## 1.5 Key word combinations

Alfalfa OR Medicago AND “organic farm\*”

Alfalfa OR Medicago AND cultivation

Alfalfa OR Medicago AND till\*

Glyphosate AND water AND contamination

Glyphosate AND air AND contamination

Glyphosate AND soil AND contamination

## 1.6 Key Questions

(numbering from original APHIS scope document)

5. What differences are there in weediness traits of conventional alfalfa versus glyphosate-tolerant alfalfa under managed crop production systems as well as in unmanaged ecosystems?

6. What is the occurrence of common and serious weeds found in organic alfalfa systems, in conventional alfalfa systems, and in glyphosate-tolerant alfalfa systems?



What are the current impacts of weeds, herbicide-tolerant weeds, weed management practices, and unmet weed management needs for organic and conventional alfalfa cultivation?  
How may the weed impacts change with the use of glyphosate-tolerant alfalfa?

7. What are the particular management practices for controlling weeds in organic alfalfa systems, in conventional alfalfa systems, and in glyphosate-tolerant alfalfa systems?  
What are the potential changes in crop rotation practices and weed management practices for control of volunteer alfalfa or herbicide-tolerant weeds in rotational crops that may occur with the use of glyphosate-tolerant alfalfa?  
What are the potential effects on alfalfa stand termination and renovation practices that may occur with the use of glyphosate-tolerant alfalfa?  
What is the potential weediness of glyphosate-tolerant alfalfa?

8. What is the potential cumulative impact of glyphosate resistant weeds, especially with the increase in acreage of glyphosate-tolerant crops?  
Are there glyphosate resistant weeds and what is their prevalence in crops and in non-crop ecosystems?  
Will the release of glyphosate-tolerant alfalfa cause an increase in glyphosate resistant weeds in alfalfa and in other crops?  
Which weeds are the most likely to gain glyphosate resistance with the use of glyphosate-tolerant alfalfa?  
What are the alternatives for management of glyphosate-tolerant or other herbicide-tolerant weeds in glyphosate-tolerant alfalfa stands or in subsequent crops?  
What are the potential changes that may occur in glyphosate-tolerant alfalfa as to susceptibility or tolerance to other herbicides?

9. What are current or prospective herbicide-tolerant weed mitigation options, including those addressed by the Environmental Protection Agency-approved label for glyphosate herbicides?

## 1.7 Results

```
S1  147012  ALFALFA OR MEDICAGO
S2  873388  ORGANIC()FARM? OR CULTIVAT? OR TILL OR TILLED OR TILLS OR
      TILLING OR TILLAGE
S628645322 PY=1926:1989 [faster to take out older than keep newer]
S7   72469  S1 NOT S6
S8   5994   S7 AND S2
S9   3010   S7 (S) S2
S10  444    S9/TI
S11  171    RD S10  (unique items)
```

12/6/1 (Item 1 from file: 203)  
01571304

Adaptability and \*cultivation\* methods of Xinjiang broad leaf \*alfalfa\*  
1990

12/6/2 (Item 2 from file: 50)  
000846209 CAB Accession Number: 20033094659  
Agronomic and energy evaluation of clover [ Trifolium sp.] and lucerne [

\*Medicago\* sativa ] mixed \*cultivation\* in forest steppe of the cis-Urals.  
Publication Year: 2003

12/6/3 (Item 3 from file: 203)

02090131

\*Alfalfa\* (\*Medicago\* sativa L.) samples \*cultivated\* in vitro and  
evaluated as selection resource (Selektsionna otsenka na obraztsi  
lyutserna (Medicago sativa L.), polucheni chrez in vitro metoda)  
1995

12/6/4 (Item 4 from file: 10)

4528411 43826342 Holding Library: AGL

\*Alfalfa\* management in no-\*tillage\* corn  
2006

12/6/5 (Item 5 from file: 10)

3151543 92012874 Holding Library: AGL

\*Alfalfa\* and orchardgrass control in no-\*till\* corn  
1991

12/6/6 (Item 6 from file: 50)

0006456718 CAB Accession Number: 19912312898

\*Alfalfa\* and orchardgrass control in no-\*till\* corn.  
Proceedings, 45th annual meeting of the Northeastern Weed Science  
Society.

Publication Year: 1991

12/6/7 (Item 7 from file: 5)

10787694 BIOSIS NO.: 199192033465

ANTAGONISTIC POTENTIAL OF SOIL MICROFLORA TO VERTICILLIUM-DAHLIAE KLEB. IN  
COTTON-\*ALFALFA\* CROP ROTATION FIELDS AS A FUNCTION OF THE DEPTH AND  
TECHNIQUES OF \*CULTIVATION\*  
1990

12/6/8 (Item 8 from file: 50)

0009012128 CAB Accession Number: 20063044893

Assessing inter and intra-population genetic diversity and structure in  
Iranian \*cultivated\* \*alfalfa\* ( \*Medicago\* sativa L.) using  
microsatellite markers.

Publication Year: 2005

12/6/9 (Item 9 from file: 203)

02673757

2006

[Breeding value of \*alfalfa\* wild species and species of limited  
occurrence as \*cultivated\* plants] (Selektsionnaya tsennost'  
dikorastushchikh i malo rasprostranennykh v kul'ture vidov lyutserny)

12/6/10 (Item 10 from file: 5)

0019803970 BIOSIS NO.: 200700463711

Basic technological criteria for \*alfalfa\* \*cultivation\*  
ORIGINAL LANGUAGE TITLE: A Lucernatermesztes Technologiaialapjai  
2007

12/6/11 (Item 11 from file: 50)

0006540291 CAB Accession Number: 19921966293

Copper fractions in the soil-plant system influenced during \*alfalfa\*  
\*cultivation\*. Proceedings - Congress of the European Society of Agronomy.  
Publication Year: 1990

12/6/12 (Item 12 from file: 203)  
02212551

Chemical composition and quality of the forage of \*alfalfa\* varieties  
\*cultivated\* under different water supply and fertilization (Khimichen  
s"stav i kachestvo na furaza ot sortove lyutserna, otglezhdani pri  
razlichna vodoosigurenost i torene)  
1996

12/6/13 (Item 13 from file: 203)  
02017956

1995  
[Chemical control of broad-leaved weeds in \*alfalfa\* \*cultivation\*] (Control  
quimico de malezas latifoliadas en implantacion del cultivo de  
alfalfa)

12/6/14 (Item 14 from file: 50)  
0008402962 CAB Accession Number: 20033036095

Chemical control of weeds in winter wheats \*cultivated\* with \*alfalfa\*  
as a companion crop.

Original Title: Chemiczne zwalczanie chwastow w zbozach ozimych z  
wsiewka, koniczyzny akowej.

Publication Year: 2002

12/6/15 (Item 15 from file: 5)  
10509480 BIOSIS NO.: 199141022106  
CHANGES IN THE BIOCHEMICAL INDICES OF \*ALFALFA\* CULTIVARS \*CULTIVATED\* IN  
THE CENTRAL ASIAN REGION USSR INDUCED BY INOCULATION WITH NODULE BACTERIA  
1990

12/6/16 (Item 16 from file: 10)  
2127848 83786077 Holding Library: AGL; AGL  
\*Alfalfa\* \*cultivation\*.  
Cultivo de la alfalfa / por Ramon Garcia Oses. -  
1921

12/6/17 (Item 17 from file: 50)  
0008640724 CAB Accession Number: 20043052199  
\*Cultivation\* of Galega orientalis and \*Medicago\* varia as a  
resource-saving measure.  
Publication Year: 2001

12/6/18 (Item 18 from file: 50)  
0007442035 CAB Accession Number: 19970709723  
\*Cultivation\* of lucerne [ \*Medicago\* sativa ] in Zemaitija, Lithuania.  
Original Title: Liucernu auginamas Zemaitijoje.  
Publication Year: 1995

12/6/19 (Item 19 from file: 50)  
0008065480 CAB Accession Number: 20013086523  
\*Cultivating\* \*alfalfa\* mixed with timothy: changes in harvest and  
nutritive value.  
Original Title: Saagi ja toitevaartuse muutused lutserni kasvatamisel

segus poldtimutiga.

Publication Year: 2001

12/6/20 (Item 20 from file: 203)

01962509

1993

[The \*cultivation\* of the \*alfalfa\* in the half zone of San Luis Potosi State] (El cultivo de la alfalfa en la zona media de San Luis Potosi)

12/6/21 (Item 21 from file: 203)

01552318

1990

\*[Cultivation\* of roughage [grasses, whole crop, \*alfalfa\*, beets, maize, textbook]] (Dyrkning af grovfoder)

12/6/22 (Item 22 from file: 203)

01856014

\*Cultivation\* technique for high yield of Xinjiang big leaf \*alfalfa\*

1993

12/6/23 (Item 23 from file: 10)

3771212 22002348 Holding Library: AGL

\*Cultivation\* of established \*alfalfa\* stands

1996

12/6/24 (Item 24 from file: 50)

0008931181 CAB Accession Number: 20053196860

Calcium and magnesium ratio in the fertility of a dystrophic dark red latosol \*cultivated\* with \*alfalfa\*.

Original Title: Relacao calcio e magnesio na fertilidade de um latossolo vermelho escuro distrofico cultivado com alfafa.

Publication Year: 2005

12/6/25 (Item 25 from file: 5)

15805592 BIOSIS NO.: 200000523905

[Study comparing the morphological features and productivity of \*alfalfa\* (\*Medicago\* media Pers.) \*cultivated\* in pure sowing and in mixtures with plants of the Papilionaceae family and grasses. Part I: Morphological features of the plants and the structure of the field in relation to the \*cultivation\* method]

ORIGINAL LANGUAGE TITLE: Studium porownawcze cech morfologicznych i produktywnosci lucerny mieszanecowej (Medicago media Pers.) uprawianej w czystym siewie i w mieszankach z roslinami motylkowatymi i trawami  
1998

12/6/26 (Item 26 from file: 50)

0007919170 CAB Accession Number: 20000710029

Comparative study of morphological traits and productivity of \*alfalfa\* (\*Medicago\* media Pers) \*cultivated\* in pure stands and in mixture with legumes and grasses. Part II. Relationship between morphological traits of legumes at the 1st cut.

Original Title: Studium porownawcze cech morfologicznych i produktywnosci lucerny mieszanecowej (Medicago media Pers) uprawianej w czystym siewie i w mieszankach z roslinami motylkowatymi i trawami. Cz. II. Wzozaleznosc cech morfologicznych roslin motylkowatych w I pokosie.

Publication Year: 1999

12/6/27 (Item 27 from file: 5)  
15897459 BIOSIS NO.: 200100069298  
[Comparative study of morphological traits and productivity of \*alfalfa\* (\*Medicago\* media Pers) \*cultivated\* in pure sowing and in mixture with papilionaceous plants and grasses. Part II. Relationship between morphological traits of papilionaceous in 1-st cutting]  
ORIGINAL LANGUAGE TITLE: Studium porownawcze cech morfologicznych i produktywnosci lucerny mieszankowej (Medicago media Pers) uprawianej w czystym siewie i w mieszkach z roslinami motylkowatymi i trawami  
1999

12/6/28 (Item 28 from file: 10)  
3427693 20445776 Holding Library: AGL  
A comparison of irrigated corn production in no-\*till\* and plowed \*alfalfa\* sod  
1995 Jan

12/6/29 (Item 29 from file: 10)  
3305068 93047263 Holding Library: AGL  
Comparison of slug Mollusca: Pulmonata) trapping in no-\*till\* \*alfalfa\*  
1993 Jun

12/6/30 (Item 30 from file: 203)  
02520808  
[The content of heavy metals in \*cultivated\* \*alfalfa\*] (Continutul metalelor grele in lucerna cultivata)  
2001  
[Breeding and technologies of cultivation of leguminous and forage crops] (Ameliorarea si tehnologiile de cultivare a culturilor leguminoase si furajere)

12/6/31 (Item 31 from file: 50)  
0007606289 CAB Accession Number: 19982303279  
Control of Johnson grass (Sorghum halepense (L.) Pers.) in \*alfalfa\* stands \*cultivated\* for forage and seeds.  
Publication Year: 1997

12/6/32 (Item 32 from file: 10)  
3700197 21806066 Holding Library: AGL  
Control of established \*alfalfa\* (\*Medicago\* sativa L.) and red clover (Trifolium pratense L.) in a no-\*till\* corn (Zea mays L.) cropping sequence  
1998

12/6/33 (Item 33 from file: 144)  
13970916 PASCAL No.: 99-0153354  
Contrasting patterns of genetic diversity in neutral markers and agromorphological traits in wild and \*cultivated\* populations of \*Medicago\* sativa L. from Spain  
Methodologies de gestion et de conservation des ressources genetiques (Methodologies of genetic resources management and conservation) 1998

12/6/35 (Item 35 from file: 10)  
3486532 20488449 Holding Library: AGL  
Conventional vs. no-\*till\* corn following \*alfalfa\*/grass: timing of vegetation kill  
1992 Sep

12/6/36 (Item 36 from file: 50)  
0008151196 CAB Accession Number: 20013097991  
Conservation \*tillage\* using organic fertilizer mulch in \*alfalfa\*.  
Original Title: Labranza de conservacion usando coberturas de abono organico en alfalfa.  
Publication Year: 2000

12/6/37 (Item 37 from file: 5)  
0019523483 BIOSIS NO.: 200700183224  
Construction of two genetic linkage maps in \*cultivated\* tetraploid \*alfalfa\* (\*Medicago\* sativa) using microsatellite and AFLP markers  
2003

12/6/38 (Item 38 from file: 10)  
3814170 22036904 Holding Library: AGL  
Differentiation between natural and \*cultivated\* populations of \*Medicago\* sativa (Leguminosae) from Spain: analysis with random amplified polymorphic DNA (RAPD) markers and comparison to allozymes  
1999

12/6/39 (Item 39 from file: 144)  
09268349 PASCAL No.: 91-0058724  
Les divers pratiques de la culture de la luzerne  
(Different practices of \*alfalfa\* \*cultivation\*)  
1990

12/6/40 (Item 40 from file: 50)  
0008742538 CAB Accession Number: 20043161675  
Study of daily water consumption by the species \*Medicago\* sativa \*cultivated\* in the Chinteni experimental field, Cluj county.  
Original Title: Cercetari privind consumul diurn de apa al speciei \*Medicago\* sativa , \*cultivata\* in campul experimental chinteni - jud. cluj.  
Publication Year: 2001

12/6/41 (Item 41 from file: 203)  
02307377  
Dry matter production and seasonal distribution and chemical composition of alfafa \*cultivates\* (\*Medicago\* sativa L.) (Producao e distribuicao de materia seca e composicao bromatologica de cultivares de alfafa (Medicago sativa L.))  
1998

12/6/42 (Item 42 from file: 5)  
14750697 BIOSIS NO.: 199900010357  
Dry matter production and seasonal distribution and chemical composition of \*alfalfa\* \*cultivates\* (\*Medicago\* sativa L.)  
1998

12/6/43 (Item 43 from file: 50)  
0008340690 CAB Accession Number: 20023168644  
Efficiency of phosphorus sources and rates for \*alfalfa\* and centrosema \*cultivated\* in an Yellow Latosol (Oxisol).  
Original Title: Eficiencia de fontes e doses de fosforo na alfafa e centrosema cultivadas em Latossolo Amarelo.  
Publication Year: 2002

12/6/44 (Item 44 from file: 50)  
0008393650 CAB Accession Number: 20033018750  
Effect of \*cultivation\* of \*Medicago\* sativa on soil fertility in  
Tabarian and Tavacolbagh rangelands of Khorasan Province.  
Publication Year: 2002

12/6/45 (Item 45 from file: 10)  
3170991 92027340 Holding Library: AGL  
Effects of coated seed on \*alfalfa\* stand density and yield in reduced  
\*tillage\* systems  
1991

12/6/46 (Item 46 from file: 50)  
0008018862 CAB Accession Number: 20013038660  
The influence of different ways of \*alfalfa\* ( \*Medicago\* sativa L.)  
stands \*cultivation\* on its yield capacity.  
Publication Year: 2001

12/6/47 (Item 47 from file: 10)  
3871266 22085890 Holding Library: AGL  
Effect of field inoculation with Sinorhizobium meliloti L33 on the  
composition of bacterial communities in rhizospheres of a target plant (  
\*Medicago\* sativa) and a non-target plant (Chenopodium album)--linking of  
16S rRNA gene-based single-strand conformation polymorphism community  
profiles to the diversity of \*cultivated\* bacteria  
2000

12/6/48 (Item 48 from file: 143)  
1248332 H.W. WILSON RECORD NUMBER: BBAI00048200  
Effect of field inoculation with Sinorhizobium meliloti L33 on the  
composition of bacterial communities in rhizospheres of a target plant (  
\*Medicago\* sativa) and a non-target plant (Chenopodium album)--linking of  
16S rRNA polymorphism community profiles to the diversity of \*cultivated\*  
bacteria  
20000800

12/6/49 (Item 49 from file: 50)  
0008843019 CAB Accession Number: 20053095618  
Effects of growing system, soil \*cultivation\* and stage of development  
on crude protein and fibre content in \*alfalfa\* ( \*Medicago\* sativa , L.).  
Publication Year: 2004

12/6/50 (Item 50 from file: 71)  
03729864 2007148475  
Effect of lucerne seed bacterization (\*Medicago\* sativa L.) on yield  
components in ecological \*cultivation\*  
ISSUE TITLE: Proceedings of the VI.ALPS-ADRIA Scientific Workshop

12/6/51 (Item 51 from file: 5)  
0019740899 BIOSIS NO.: 200700400640  
Effect of lucerne seed bacterization (\*Medicago\* sativa L.) on yield  
components in ecological \*cultivation\*  
2007

12/6/52 (Item 52 from file: 203)

02168404

Influence of the intensive factors on the yield of \*alfalfa\*  
\*cultivated\* on calcareous chernozem (Vliyanie na intenzivnite faktori  
v"rkhu dobiva ot lyutserna, otglezhdana na karbonaten chernozem)  
1996

12/6/53 (Item 53 from file: 10)  
3394370 20418661 Holding Library: AGL  
Effect of plant genotype on the transformation of \*cultivated\* \*alfalfa\*  
(\*Medicago\* sativa) by Agrobacterium tumefaciens  
1994

12/6/54 (Item 54 from file: 144)  
11444615 PASCAL No.: 94-0278975  
Effect of plant genotype on the transformation of \*cultivated\* \*alfalfa\*  
(\*Medicago\* sativa) by Agrobacterium tumefaciens  
1994

12/6/55 (Item 55 from file: 10)  
3411103 20432820 Holding Library: AGL  
Effects of \*tillage\* on \*alfalfa\* establishment and production  
1992

12/6/56 (Item 56 from file: 10)  
3302369 93044457 Holding Library: AGL  
Effect of \*tillage\* on nitrogen response in corn (Zea mays L.) after  
established \*alfalfa\* (\*Medicago\* sativa L.)  
1993 Jan

12/6/58 (Item 58 from file: 10)  
3037938 90056775 Holding Library: AGL  
Effect of \*tillage\* on soil water and \*alfalfa\* establishment in corn  
stubble  
1990

12/6/59 (Item 59 from file: 10)  
3372335 20398036 Holding Library: AGL  
Effect of \*tillage\* system on the spontaneous regeneration of two annual  
medics (\*Medicago\* spp.) after wheat in north Syria  
1994 Apr

12/6/60 (Item 60 from file: 10)  
3035972 90057355 Holding Library: AGL  
Effect of atrazine and \*tillage\* on \*alfalfa\* (\*Medicago\* sativa)  
establishment in corn (Zea mays)-\*alfalfa\* rotation  
1990 Apr

12/6/61 (Item 61 from file: 50)  
0008564470 CAB Accession Number: 20033213695  
The influence of stands \*cultivation\* on persistency of different  
cultivars of \*Medicago\* sativa L.  
Publication Year: 2003

12/6/62 (Item 62 from file: 5)  
11790180 BIOSIS NO.: 199395092446  
The effect of C 360 tractor traffic over the soil in the third year of



\*alfalfa\* (\*Medicago\* varia Martin) \*cultivation\*  
1993

12/6/63 (Item 63 from file: 50)  
0007250070 CAB Accession Number: 19961608176  
Early screening for drought tolerance in \*cultivated\* \*alfalfa\*.  
Publication Year: 1995

12/6/64 (Item 64 from file: 10)  
3452772 20465300 Holding Library: AGL  
Erosion from \*alfalfa\* established with oat under conservation \*tillage\*  
1995 Mar

12/6/65 (Item 65 from file: 144)  
14249409 PASCAL No.: 99-0452382  
Etude des populations naturelles en contact avec un compartiment cultive  
apparente. Le cas de Medicago sativa L. en Espagne  
(The study of natural populations in contact with related \*cultivated\*  
forms. The case of \*Medicago\* sativa L. from Spain) 1998-04; 1998

12/6/66 (Item 66 from file: 10)  
3790409 22017001 Holding Library: AGL  
Evidence for gene flow between wild and \*cultivated\* \*Medicago\* sativa  
(Leguminosae) based on allozyme markers and quantitative traits  
1999

12/6/67 (Item 67 from file: 5)  
16680662 BIOSIS NO.: 200200274173  
Evaluation of \*cultivates\* of \*alfalfa\* (\*Medicago\* sativa L.) by in situ  
degradability technique  
2001

12/6/68 (Item 68 from file: 50)  
0009253280 CAB Accession Number: 20073084627  
Evaluation and recommendations for the use and management of soil,  
irrigation system and \*alfalfa\* \*cultivation\* on a farm in Zapala  
Department (Neuquen).  
Original Title: Evaluacion y recomendaciones para el uso y manejo de  
los suelos, el riego y el cultivo de alfalfa en un establecimiento del  
departamento Zapala (Neuquen).  
Publication Year: 2006

12/6/69 (Item 69 from file: 10)  
3009760 90037353 Holding Library: AGL  
The evolution of hemolytic saponin content in wild and \*cultivated\*  
\*alfalfa\* (\*Medicago\* sativa, Fabaceae)  
1990 Apr

12/6/70 (Item 70 from file: 50)  
0006540285 CAB Accession Number: 19921966287  
Evolution of plant Zn concentration and chemical fractions of Zn in soil  
during \*alfalfa\* \*cultivation\*.  
Proceedings - Congress of the European Society of Agronomy.  
Publication Year: 1990

12/6/71 (Item 71 from file: 50)

0008304437 CAB Accession Number: 20023003982

Evaluation of soil chemical properties in 'suka kollus' \*cultivated\* with association of fodder plants and \*alfalfa\*, locality of Batallas, Department of La Paz [Bolivia].

Original Title: Evaluacion de propiedades quimicas en suelos de suka kollus cultivados con asociaciones de forrajeras y alfa-alfa, localidad Batallas, Departamento de La Paz.

Publication Year: 2001

12/6/73 (Item 73 from file: 5)

14873730 BIOSIS NO.: 199900133390

Establishment of corn in rotation and \*alfalfa\* and rye: Influence of grazing, \*tillage\*, and herbicides  
1998

12/6/74 (Item 74 from file: 10)

3762070 21990427 Holding Library: AGL

Establishment of corn in rotation with \*alfalfa\* and rye: influence of grazing, \*tillage\*, and herbicides  
1998

12/6/75 (Item 75 from file: 10)

3128195 91053684 Holding Library: AGL

Establishing \*alfalfa\* in corn ground with various \*tillage\* and weed control treatments  
1990

12/6/76 (Item 76 from file: 10)

3785417 22011750 Holding Library: AGL

The establishment of \*alfalfa\* into different maize residues by conservation-\*tillage\* and its effect on insect infestation  
1999

12/6/77 (Item 77 from file: 203)

02520264

[The influence of chemical fertilizers on \*cultivated\* \*alfalfa\* productivity] (Influenta ingrasamintelor chimice asupra productivitatii lucernei cultivate)

2001

[Breeding and technologies of cultivation of leguminous and forage crops] (Ameliorarea si tehnologiile de cultivare a culturilor leguminoase si furagere)

12/6/78 (Item 78 from file: 50)

0007661422 CAB Accession Number: 19990700103

Forage yield, \*cultivation\*, management and utilization of \*Medicago\* sativa and *Onobrychis viciifolia* in different sowing methods in forage-grain crop rotation.

Publication Year: 1997

12/6/79 (Item 79 from file: 203)

01903532

(US farmers are enthusiastic - \*alfalfa\* \*cultivation\* without regrets?)  
(US-Farmer sind begeistert: Luzerne: Anbau ohne Reue?)

1994

12/6/80 (Item 80 from file: 5)  
10468764 BIOSIS NO.: 199140111655  
FERTILIZER NITROGEN BALANCE IN TYPICAL SIEROZEM SOILS IN THE \*CULTIVATION\*  
OF COTTON FOLLOWING THE \*CULTIVATION\* OF \*ALFALFA\*  
1990

12/6/81 (Item 81 from file: 10)  
3900178 22438416 Holding Library: AGL  
Genetic diversity of Sinorhizobium populations recovered from different  
\*Medicago\* varieties \*cultivated\* in Tunisian soils  
2001

12/6/82 (Item 82 from file: 10)  
3194999 92044498 Holding Library: AGL  
Genetic segregation of random amplified polymorphic DNA in diploid  
\*cultivated\* \*alfalfa\*  
1992 Feb

12/6/83 (Item 83 from file: 5)  
12604583 BIOSIS NO.: 199598072416  
Germplasm transfer to \*cultivated\* \*alfalfa\* mediated by 2n gametes  
1994

12/6/84 (Item 84 from file: 10)  
3239862 92074549 Holding Library: AGL  
Habitat and food preferences of Allonemobius allardi (Orthoptera:  
Gryllidae) and potential damage to \*alfalfa\* in conservation-\*tillage\*  
systems  
1992 Oct

12/6/85 (Item 85 from file: 10)  
3170989 92027338 Holding Library: AGL  
Are herbicides necessary for \*alfalfa\* establishment?: Results from  
studies with conventional and no-\*till\* \*alfalfa\*  
1991

12/6/86 (Item 86 from file: 10)  
3967276 23253325 Holding Library: AGL  
How mitochondrial DNA diversity can help to understand the dynamics of  
wild-\*cultivated\* complexes. The case of \*Medicago\* sativa in Spain  
2001

12/6/87 (Item 87 from file: 5)  
18559785 BIOSIS NO.: 200510254285  
Study of hypocholesterolemic and antiatherosclerotic properties of  
\*Medicago\* sativa L. \*cultivated\* in Egypt  
2005

12/6/88 (Item 88 from file: 5)  
0019504159 BIOSIS NO.: 200700163900  
Improvement of \*tillage\* practices after \*alfalfa\* growing on leached black  
earth in central Pre-Caucasus  
2006

12/6/89 (Item 89 from file: 10)

3213307 92056911 Holding Library: AGL  
 Inbreeding \*cultivated\* \*alfalfa\* at the diploid level by selfing and  
 sib-mating  
 1992 Mar

12/6/91 (Item 91 from file: 5)  
 0019879658 BIOSIS NO.: 200700539399  
 Increase in \*alfalfa\* \*cultivation\* effectiveness based upon  
 intensification of symbiotic nitrogen fixation  
 2007

12/6/92 (Item 92 from file: 76)  
 0000975969 IP ACCESSION NO: 3672797  
 Increased yields of \*alfalfa\* (\*Medicago\* sativa) inoculated with N  
 sub(2)-fixing bacteria and \*cultivated\* in a calcareous soil of northwestern  
 Egypt  
 PUBLICATION DATE: 1994

12/6/93 (Item 93 from file: 10)  
 3428134 20446227 Holding Library: AGL  
 Increased yields of \*alfalfa\* (\*Medicago\* sativa) inoculated with  
 N<sub>2</sub>-fixing bacteria and \*cultivated\* in a calcareous soil of northwestern  
 Egypt  
 1994 Oct

12/6/94 (Item 94 from file: 10)  
 3008763 90036313 Holding Library: AGL  
 Infiltration rate as affected by an \*alfalfa\* and no-\*till\* cotton  
 cropping system  
 1990 Mar

12/6/95 (Item 95 from file: 10)  
 3379233 20406432 Holding Library: AGL  
 Interrow \*cultivation\* to reduce herbicide use in corn following  
 \*alfalfa\* without \*tillage\*  
 1994 Jan

12/6/96 (Item 96 from file: 203)  
 02252740  
 \*[Alfalfa\*: \*cultivation\*, transformation and consumption] (Alfalfa:  
 cultivo, transformacion y consumo)  
 1998

12/6/97 (Item 97 from file: 203)  
 01916109  
 \*[Alfalfa\*: a good \*cultivation\*] (Luzerne: la bonne conduite)  
 1995

12/6/98 (Item 98 from file: 203)  
 02149478  
 \*[Alfalfa\* sowing under the cover of \*tilled\* crops] (Posev lutserny  
 pod pokrovom propashnykh kul'tur)  
 1997

12/6/99 (Item 99 from file: 10)

4872307 23227205 Holding Library: AGL  
 Leaf spot diseases on winter wheat influenced by nitrogen, \*tillage\*, and  
 haying after a grass-\*alfalfa\* mixture in the Conservation Reserve Program  
 2001  
 URL: <http://hdl.handle.net/10113/14876>

12/6/100 (Item 100 from file: 144)  
 09890023 PASCAL No.: 92-0092514  
 La luzerne. Culture-Utilisation  
 (\*Alfalfa\*. \*Cultivation\*-Utilization) s.d.

12/6/101 (Item 101 from file: 10)  
 2997351 90029703 Holding Library: AGL  
 Late-winter no-\*till\* seeding of \*alfalfa\* into autumn-suppressed tall  
 fescue  
 1990 Mar

12/6/102 (Item 102 from file: 10)  
 3702381 21804154 Holding Library: AGL  
 Medicagenic acid content in foliage of ten varieties of \*alfalfa\* (  
 \*Medicago\* sativa L.) \*cultivated\* in Mexico  
 1997

12/6/103 (Item 103 from file: 203)  
 02088863  
 \*[Medicago\* sativa \*cultivation\* in the Western Cape, South Africa] (  
 Verbouing van lusern in die Wes-kaap [Suid-Afrika])  
 1996  
 [Information Day Lectures] (Inligtingsdag Lesings)

12/6/104 (Item 104 from file: 50)  
 0009406962 CAB Accession Number: 20073241497  
 Mielga ( \*Medicago\* sativa L.): origin, characteristics and value for  
 \*cultivation\* and use.  
 Original Title: La mielga ( Medicago sativa L.): origen,  
 caracterizacion y valor agronomico.  
 Publication Year: 2005

12/6/105 (Item 105 from file: 203)  
 01584127  
 1990  
 [Impact of \*alfalfa\* \*cultivation\* for more than 5 years on some  
 biological, chemical and physical characters and on nitrogeneous content  
 for sandy soil under coastal region conditions] ('at"ar zira:3at>  
 al-fis\*at> li'akt"ar min h\*ams/i sanawa:t 3ala> ba3d\*/i al-s\*ifa:t  
 al-fi:zi:a:'iyt> wa-l-ki:mi:a:'iyat> liturbat> ramli:at> fi: al-sa:h"il)

12/6/106 (Item 106 from file: 5)  
 16523762 BIOSIS NO.: 200200117273  
 Mitochondrial DNA diversity and phenotypic variation in wild and  
 \*cultivated\* populations of \*Medicago\* sativa: Insights into the dynamics  
 of contact zones between the two related forms  
 2001

12/6/107 (Item 107 from file: 203)  
 01826594  
 [Methods for \*cultivation\* of isolated cells, tissues and organs in

\*alfalfa\* breeding] (Priemy kul'tivirovaniya izolirovannykh kletok, tkanej i organov v selektsii lyutserny)

1992

[Breeding and seed production of field crops under conditions of irrigation] (Selektsiya i semenovodstvo polevykh kul'tur v usloviyakh orosheniya)

12/6/108 (Item 108 from file: 50)

0006978754 CAB Accession Number: 19952302617

Mycobiota of \*Medicago\* L. species seeds in Lithuania. 1. Composition and distribution of micromycete species of \*cultivated\* and wild \*alfalfa\* seeds.

Publication Year: 1993

12/6/109 (Item 109 from file: 10)

3331674 20361850 Holding Library: AGL

Nitrogen fertilization of wheat no-\*till\* planted in \*alfalfa\* stubble  
1993 Jul

12/6/110 (Item 110 from file: 10)

3603762 20588737 Holding Library: AGL

No \*till\* corn in living \*alfalfa\* sod  
1990

12/6/111 (Item 111 from file: 10)

3474525 20481626 Holding Library: AGL

No-\*tillage\* corn production in an \*alfalfa\*-grass sod  
1990 Jan

12/6/112 (Item 112 from file: 10)

3415666 20436362 Holding Library: AGL

No-\*till\* \*alfalfa\* production: limestone amendment for acid soil  
1994 Oct

12/6/113 (Item 113 from file: 10)

3367867 20393497 Holding Library: AGL

No-\*till\* \*alfalfa\* establishment after small-grain cereals  
1993 Mar

12/6/115 (Item 115 from file: 10)

3805408 22029807 Holding Library: AGL

No-\*till\* \*alfalfa\* stand termination strategies: \*alfalfa\* control and wheat and barley production  
1999

12/6/116 (Item 116 from file: 10)

3550140 20545270 Holding Library: AGL

No-\*till\* seeding of grazing-tolerant \*alfalfa\* as influenced by grass suppression, fungicide, and insecticide  
1996 Jul

12/6/117 (Item 117 from file: 10)

3003461 90033185 Holding Library: AGL

No-\*till\* seeding of ladino clover and \*alfalfa\* into grass sod as affected by insects, grass competition, and time of planting  
1990 Feb

12/6/118 (Item 118 from file: 10)  
 3538298 20536230 Holding Library: AGL  
 No-\*till\* establishment of ladino clover, and \*alfalfa\* as influenced by  
 time of seeding, time of grass suppression, and insects  
 1993

12/6/119 (Item 119 from file: 10)  
 3806896 22031604 Holding Library: AGL  
 The nutritive value and yield of \*alfalfa\* \*cultivated\* on sulphur  
 postmining lands  
 1999

12/6/120 (Item 120 from file: 10)  
 3613400 20597399 Holding Library: AGL  
 Nitrous oxide emission as affected by \*tillage\*, corn-soybean-\*alfalfa\*  
 rotations and nitrogen fertilization  
 1997

12/6/121 (Item 121 from file: 10)  
 3729702 21968507 Holding Library: AGL  
 Nitrous oxide emission in three years as affected by \*tillage\*,  
 corn-soybean-\*alfalfa\* rotations, and nitrogen fertilization  
 1998

12/6/122 (Item 122 from file: 10)  
 3245287 92078024 Holding Library: AGL  
 Nitrogen availability from \*alfalfa\* suppressed or killed for no-\*till\*  
 production  
 1991

12/6/123 (Item 123 from file: 203)  
 02506090

A new lucerne variety for \*organic\* \*farming\* [\*Medicago\* sativa L. -  
 Umbria (Italy)] (Costituzione di una varieta' di erba medica per  
 l'agricoltura biologica [Medicago sativa L. - Umbria])  
 2001

12/6/124 (Item 124 from file: 5)  
 11801519 BIOSIS NO.: 199395103785  
 Study on the \*cultivation\* of \*alfalfa\* (\*Medicago\* sativa L.) on hill  
 land: 1. Effect of Rhizobium inoculation method on the early growth of  
 \*alfalfa\* (\*Medicago\* sativa L.)  
 1992

12/6/125 (Item 125 from file: 5)  
 12468965 BIOSIS NO.: 199497490250  
 Study on the \*cultivation\* of \*alfalfa\* on hill land: 2. Effect of  
 rhizobium inoculation method on the DM yield and nutritive value of  
 \*alfalfa\*  
 1994

12/6/126 (Item 126 from file: 50)  
 0008187355 CAB Accession Number: 20023039442  
 Study on high-yield and high-quality \*cultivation\* techniques of  
 \*Medicago\* sativa in Minqin Desert Oasis, China.  
 Publication Year: 2001

12/6/127 (Item 127 from file: 203)  
01867145  
Studies on establishing a standard for \*cultivation\* of \*alfalfa\*  
1990

12/6/128 (Item 128 from file: 10)  
4872361 23291624 Holding Library: AGL  
Organelle based molecular analyses of the genetic relatedness of  
\*cultivated\* \*alfalfa\* (\*Medicago\* sativa L) to \*Medicago\* edgeworthii  
Sirjaev, and \*Medicago\* ruthenica (L.) Ledebour  
2002  
URL: <http://hdl.handle.net/10113/14367>

12/6/129 (Item 129 from file: 10)  
3511018 10748381 Holding Library: AGL  
Plant \*cultivation\* studies on red clover and \*alfalfa\* grass green  
fallow in the modified crop rotation sugarbeets-winter wheat-winter barley  
Pflanzenbauliche Untersuchungen zu Rotklee- und Luzernegrass-Grünbrachen  
in der modifizierten Fruchtfolge zuckerruben-Winterweizen-Wintergerste /  
vorgelegt von Stefan Dreesmann  
1994

12/6/130 (Item 130 from file: 10)  
3213516 92057122 Holding Library: AGL  
Producing no-\*till\* cereal or corn following \*alfalfa\* on  
furrow-irrigated land  
1991 Apr

12/6/131 (Item 131 from file: 203)  
02520031  
[The productivity of \*cultivated\* \*alfalfa\* on green mass and seeds] (  
Productivitatea lucernei cultivata la masa verde si seminte)  
2001  
[Breeding and technologies of cultivation of leguminous and forage  
crops] (Ameliorarea si tehnologiile de cultivare a culturilor leguminoase  
si furajere)

12/6/132 (Item 132 from file: 50)  
0008302726 CAB Accession Number: 20023128213  
Productivity of lucerne [ \*Medicago\* L.] \*cultivated\* in the  
forest-steppe of the Northern Trans-Urals.  
Publication Year: 2002

12/6/133 (Item 133 from file: 5)  
11894400 BIOSIS NO.: 199396058816  
Production and nutrient levels in \*alfalfa\* (\*Medicago\* sativa) in the  
first year of \*cultivation\* in the Zona da Mata of Minas Gerais  
1993

12/6/134 (Item 134 from file: 10)  
3359745 20386446 Holding Library: AGL  
Primary \*tillage\* effects on \*alfalfa\* establishment and yield  
1993 Nov

12/6/135 (Item 135 from file: 5)  
11976733 BIOSIS NO.: 199396141149



Peroxidase in \*cultivated\* \*alfalfa\* cells  
1992

12/6/136 (Item 136 from file: 5)  
13985457 BIOSIS NO.: 199799619517  
The persistence of bioluminescent Rhizobium meliloti strains L1 (RecA-) and L33 (RecA+) in non-sterile microcosms depends on the soil type, on the co-\*cultivation\* of the host legume \*alfalfa\* and on the presence of an indigenous R. meliloti population  
1997

12/6/140 (Item 140 from file: 203)  
02056567  
[Optimal estimation of function response of the area \*cultivated\* with \*alfalfa\*]  
1990

12/6/141 (Item 141 from file: 203)  
01601240  
Quality of \*alfalfa\* \*cultivated\* in Mediterranean climates (Rapport sur la qualite de la luzerne cultivee en climat mediterraneen)  
1991  
Mediterranean Forages and By Products, Montpellier (France), 5-6 Jul 1990 (Fourrages et Sous-produits Mediterraneens)

12/6/142 (Item 142 from file: 203)  
02225699  
1996  
[Recommendations for \*alfalfa\* \*cultivation\* in Asturias [Spain]] (Recomendaciones para el cultivo de la alfalfa en Asturias)

12/6/143 (Item 143 from file: 203)  
02669726  
2006  
[Irrigation and fertilization of \*alfalfa\* \*cultivated\* under pivot] (Riego y abonado en alfalfa cultivada bajo pivot)

12/6/144 (Item 144 from file: 5)  
15615263 BIOSIS NO.: 200000333576  
Regeneration of F1 hybrids derived from crosses between \*cultivated\* \*alfalfa\* and a highly regenerable Regen SY line  
2000

12/6/145 (Item 145 from file: 203)  
01613245  
[Irrigation regime, methods and rates of \*alfalfa\* sowing during \*cultivation\* for seeds under conditions of the central black-earth zone] (Rezhim orosheniya, sposoby i normy vyseva lyutserny pri vyrashchivanii i semena v usloviyakh Tsentral'no-Chernozemnoj zony)  
1990  
[Irrigated chernozems and their rational use] (Oroshaemye chernozemy i ikh ratsional'noe ispol'zovanie)

12/6/146 (Item 146 from file: 203)  
01682957  
Rhizobium meliloti populations and \*alfalfa\* yields due to nitrogen fertilization and inoculation methods at \*cultivated\* upland soil

1992

12/6/147 (Item 147 from file: 10)  
4018684 23293612 Holding Library: AGL  
Rainfall and \*tillage\* effects on soil structure after \*alfalfa\*  
conversion to maize on a clay loam soil in New York  
2002

12/6/148 (Item 148 from file: 203)  
02209400  
1990  
[Response to the inoculation with Rhizobium sp. in the \*cultivation\* of  
\*alfalfa\* (\*Medicago\* sativa L.) in the zone of Tunja, Boyaca [Colombia]]  
(Respuesta a la inoculacion con Rhizobium sp. en el cultivo de la alfalfa  
Medicago sativa L. en la zona de Tunja, Boyaca)

12/6/149 (Item 149 from file: 203)  
01650149  
Research on \*cultivation\* techniques of \*alfalfa\* in Weibei rainfed  
highlands, Shaanxi Province [China]  
1992

12/6/150 (Item 150 from file: 50)  
0007188832 CAB Accession Number: 19960703606  
Selection of strains of Rhizobium meliloti tolerant to soil acidity for  
\*cultivation\* of \*Medicago\* spp.  
Original Title: Selection de souches de Rhizobium meliloti tolerantes a  
l'acidite des sols pour la culture de Medicago spp.  
Publication Year: 1994

12/6/151 (Item 151 from file: 203)  
01969587  
Soil pH is a major determinant of the numbers of naturally occurring  
Rhizobium meliloti in non-\*cultivated\* soils in central New South Wales  
[\*Medicago\* species]  
1991

12/6/152 (Item 152 from file: 10)  
3878150 22088464 Holding Library: AGL  
Soil and maize response to plow and no-\*tillage\* after \*alfalfa\*-to-maize  
conversion on a clay loam soil in New York  
2000

12/6/153 (Item 153 from file: 203)  
02104203  
The soil \*tillage\* and \*alfalfa\* sowing machines (Masine za pripremu  
zemljista i setvu lucerke)  
1996

12/6/154 (Item 154 from file: 10)  
3631894 20610751 Holding Library: AGL  
Surface \*alfalfa\* residue removal by earthworms Lumbricus terrestris L.  
in a no-\*till\* agroecosystem  
1997

12/6/155 (Item 155 from file: 50)  
0007147192 CAB Accession Number: 19951913686

Survey, selection and testing of acid-tolerant *Rhizobium meliloti* strains for the \*cultivation\* of annual \*Medicago\* species on acid and slightly acid soils in Morocco.

Original Title: Prospektion, Selektion sowie Prufung auf Effektivitat von sauretoleranten *Rhizobium meliloti* -Stammen fur den Anbau von annuellen *Medicago* -Arten auf sauren und schwach sauren Boden in Marokko.

Publication Year: 1994

12/6/156 (Item 156 from file: 50)

0006786809 CAB Accession Number: 19932461063

Theoretical and experimental comparison of an agricultural drainage system beneath two \*cultivated\* soils: \*alfalfa\*.

Original Title: Comparacion teorica-experimental de un sistema de drenaje agricola bajo dos suelos cultivados: alfalfa.

Memoria del III congreso nacional [Proceedings of the III national congress]. Held in Queretaro, Mexico, 13-15 October, 1993.

Publication Year: 1993

12/6/157 (Item 157 from file: 10)

3601589 20584735 Holding Library: AGL

Tall fescue response to clipping and competition with no-\*till\* seeded \*alfalfa\* as affected by fungal endophyte  
1997

12/6/158 (Item 158 from file: 10)

3079717 91018440 Holding Library: AGL

\*Tillage\* and canopy cover effects on interrill erosion from first-year \*alfalfa\*  
1990 Nov

12/6/159 (Item 159 from file: 10)

3610786 20594298 Holding Library: AGL

\*Tillage\* effects on nitrogen management for corn after \*alfalfa\* on irrigated sandy soils  
1995

12/6/160 (Item 160 from file: 10)

3793908 22016853 Holding Library: AGL

\*Tillage\* effects on soil nitrogen and plant biomass in a corn-\*alfalfa\* rotation  
1999

12/6/161 (Item 161 from file: 10)

4678696 43939284 Holding Library: AGL

\*Tillage\* System and Seeding Time Effects on Forage and Seed Yield of \*Alfalfa\* and Bromegrass  
2007

12/6/162 (Item 162 from file: 5)

17149484 BIOSIS NO.: 200300108203

Temporal pattern of arthropod community on \*cultivated\* \*alfalfa\* grassland.  
2002

12/6/163 (Item 163 from file: 50)

0006209709 CAB Accession Number: 19900732228

Utilization of selected *Rhizobium meliloti* strains in \*Medicago\*

rigidula L. and \*Medicago\* noeana Boiss. \*cultivation\*.  
 Original Title: Utilizzazione di ceppi selezionati di Rhizobium meliloti nella coltivazione di Medicago rigidula L. e Medicago noeana Boiss.  
 Publication Year: 1987, publ. 1989

12/6/164 (Item 164 from file: 10)  
 3537352 20535100 Holding Library: AGL  
 Vegetation management and interrill erosion in no-\*till\* corn following \*alfalfa\*  
 1996 Jul

12/6/165 (Item 165 from file: 50)  
 0006969322 CAB Accession Number: 19950702351  
 Yield of lucerne ( \*Medicago\* sativa L.) in its first year of \*cultivation\* in relation to the management strategy in the Tadla area of Morocco.  
 Original Title: Production de la luzerne ( Medicago sativa L.) en 1<sup>re</sup> année en relation avec le rythme d'exploitation dans le Tadla.  
 Publication Year: 1992

12/6/166 (Item 166 from file: 50)  
 0007069015 CAB Accession Number: 19950709286  
 Yields and nutrient contents in \*alfalfa\* ( \*Medicago\* sativa L.) in the first year of \*cultivation\* in the Zona da Mata, Minas Gerais.  
 Original Title: Producao e niveis de nutrientes em alfafa ( Medicago sativa L.) no primeiro ano de cultivo, na Zona da Mata de MG.  
 Publication Year: 1993

12/6/167 (Item 167 from file: 10)  
 3550157 20545288 Holding Library: AGL  
 Yield response to \*cultivation\* of established \*alfalfa\*  
 1995 Nov

12/6/168 (Item 168 from file: 5)  
 16433183 BIOSIS NO.: 200200026694  
 [Saponins and tannins in twenty-eight \*alfalfa\* (\*Medicago\* sativa L.) \*cultivates\* grown in Botucatu - SP.]  
 ORIGINAL LANGUAGE TITLE: Porcentagens de Saponinas e Taninos em Vinte e Oito Cultivares de Alfafa (Medicago sativa L.) em Duas Epocas de Corte - Botucatu - SP  
 2001

12/6/169 (Item 169 from file: 5)  
 12422212 BIOSIS NO.: 199497443497  
 Zero-\*tillage\* establishment of \*alfalfa\* and meadow bromegrass as influenced by previous annual grain crop  
 1994

12/6/170 (Item 170 from file: 203)  
 02584622  
 [Strategy in the herbicides use on \*alfalfa\* \*cultivation\*] ( Estrategia del empleo de los herbicidas en el cultivo de la alfalfa)  
 2004

12/6/171 (Item 171 from file: 203)  
 02408117

[The sowing machines for common sowing of \*alfalfa\* under the protection of \*tilled\* crops] (Semanatoare pentru insamintarea comuna a lucernei sub protectia culturilor prasitoare)

1999

[Results and perspectives of scientific researches in the field of plant breeding and crop technologies of cereals] (Rezultatele si perspectivele cercetarilor stiintifice in domeniul ameliorarii si tehnologiilor de cultura a cerealelor)

SETS IN SAME PARAGRAPH/FIELD AND ONE TERM OF EITHER SET IN TITLE

S9 3010 S7 (S) S2

S10 444 S9/TI

S13 2566 S9 NOT S10

S14 1323 RD S13 (unique items)

S15 559 S14 AND (S7 OR S2)/TI

16/6/1 (Item 1 from file: 10)

3913741 23211258 Holding Library: AGL

Abundance of cereal aphids (Homoptera: Aphididae) and their predators in spring wheat-\*alfalfa\* intercrops under different crop management intensities

2000

16/6/2 (Item 2 from file: 143)

1794824 H.W. WILSON RECORD NUMBER: BBAI04158344

Above- and below-ground effects from \*alfalfa\* and marsh reedgrass on aspen seedlings

20041011

16/6/3 (Item 3 from file: 50)

0009317870 CAB Accession Number: 20073169348

Acacia nilotica and \*Medicago\* sativa , suitable plants for agro-forestry in southern coasts of Iran.

Publication Year: 2007

16/6/4 (Item 4 from file: 5)

11776574 BIOSIS NO.: 199395078840

The action of chloride salinization on the formation and activity of symbiotic \*alfalfa\* system

1992

16/6/5 (Item 5 from file: 5)

17878566 BIOSIS NO.: 200400247513

Acyrtosiphon (A.) loti (Homoptera: Aphididae) founded on Lucerne in Argentina.

ORIGINAL LANGUAGE TITLE: Acyrtosiphon (A.) loti (Homoptera: Aphididae) hallado sobre \*alfalfa\* en la Argentina.

2003

16/6/6 (Item 6 from file: 5)

10861220 BIOSIS NO.: 199192106991

ADAPTIVE RESPONSES OF ROOT SYSTEMS OF SOME NATIVE AND \*CULTIVATED\* SPECIES TO DESERT CONDITIONS

1991

16/6/7 (Item 7 from file: 10)

3937933 23230842 Holding Library: AGL

Adopting zero \*tillage\* management: impact on soil C and N under long-term crop rotations in a thin Black chernozem

2001

16/6/8 (Item 8 from file: 10)

3793379 22012950 Holding Library: AGL

AFLP fingerprinting in \*Medicago\* spp.: its development and application in linkage mapping

1999

16/6/9 (Item 9 from file: 5)  
17144555 BIOSIS NO.: 200300103274  
Agrobacterium-mediated transformation of lucerne (\*Medicago\* sativa Linn.):  
Optimizing biological and physical parameters.  
2002

16/6/10 (Item 10 from file: 50)  
0007879902 CAB Accession Number: 20001909205  
Agrophysical properties of the soil under \*cultivation\* of fodder and  
cereals crops in crop rotation.  
Publication Year: 1999

16/6/11 (Item 11 from file: 203)  
02377142  
Agronomic effects and economic results of \*alfalfa\* sod-seeding with  
cocksfoot (Agronomiczno-ekonomiczne efekty podsiewu lucerny kupkowka  
pospolita)  
1999

16/6/12 (Item 12 from file: 10)  
3627085 20606976 Holding Library: AGL  
Agronomic evaluation of \*Medicago\* ruthenica collected in Inner Mongolia  
1997

16/6/13 (Item 13 from file: 40)  
00603958 ENVIROLINE NUMBER: 01-09738  
\*Alfalfa\*  
May-Jun 01

16/6/14 (Item 14 from file: 266)  
00576456  
IDENTIFYING NO.: 0209978 AGENCY CODE: AGRIC  
\*Alfalfa\* Breeding and ManagementSDTDPXAT

16/6/15 (Item 15 from file: 50)  
0006658103 CAB Accession Number: 19931636157  
\*Alfalfa\* cytogenetics.  
Book Title: Chromosome engineering in plants: genetics, breeding,  
evolution. Part B.  
Publication Year: 1991

16/6/16 (Item 16 from file: 143)  
0405091 H.W. WILSON RECORD NUMBER: BBAI93003915  
\*Alfalfa\* development after simulated \*alfalfa\* weevil injury  
19921100

16/6/17 (Item 17 from file: 143)  
1990914 H.W. WILSON RECORD NUMBER: BBAI07100081  
\*Alfalfa\* Fiber Estimation in Mixed Stands and Its Relationship to Plant  
Morphology  
20061100

16/6/18 (Item 18 from file: 71)  
02077802 2002157874  
\*Alfalfa\* growth promotion by bacteria grown under iron limiting conditions

16/6/19 (Item 19 from file: 143)  
2131127 H.W. WILSON RECORD NUMBER: BBAI06129707  
\*Alfalfa\* as an Alternative to Bermudagrass for Pastured Stocker Cattle  
Systems in the Southern USA  
20060500

16/6/20 (Item 20 from file: 5)  
10861148 BIOSIS NO.: 199192106919  
\*ALFALFA\* \*MEDICAGO\*-SATIVA L. WATER USE EFFICIENCY AS AFFECTED BY HARVEST  
TRAFFIC AND SOIL COMPACTION IN A SANDY LOAM SOIL  
1991

16/6/21 (Item 21 from file: 143)  
0326900 H.W. WILSON RECORD NUMBER: BBAI91030987  
\*Alfalfa\* and the nitrogen cycle in the corn belt  
19910500

16/6/22 (Item 22 from file: 50)  
0006299574 CAB Accession Number: 19900738191  
\*Alfalfa\* production manual.  
Original Title: Manual de producao de \*alfalfa\*.  
Publication Year: 1990

16/6/23 (Item 23 from file: 5)  
10651788 BIOSIS NO.: 199191034679  
\*ALFALFA\* RESPONSE TO LIME PHOSPHORUS POTASSIUM MAGNESIUM AND MOLYBDENUM ON  
ACID ULTISOLS  
1990

16/6/24 (Item 24 from file: 143)  
1799799 H.W. WILSON RECORD NUMBER: BBAI03111355  
\*Alfalfa\* Autotoxicity: Effects of Reseeding Delay, Original Stand Age, and  
Cultivar  
20020700

16/6/25 (Item 25 from file: 5)  
10849172 BIOSIS NO.: 199192094943  
\*ALFALFA\* YIELD AS AFFECTED BY HARVEST TRAFFIC AND SOIL COMPACTION IN A SANDY  
LOAM SOIL  
1991

16/6/26 (Item 26 from file: 143)  
0481400 H.W. WILSON RECORD NUMBER: BBAI94031861  
\*Alfalfa\* yield and quality are affected by soil hydrologic conditions  
19940500

16/6/27 (Item 27 from file: 10)  
4378426 43757416 Holding Library: AGL  
\*Alfalfa\* yield and nutrient uptake as affected by pH and applied K  
2005

16/6/28 (Item 28 from file: 5)  
12062721 BIOSIS NO.: 199497084006  
\*Alfalfa\* yield programming under irrigation  
1993

16/6/29 (Item 29 from file: 143)



0628433 H.W. WILSON RECORD NUMBER: BBAI95023472  
 \*Alfalfa\* establishment with barley and oat companion crops differing in  
 stature  
 19950300

16/6/30 (Item 30 from file: 10)  
 3415667 20436363 Holding Library: AGL  
 \*Alfalfa\* establishment with and without spring-applied herbicides  
 1994 Oct

16/6/31 (Item 31 from file: 10)  
 3353825 20381296 Holding Library: AGL  
 \*Alfalfa\* stand establishment  
 1993 Feb

16/6/32 (Item 32 from file: 266)  
 00572992  
 IDENTIFYING NO.: 0205738 AGENCY CODE: AGRIC  
 Alternative Crop, Rotation, and \*Tillage\* Practices

16/6/33 (Item 33 from file: 143)  
 0545865 H.W. WILSON RECORD NUMBER: BBAI95042192  
 Alternating strips of grass and legume, and nitrogen fertilization  
 strategy, for long-term herbage production from a brome-\*alfalfa\* stand  
 19950700

16/6/34 (Item 34 from file: 5)  
 17244495 BIOSIS NO.: 200300203214  
 Annual \*Medicago\* as a smother crop in soybean.  
 2002

16/6/35 (Item 35 from file: 50)  
 0007912594 CAB Accession Number: 20000709552  
 Use of annual medics in sustainable agriculture systems.  
 Lucerne and medics for the XXI century. Proceedings XIII EUCARPIA  
 \*Medicago\* spp. Group Meeting, Perugia, Italy, 13-16 September 1999.  
 Publication Year: 2000

16/6/36 (Item 36 from file: 5)  
 17687382 BIOSIS NO.: 200400054912  
 Analysis of different types of competitive capacity in the \*alfalfa\*  
 rhizobia (*Sinorhizobium meliloti*) Tn5 mutants.  
 2001

16/6/37 (Item 37 from file: 10)  
 4700748 43952530 Holding Library: AGL  
 Analyses of a multi-parent population derived from two diverse \*alfalfa\*  
 germplasms: testcross evaluations and phenotype-DNA associations  
 2007  
 URL: <http://dx.doi.org/10.1007/s00122-007-0614-1>

16/6/38 (Item 38 from file: 76)  
 0001816566 IP ACCESSION NO: 5990250  
 Analysis on Water-saving Irrigation and Water Effectiveness of \*Medicago\*  
 sativa in Arid Desert Oasis --An Example of Minqin County  
 PUBLICATION DATE: 2004

16/6/40 (Item 40 from file: 156)  
 4196992 NLM Doc No: 17157359  
 The arbuscular mycorrhizal fungus *Glomus mosseae* gives contradictory effects on phosphorus and arsenic acquisition by *\*Medicago\* sativa* Linn.  
 Jul 1 2007

16/6/41 (Item 41 from file: 24)  
 0002281571 IP ACCESSION NO: 5297102  
 Arbuscular mycorrhiza in mini-mycorrhizotrons: first contact of *\*Medicago\* truncatula* roots with *Glomus intraradices* induces chalcone synthase  
 PUBLICATION DATE: 2001

16/6/42 (Item 42 from file: 71)  
 03639809 2007056546  
 Availability and contributions of soil phosphorus to forage production of seeded *\*alfalfa\** in semiarid Loess Plateau

16/6/43 (Item 43 from file: 50)  
 0008364590 CAB Accession Number: 20033004750  
 Aspects regarding the crop technology of *\*alfalfa\** and Alexandria clover mixture under Burnas plain conditions.  
 Original Title: Aspecte privind tehnologia de cultura a lucernei in amestec cu trifoiul de Alexandria in campia Burnasului.  
 Publication Year: 2001

16/6/44 (Item 44 from file: 5)  
 14661538 BIOSIS NO.: 199800455785  
 Assessing *\*tillage\**- and cropping-induced changes in relative conductivity  
 1998

16/6/45 (Item 45 from file: 5)  
 11180275 BIOSIS NO.: 199293023166  
 BIOCHEMICAL ACTIVITY OF IRRIGATED SIEROZEMS AS IT DEPENDS ON THE METHOD OF PLANT *\*CULTIVATION\**  
 1991

16/6/46 (Item 46 from file: 10)  
 3066779 91009532 Holding Library: AGL  
 Backcrossing tetraploidy into diploid *\*Medicago\* falcata* L. using 2n eggs  
 1990 Nov

16/6/47 (Item 47 from file: 50)  
 0008471114 CAB Accession Number: 20033083621  
 Biodiversity on *\*organic\* \*farms\**.  
 Original Title: La biodiversita nell'azienda biologica.  
 Publication Year: 2001

16/6/48 (Item 48 from file: 50)  
 0006642355 CAB Accession Number: 19931974266  
 Biological activity of irrigated serozems under cotton as depending on the technology of cotton *\*cultivation\**.  
 Publication Year: 1991

16/6/49 (Item 49 from file: 50)  
 0007840803 CAB Accession Number: 20001906122  
 The biological fundamentals of water-saving irrigation conditions for two- to three-year-old *\*alfalfa\** in the semidesert of Kalmykia.

Publication Year: 1998, publ. 1999

16/6/50 (Item 50 from file: 266)  
00572611

IDENTIFYING NO.: 0205214 AGENCY CODE: AGRIC  
Biology and Management of Vegetable and Field Crop Insects and Diseases  
and the Effects of Conservation \*Tillage\* on Corn Insects

16/6/51 (Item 51 from file: 10)  
4827810 43637521 Holding Library: AGL  
Bulk density as a soil quality indicator during conversion to no-  
\*tillage\*  
2004  
URL: <http://hdl.handle.net/10113/10542>

16/6/52 (Item 52 from file: 50)  
0007202951 CAB Accession Number: 19960704799  
Biomass production in two crop rotation at different fertilization and  
soil \*tillage\*.  
Original Title: Produkcia biomasy v dvoch osevných postupoch pri roznom  
hnojení a obrábaní pody.  
Publication Year: 1995

16/6/53 (Item 53 from file: 203)  
02181414  
Breeding of "Hisawakaba" \*alfalfa\* [\*Medicago\* sativa] and its  
characteristics  
1995

16/6/54 (Item 54 from file: 5)  
0001413839 BIOSIS NO.: 19644500035030  
Breeding of \*alfalfa\* varieties resistant to diseases  
ORIGINAL LANGUAGE TITLE: Vyvedenie sortov lyutserny, ustoichivyykh k boleznyam

16/6/55 (Item 55 from file: 24)  
0002207538 IP ACCESSION NO: 5111824  
Brief communication. Physical mapping of rRNA genes in \*Medicago\* sativa  
and M. glomerata by fluorescent in situ hybridization  
PUBLICATION DATE: 2000

16/6/56 (Item 56 from file: 41)  
0000254257 IP ACCESSION NO: 6469076  
Bioremediation of Copper and Benzo[a]pyrene-Contaminated Soil by \*Alfalfa\*  
PUBLICATION DATE: 2005

16/6/57 (Item 57 from file: 5)  
13377831 BIOSIS NO.: 199699011891  
Betaines as methyl group donors in \*alfalfa\* seedlings exposed to salt  
1995

16/6/58 (Item 58 from file: 143)  
1141332 H.W. WILSON RECORD NUMBER: BBAI91019222  
Changes in the baseline of the crop water stress index for lucerne (  
\*Medicago\* sativa) over 3 years  
19910200

16/6/59 (Item 59 from file: 5)

11952126 BIOSIS NO.: 199396116542  
 Changes in pattern of phenolic acids induced by culture filtrate of  
*Fusarium oxysporum* in \*alfalfa\* plants differing in susceptibility to the  
 pathogen  
 1993

16/6/60 (Item 60 from file: 203)  
 01653082  
 [Characteristics of \*alfalfa\* mosaic virus pathogens of bean in Emilia  
 Romagna] (Caratteristiche del virus del mosaico dell'erba medica patogeno  
 del fagiolo in Emilia Romagna)  
 1991

16/6/61 (Item 61 from file: 50)  
 0009268216 CAB Accession Number: 20073122636  
 Chromatographic (GC-MS) and virological evaluations of *Lavandula hybrida*  
 "Alardi" infected by \*Alfalfa\* mosaic virus.  
 Publication Year: 2006

16/6/62 (Item 62 from file: 10)  
 3674192 21234542 Holding Library: AGL  
 Chromosomal and molecular rearrangements in somatic hybrids between  
 tetraploid \*Medicago\* sativa and diploid \*Medicago\* falcata  
 1997

16/6/63 (Item 63 from file: 50)  
 0007913653 CAB Accession Number: 20001612633  
 Collecting and breeding \*Medicago\* perennial species in Greece.  
 Lucerne and medics for the XXI Century. Proceedings XIII Eucarpia  
 \*Medicago\* spp. Group Meeting, Perugia, Italy, 13-16 September 1999.  
 Publication Year: 2000

16/6/64 (Item 64 from file: 5)  
 15597040 BIOSIS NO.: 200000315353  
 Clones of pea aphid, *Acyrtosiphon pisum* (Hemiptera: Aphididae)  
 distinguished using genetic markers, differ in their damaging effect on a  
 resistant \*alfalfa\* cultivar  
 2000

16/6/65 (Item 65 from file: 10)  
 4740844 43981807 Holding Library: AGL  
 The \*cultivation\* bias: different communities of arbuscular mycorrhizal  
 fungi detected in roots from the field, from bait plants transplanted to  
 the field, and from a greenhouse trap experiment  
 2007  
 URL: <http://dx.doi.org/10.1007/s00572-007-0147-0>

16/6/67 (Item 67 from file: 5)  
 15603415 BIOSIS NO.: 200000321728  
 \*Cultivation\* effects on phosphate forms and sorption in loess-soils of  
 Argentina  
 2000

16/6/68 (Item 68 from file: 50)  
 0006593716 CAB Accession Number: 19920757564  
 \*Cultivation\* of grasses for land improvement transforms solonetz soils.  
 Publication Year: 1992

16/6/69 (Item 69 from file: 5)  
17394117 BIOSIS NO.: 200300352836  
\*Cultivation\* and grassland type effects on light fraction and total  
organic C and N in a Dark Brown Chernozemic soil.  
2003

16/6/70 (Item 70 from file: 50)  
0006468657 CAB Accession Number: 19910749145  
\*Cultivation\* of millet and related crops in irrigated fields.  
Publication Year: 1990

16/6/71 (Item 71 from file: 50)  
0007354687 CAB Accession Number: 19970603981  
\*Cultivation\* methods for controlling erosion in the semiarid zone of  
Chile. Preliminary results.  
Original Title: Tecnicas de cultivo para el control de la erosion en la  
zona semiarida. Resultados preliminares.  
Publication Year: 1995

16/6/72 (Item 72 from file: 50)  
0006441849 CAB Accession Number: 19910747640  
\*Cultivation\* techniques and [lucerne] yield.  
Publication Year: 1990

16/6/73 (Item 73 from file: 50)  
0009231970 CAB Accession Number: 20073056859  
Combined influence of \*tillage\* and herbicide application on weed  
dynamics and yield of wheat under rice - wheat system.  
Publication Year: 2006

16/6/74 (Item 74 from file: 10)  
3848699 22056478 Holding Library: AGL  
Completion of the agronomic evaluations of \*Medicago\* ruthenica [(L.)  
Ledebour] germplasm collected in Inner Mongolia  
1999

16/6/75 (Item 75 from file: 76)  
0001998256 IP ACCESSION NO: 6458603  
Comparing agroecosystems: Effects of cropping and \*tillage\* patterns on  
soil, water, energy use and productivity  
PUBLICATION DATE: 2005

16/6/76 (Item 76 from file: 10)  
3972073 23252580 Holding Library: AGL  
Comparing pocket gopher (*Thomomys bottae*) density in \*alfalfa\* stands to  
assess management and conservation goals in northern California  
2001

16/6/77 (Item 77 from file: 40)  
00682492 ENVIROLINE NUMBER: 05-10605  
A Comparison of Conventional and Alternative Agroecosystems Using \*Alfalfa\*  
(\**Medicago sativa*) and Winter Wheat (*Triticum aestivum*)  
Mar 05

16/6/78 (Item 78 from file: 50)  
0007484716 CAB Accession Number: 19980701485

Comparisons of new \*Medicago\* spp. in South Australia.  
Proceedings of the 8th Australian Agronomy Conference, Toowoomba,  
Queensland, Australia, 30 January-2 February, 1996.  
Publication Year: 1996

16/6/79 (Item 79 from file: 143)  
0836483 H.W. WILSON RECORD NUMBER: BBAI98008470  
Comparison of sodseeding versus slotseeding of \*alfalfa\* into established  
crested wheatgrass in southwestern Saskatchewan  
19971000

16/6/80 (Item 80 from file: 10)  
4435561 43658596 Holding Library: AGL  
Competition and facilitation in mixtures of aspen seedlings, \*alfalfa\*,  
and marsh reedgrass Summary in French.  
2004

16/6/81 (Item 81 from file: 5)  
19361619 BIOSIS NO.: 200700021360  
Composition diversity of lactic acid bacteria (LAB) community A12 used for  
\*alfalfa\* silage  
2006

16/6/82 (Item 82 from file: 203)  
01747465  
[Economic analysis on non traditional forage \*cultivation\* and effects  
on management of cattle husbandry [Umbria]] (Analisi economica di colture  
foraggiere non tradizionali e riflessi sulla gestione di allevamenti bovini  
[Umbria])  
1992

16/6/83 (Item 83 from file: 50)  
0008730244 CAB Accession Number: 20043182078  
A contribution to the study of the distribution of \*Medicago\*  
-Sinorhizobium symbiosis in Sardinia (Italy).  
Publication Year: 2004

16/6/84 (Item 84 from file: 203)  
01925849  
Contribution to the knowledge of the Heteroptera fauna in seed \*alfalfa\*  
crops (Contributii la cunoasterea faunei de heteroptere din lucernierele  
semincere)  
1994

16/6/85 (Item 85 from file: 10)  
3363123 20389893 Holding Library: AGL  
Conservation \*tillage\* crop yields in relation to grey garden slug  
[Deroceras reticulatum (Muller)] (Mollusca: Agriolimacidae) density during  
establishment  
1994 Feb

16/6/86 (Item 86 from file: 10)  
3472868 20479616 Holding Library: AGL  
Conservation-\*tillage\* grain drill for furrow-irrigated cropping systems  
1994 Nov

16/6/87 (Item 87 from file: 143)

1446419 H.W. WILSON RECORD NUMBER: BBAI96053343  
Conserving water and increasing \*alfalfa\* production using a tall wheatgrass  
windbreak system  
19960900

16/6/88 (Item 88 from file: 5)  
17806124 BIOSIS NO.: 200400176881  
Construction and validation of cDNA-based Mt6k-RIT macro- and microarrays  
to explore root endosymbioses in the model legume \*Medicago\* truncatula.  
2004

16/6/89 (Item 89 from file: 10)  
3828932 22040864 Holding Library: AGL  
Constitutive heterochromatin DNA polymorphisms in diploid \*Medicago\*  
sativa ssp. falcata  
1999

16/6/90 (Item 90 from file: 10)  
4870149 44061843 Holding Library: AGL  
Capacity of high milk yielding goats for utilizing \*cultivated\* pasture  
2008  
URL: <http://dx.doi.org/10.1016/j.smallrumres.2008.03.011>

16/6/91 (Item 91 from file: 10)  
3238271 92072917 Holding Library: AGL  
Corn growth and yield in an \*alfalfa\* living mulch system  
1992 Jul

16/6/92 (Item 92 from file: 10)  
3383614 20411504 Holding Library: AGL  
Crop management systems for corn (Zea mays L.) following established  
\*alfalfa\* (\*Medicago\* sativa L.)  
1994 Apr

16/6/93 (Item 93 from file: 10)  
4049771 23319640 Holding Library: AGL  
Crop rotation, \*tillage\* and crop residue management for wheat and maize  
in the sub-humid tropical highlands. I. Wheat and legume performance  
2002

16/6/94 (Item 94 from file: 10)  
4049772 23319644 Holding Library: AGL  
Crop rotation, \*tillage\* and crop residue management for wheat and maize  
in the sub-humid tropical highlands. II. Maize and system performance  
2002

16/6/95 (Item 95 from file: 10)  
3151032 92012362 Holding Library: AGL  
Crop rotation and \*tillage\* effects on corn growth and soil structural  
stability  
1991 Nov

16/6/96 (Item 96 from file: 10)  
4044856 23308688 Holding Library: AGL  
Crop rotation and \*tillage\* system effects on weed seedbanks  
2002

16/6/97 (Item 97 from file: 50)  
0006697243 CAB Accession Number: 19931977825  
Crop and \*tillage\* induced changes in macropore geometry.  
Preferential flow: proceedings of the National Symposium, Chicago,  
Illinois, USA, 16-17 December 1991.  
Publication Year: 1991

16/6/98 (Item 98 from file: 40)  
00387018 ENVIROLINE NUMBER: 91-06123  
Cropping and \*Tillage\* Options to Achieve Erosion Control Goals and Maximum  
Profit on Irregular Slopes  
Nov-Dec 90

16/6/99 (Item 99 from file: 5)  
11275733 BIOSIS NO.: 199293118624  
CROP SEQUENCE AND \*TILLAGE\* EFFECTS ON WINTER WHEAT DEVELOPMENT AND YIELD  
1991

16/6/100 (Item 100 from file: 10)  
3111515 91041770 Holding Library: AGL  
Crop sequences and \*tillage\* practices in relation to diseases of winter  
wheat in Ontario  
1990 Dec

16/6/102 (Item 102 from file: 50)  
0006474740 CAB Accession Number: 19910749089  
Cropping systems using living mulches for no-\*till\* corn ( Zea mays )  
production.  
Publication Year: 1991

16/6/103 (Item 103 from file: 203)  
02524837  
Cirsium arvense - problematic weed in \*organic\* \*farming\*  
2002  
International Scientific Conference "Scientific Aspects of \*Organic\*  
\*Farming\*". Proceedings of the conference held in Jelgava, Latvia, March  
21-22, 2002 (Biologiskas lauksaimniecibas zinatniskie aspekti. Konferences  
materiali, Latvija, Jelgava, 21.-22.marts, 2002)

16/6/104 (Item 104 from file: 50)  
0008952682 CAB Accession Number: 20053211499  
Cutting effects on persistence and sustainability of an \*alfalfa\*-tall  
fescue mixture.  
Book Title: Integrating efficient grassland farming and biodiversity.  
Proceedings of the 13th International Occasional Symposium of the European  
Grassland Federation, Tartu, Estonia, 29-31 August 2005  
Publication Year: 2005

16/6/105 (Item 105 from file: 143)  
1252569 H.W. WILSON RECORD NUMBER: BBAI91034437  
Cutting interval and irrigation timing in \*alfalfa\*: yellow foxtail  
invasion and economic analysis  
19910500

16/6/106 (Item 106 from file: 10)  
3895152 22301308 Holding Library: AGL  
Use of cover crop mulches in a no-\*till\* furrow-irrigated processing



tomato production system  
2001

16/6/107 (Item 107 from file: 10)  
3530087 20528932 Holding Library: AGL  
Cover crops in reduced \*tillage\* systems  
1995

16/6/108 (Item 108 from file: 5)  
15458689 BIOSIS NO.: 200000177002  
Cover crops and interrow \*tillage\* for weed control in short season maize  
(Zea mays)  
2000

16/6/109 (Item 109 from file: 50)  
0008220303 CAB Accession Number: 20023059359  
Cynoglossum officinale , a new natural host of \*Alfalfa\* mosaic virus .  
Publication Year: 2002

16/6/110 (Item 110 from file: 50)  
0008032669 CAB Accession Number: 20003034912  
Cytogenetics in \*alfalfa\* ( \*Medicago\* sativa L.) breeding.  
Original Title: Citogenetica no melhoramento de alfafa ( \*Medicago\*  
sativa L.).  
Publication Year: 2000

16/6/111 (Item 111 from file: 5)  
10825019 BIOSIS NO.: 199192070790  
DIFFERENTIAL GIEMSA STAINING IN \*MEDICAGO\*-SPP  
1990

16/6/112 (Item 112 from file: 50)  
0008639807 CAB Accession Number: 20043078091  
Different nutritive values of \*alfalfa\* silages based on mixed and  
unmixed sowings.  
Original Title: Puhas- ja segukulvi lutsernisilo toitevaartuse  
erinevusi.  
Publication Year: 2003

16/6/113 (Item 113 from file: 5)  
19264232 BIOSIS NO.: 200600609627  
Differences in syntenic complexity between \*Medicago\* truncatula with Lens  
culinaris and Lupinus albus  
2006

16/6/114 (Item 114 from file: 10)  
3327253 20358561 Holding Library: AGL  
Delayed seeding of \*alfalfa\* avoids autotoxicity after plowing or  
glyphosate treatment of established stands  
1993 Mar

16/6/115 (Item 115 from file: 10)  
3641935 20619637 Holding Library: AGL  
Denitrification estimates in monoculture and rotation corn as influenced  
by \*tillage\* and nitrogen fertilizer  
1997

16/6/116 (Item 116 from file: 24)  
0001714043 IP ACCESSION NO: 4039418  
The density of *Bombus lucorum* (L.) required to effect maximum pollination  
of \*alfalfa\* in Estonia  
PUBLICATION DATE: 1996

16/6/117 (Item 117 from file: 6)  
2040334 NTIS Accession Number: MIC-97-07002/XAB  
Direct seeding of \*alfalfa\* and meadow brome grass for hay and seed  
production: Final report  
c1997

16/6/118 (Item 118 from file: 10)  
3484516 20492225 Holding Library: AGL  
Direct seeding of \*alfalfa\* in grain stubble and brome grass sod  
1994 Oct

16/6/119 (Item 119 from file: 143)  
1701017 H.W. WILSON RECORD NUMBER: BBAI94042871  
Direct seeding of \*alfalfa\* into established Russian wildrye pasture in  
southwest Saskatchewan  
19940700

16/6/120 (Item 120 from file: 5)  
11788125 BIOSIS NO.: 199395090391  
Dark-induced changes in the content of phenolic acids in callus culture of  
\*alfalfa\* (\*Medicago\* sativa)  
1990

16/6/121 (Item 121 from file: 143)  
1128286 H.W. WILSON RECORD NUMBER: BBAI95006483  
Dairy manure applications to \*alfalfa\*: crop response, soil nitrate, and  
nitrate in soil water  
19941100

16/6/122 (Item 122 from file: 143)  
1629764 H.W. WILSON RECORD NUMBER: BBAI03109904  
Dry Matter Yields of Cool-Season Grass Monocultures and Grass-\*Alfalfa\*  
Binary Mixtures  
20010300

16/6/123 (Item 123 from file: 50)  
0007747812 CAB Accession Number: 19991907666  
Drying out of small prairie wetlands after conversion of their  
catchments from \*cultivation\* to permanent brome grass.  
Publication Year: 1999

16/6/124 (Item 124 from file: 203)  
02392652  
Detection of the nematode *Ditylenchus dipsaci* on seed of \*alfalfa\* (  
\*Medicago\* sativa L.) (Controllo del nematode *Ditylenchus dipsaci* su  
semente di erba medica [\*Medicago\* sativa L.])  
1999

16/6/125 (Item 125 from file: 203)  
02611000

Development of \*alfalfa\* tolerant to salinity stress using organogenesis technique  
2004

16/6/126 (Item 126 from file: 50)  
0008313220 CAB Accession Number: 20023026132  
Development of a new lucerne variety for \*organic\* \*farming\*.  
Original Title: Costituzione di una varieta di erba medica per l'agricoltura biologica.  
Publication Year: 2001

16/6/127 (Item 127 from file: 266)  
00557407  
IDENTIFYING NO.: 0184846 AGENCY CODE: AGRIC  
DEVELOPMENT OF PEST MANAGEMENT STRATEGIES FOR FORAGE \*ALFALFA\* PERSISTENCE

16/6/128 (Item 128 from file: 50)  
0006404901 CAB Accession Number: 19910744943  
Development of a renovation method for grassland with reduced rotary \*cultivation\*. I. Main factors affecting establishment of herbage.  
Publication Year: 1990

16/6/129 (Item 129 from file: 266)  
00583087  
IDENTIFYING NO.: 0406943 AGENCY CODE: AGRIC  
DEVELOPMENT AND UTILIZATION OF SIMPLE SEQUENCE REPEAT (SSR) MOLECULAR MARKERS FOR THE IMPROVEMENT OF \*ALFALFA\* AND RELATED SPECIES

16/6/130 (Item 130 from file: 5)  
18765501 BIOSIS NO.: 200600110896  
Development of weed populations with no-\*tillage\* of winter wheat into living mulches  
ORIGINAL LANGUAGE TITLE: Entwicklung der Unkrautpopulationen bei Direktuat von Winterweizen in Lebendmulche  
2002

16/6/131 (Item 131 from file: 10)  
3608622 20590999 Holding Library: AGL  
Diversity and longevity of the soybean debris mycobiota in a no-\*tillage\* system  
1997

16/6/132 (Item 132 from file: 203)  
01697339  
Dynamics of occurrence of *Sitona humeralis* Steph. on \*alfalfa\* fields in south-eastern region of Poland (Dynamika wystepowania oprzedzika wilzynowego (*Sitona humeralis* Steph.) na plantacjach lucerny siewnej w poludniowo-wschodniej Polsce)  
1991  
Materials of the 31st Research Session of Institute for Plant Protection. Pt. 2. Posters (Materialy 31 Sesji Naukowej Instytutu Ochrony Roslin. Cz. 2. Postery)

16/6/133 (Item 133 from file: 5)  
18941264 BIOSIS NO.: 200600286659  
Dynamic of the genetic structure of bacterial and fungal communities at

different developmental stages of \*Medicago\* truncatula Gaertn. cv. Jemalong  
line J5  
2006

16/6/135 (Item 135 from file: 5)  
05894570 BIOSIS NO.: 198069008557  
DYNAMICS OF SOIL COLLEMBOLA POPULATIONS INSECTA APTERYGOTA UNDER \*ALFALFA\*  
CULTURE IN THE SOMES VALLEY CLUJ DEPARTMENT ROMANIA

16/6/136 (Item 136 from file: 10)  
4632518 43919323 Holding Library: AGL  
Dynamics of soil organic carbon and soil fertility affected by \*alfalfa\*  
productivity in a semiarid agro-ecosystem  
2006  
URL: <http://dx.doi.org/10.1007/s10533-006-9020-z>

16/6/138 (Item 138 from file: 5)  
10063442 BIOSIS NO.: 199039116831  
DISSERTATIONES BOTANICAE VOL. 153. ECOLOGICAL INVESTIGATIONS ON WILD AND  
\*CULTIVATED\* PLANTS IN THE EXTREME DESERT OF SOUTH EGYPT  
BOOK TITLE: SCHNEIDER, U. DISSERTATIONES BOTANICAE, BAND 153.  
PFLANZENOEKOLOGISCHE UNTERSUCHUNGEN AN WILD- UND KULTURPFLANZEN IN DER  
EXTREMWUESTE SUEDAEGYPTENS; (DISSERTATIONES BOTANICAE, VOL. 153.  
ECOLOGICAL INVESTIGATIONS ON WILD AND \*CULTIVATED\* PLANTS IN THE EXTREME  
DESERT OF SOUTH EGYPT). II+292P. E. SCHWEIZERBART'SCHE  
VERLAGSBUCHHANDLUNG: STUTTGART, WEST GERMANY; J. CRAMER IN DER GEBRUEDER  
BORNTAEGER VERLAGSBUCHHANDLUNG: BERLIN, WEST GERMANY. ILLUS. MAPS. PAPER  
1990

16/6/139 (Item 139 from file: 5)  
15494318 BIOSIS NO.: 200000212631  
Distribution of range and \*cultivated\* grassland plants in southern Alberta  
2000

16/6/140 (Item 140 from file: 266)  
00572769  
IDENTIFYING NO.: 0205406 AGENCY CODE: AGRIC  
Ecology and Development of Yellow-flowered \*Alfalfa\*

16/6/141 (Item 141 from file: 50)  
0009472078 CAB Accession Number: 20083031575  
Effects of CaCo SUB 3 on \*alfalfa\* salinity tolerance.  
Publication Year: 2006

16/6/142 (Item 142 from file: 50)  
0007662176 CAB Accession Number: 19991900235  
Effects of the \*cultivation\* of several fodder crops without irrigation  
on the regional water balance situation in the Beerze-Reusel area.  
Original Title: Effect van de teelt van verschillende voedergewassen  
zonder berekening op de regionale waterhuishouding in het Beerze-Reusel  
gebied.  
Rapport - DLO Staring Centrum, Instituut voor Onderzoek van het  
Landelijk Gebied  
Publication Year: 1998

16/6/143 (Item 143 from file: 10)  
3759438 21993809 Holding Library: AGL

Effect of crop management on C and N in long-term crop rotations after adopting no-\*tillage\* management: comparison of soil sampling strategies  
1998

16/6/144 (Item 144 from file: 10)  
3789343 22012154 Holding Library: AGL  
Influence of crop rotation, \*tillage\*, and management inputs on weed seed production  
1999

16/6/145 (Item 145 from file: 50)  
0009369207 CAB Accession Number: 20073239673  
Effects of crop rotation and \*tillage\* on infestation of *Cirsium arvense* in \*organic\* \*farming\* systems.  
Book Title: European weed research society. Proceedings of the 6th EWRS workshop on physical and cultural weed control, Lillehammer, Norway, 8-10 March, 2004  
Publication Year: 2004

16/6/146 (Item 146 from file: 50)  
0008639339 CAB Accession Number: 20043078912  
Effect of crop rotation, \*tillage\* and residue management on tan spot in the subhumid tropical highlands.  
Book Title: Proceedings of Fourth International Wheat Tan Spot and Spot Blotch Workshop, Bemidji, Minnesota, USA, 21-24 July, 2002  
Publication Year: 2003

16/6/147 (Item 147 from file: 50)  
0007267247 CAB Accession Number: 19960709795  
Influence of crop succession and soil \*tillage\* on wheat take-all (*Gaeumannomyces graminis* var. *tritici* ).  
Proceedings of the third congress of the European Society for Agronomy, Padova University, Abano-Padova, Italy, 18-22 September 1994.  
Publication Year: 1994

16/6/148 (Item 148 from file: 10)  
3027479 90050589 Holding Library: AGL  
Influence of cover crops and \*tillage\* on seedcorn maggot (Diptera: anthomyiidae) populations in soybeans  
1990 Jun

16/6/149 (Item 149 from file: 5)  
13515338 BIOSIS NO.: 199699149398  
Effect of doubled-CO<sub>2</sub> concentration on the ultrastructure of chloroplasts from \*Medicago sativa\* and *Setaria italica*  
1996

16/6/150 (Item 150 from file: 50)  
0007678255 CAB Accession Number: 19990701361  
Effect of different periods of drought stress on regrowth and yield of \*alfalfa\* cultivar Mesasersa in Kuzestan.  
Publication Year: 1998

16/6/151 (Item 151 from file: 50)  
0008853924 CAB Accession Number: 20053111212  
Effect of different \*tillage\* and rice residue management practices on weed dynamics and grain yield of wheat.

Publication Year: 2004

- 16/6/152 (Item 152 from file: 50)  
0007987802 CAB Accession Number: 20003021118  
The effect of different soil \*tillage\* on the yields of winter wheat.  
Original Title: Vliv ruzneho zpracovani pudy na vynosy ozime psenice.  
Publication Year: 2000
- 16/6/153 (Item 153 from file: 50)  
0007539674 CAB Accession Number: 19980705351  
The effect of forecrop, soil \*tillage\* and fertilizer application on yield, its structure and efficiency of winter wheat growing.  
Original Title: Vplyv roznej predplodiny, obrabania pody a hnojenia na vysku a strukturu urody a efektivnost' pestovania ozimnej psenice.  
Publication Year: 1998
- 16/6/154 (Item 154 from file: 10)  
3771225 22002404 Holding Library: AGL  
Effect of phytophthora resistance levels and time of planting on \*alfalfa\* autotoxicity  
1996
- 16/6/155 (Item 155 from file: 144)  
15306009 PASCAL No.: 01-0480004  
Efeito de sistemas de producao de graos e de pastagens sob plantio direto sobre o nivel de fertilidade do solo apos cinco anos  
(Effect of grain and forage crop production systems under no-\*tillage\* on soil fertility after five years)  
2001
- 16/6/156 (Item 156 from file: 50)  
0009268866 CAB Accession Number: 20073122054  
Effects of grain production systems including pastures under no-\*tillage\* on soil physical properties and yield.  
Original Title: Efeitos de sistemas de producao de graos envolvendo pastagens sob plantio direto nos atributos fisicos de solo e na produtividade.  
Publication Year: 2004
- 16/6/157 (Item 157 from file: 50)  
0007504814 CAB Accession Number: 19980703050  
Effects of great bustards ( Otis tarda ) on \*cultivated\* areas in west-central Spain.  
Publication Year: 1998
- 16/6/158 (Item 158 from file: 5)  
10802365 BIOSIS NO.: 199192048136  
EFFECT OF HERBICIDES ON THE THERMOLUMINESCENCE OF \*CULTIVATED\* PLANTS AND SEEDS  
1990
- 16/6/159 (Item 159 from file: 5)  
13313957 BIOSIS NO.: 199698781790  
Effect of hydrocarbons and crude oil contamination on the sensitivity of French bean to \*alfalfa\* mosaic virus  
1995

16/6/160 (Item 160 from file: 5)  
13094218 BIOSIS NO.: 199698562051  
Influence of \*alfalfa\* (\*Medicago\* sativa L.) intercropping and  
polyethylene mulching on early growth of walnut (*Juglans* spp.) in central  
Italy  
1995

16/6/161 (Item 161 from file: 10)  
3583160 20571777 Holding Library: AGL  
Influence of \*alfalfa\* escapes on estimating spring barley yield  
1995

16/6/162 (Item 162 from file: 203)  
01903529  
Effect of the \*alfalfa\* stand establishment method on seed yields (  
Vplyv sposobu zalozenia porastu lucrny na urodu semena)  
1995

16/6/163 (Item 163 from file: 50)  
0006805441 CAB Accession Number: 19942301417  
Effects of mechanical \*cultivation\*, hoeing, single and combined  
herbicidal treatments on weed control in faba beans.  
Publication Year: 1991

16/6/164 (Item 164 from file: 50)  
0007917685 CAB Accession Number: 20000709843  
Effects of \*Medicago\* polymorpha L. cover cropping in Sardinia  
vineyards.  
Publication Year: 2000

16/6/165 (Item 165 from file: 50)  
0006725381 CAB Accession Number: 19930765530  
Effect of mineral fertilizers and methods of soil \*tillage\* on crop  
productivity and nutrient balance in a soil-protecting crop rotation in  
the Ukrainian forest steppe.  
Publication Year: 1990

16/6/166 (Item 166 from file: 5)  
10788013 BIOSIS NO.: 199192033784  
THE EFFECT OF AMINOETHOXYVINYLGLYCINE AND SILVER ON ETHYLENE SYNTHESIS AND  
ACTIVITY OF PHENYLALANINE AMMONIA-LYASE IN \*ALFALFA\* CELL SUSPENSION  
CULTURE  
1991

16/6/167 (Item 167 from file: 144)  
16252707 PASCAL No.: 03-0413989  
Efeito de sistemas de producao mistos sob plantio direto sobre  
fertilidade do solo apos oito anos  
(Effect of mixed crop production systems under no-\*tillage\* on soil  
fertility after eight years)  
2003

16/6/169 (Item 169 from file: 5)  
18753978 BIOSIS NO.: 200600099373  
Effects of the mycorrhizal fungus *Glomus intraradices* on uranium uptake and  
accumulation by \*Medicago\* truncatula L. from uranium-contaminated soil  
2005

16/6/170 (Item 170 from file: 10)  
3136449 91959993 Holding Library: SDS; AGL  
Effects of including \*alfalfa\* in whole-farm plans comparison of  
conventional, ridge \*till\*, and alternative farming systems / by Clarence  
Mends and Thomas L. Dobbs  
1991

16/6/171 (Item 171 from file: 50)  
0009378019 CAB Accession Number: 20073209564  
Effect of inoculating lactic bacteria community A12 and microbial shifts  
during \*alfalfa\* ensiling process.  
Publication Year: 2007

16/6/172 (Item 172 from file: 50)  
0008891153 CAB Accession Number: 20053150735  
Effect of the inherent variation in the mineral concentration of  
\*alfalfa\* cultivars on aphid populations.  
Publication Year: 2005

16/6/173 (Item 173 from file: 5)  
0019495370 BIOSIS NO.: 200700155111  
Effect of the inherent variation in the mineral concentration of \*alfalfa\*  
cultivars on aphid populations  
2005

16/6/174 (Item 174 from file: 50)  
0009526997 CAB Accession Number: 20083113534  
Effects of no \*tillage\* and genetic resistance on sunflower wilt by  
Verticillium dahliae .  
Publication Year: 2008

16/6/175 (Item 175 from file: 5)  
17649482 BIOSIS NO.: 200400016466  
The effect on soil phosphorus in long-term continuous cropping of \*alfalfa\*  
in the arid loess regions.  
2003

16/6/176 (Item 176 from file: 5)  
14055984 BIOSIS NO.: 199799690044  
Effect of plastic mulching and \*alfalfa\* intercropping (\*Medicago\* sativa  
L.) on walnut (Juglans spp.) growth and tree-soil water relations during  
early plantation phases  
1994

16/6/177 (Item 177 from file: 50)  
0007633313 CAB Accession Number: 19980614914  
Effects of plastic mulching and intercropping with \*alfalfa\* (  
\*Medicago\* sativa ) on walnut ( Juglans spp.) growth and tree/soil water  
relations during early plantation phases.  
Original Title: Effetto della pacciamatura plastica e della  
consociazione con l'erba medica ( \*Medicago\* sativa L.) sull'accrescimento  
e sulle relazioni idriche del noce ( Juglans spp.) durante le fasi  
giovani.  
Publication Year: 1994/1995, publ. 1997

16/6/178 (Item 178 from file: 5)



11217233 BIOSIS NO.: 199293060124  
EFFECTS OF PERENNIAL FORAGE-LEGUME LIVING MULCHES ON NO-\*TILL\* WINTER WHEAT  
AND RYE  
1991

16/6/179 (Item 179 from file: 50)  
0007213207 CAB Accession Number: 19960705637  
The effect of preplant fertilization in the establishment of \*alfalfa\*  
-kikuyu grass intercropping in the Venezuelan Andes.  
Ecophysiology of tropical intercropping. Proceedings of an international  
meeting held in Guadeloupe on 6-10 Dec. 1994.  
Publication Year: 1995

16/6/180 (Item 180 from file: 5)  
0019893882 BIOSIS NO.: 200700553623  
Effect of ridge and furrow micro-catchment on soil water in seeded  
\*Medicago\* sativa grassland in the semiarid loess hill and gully region  
of northwestern China  
2007

16/6/181 (Item 181 from file: 203)  
02158202  
Effect of irrigation with saline water on root distribution and forage  
yield by different root types of \*alfalfa\* (\*Medicago\* sativa) under  
different soil salinity conditions with zero leaching  
1996  
The Genus \*Medicago\* in the Mediterranean Region: Current Situation and  
Prospects in Research (Le Genre \*Medicago\* en Mediterranee : Bilan et  
Perspectives de la Recherche)

16/6/182 (Item 182 from file: 50)  
0007639497 CAB Accession Number: 19981915362  
Effect of irrigation water quality on salt accumulation in soil and  
mineral contents of \*alfalfa\* in the United Arab Emirates.  
Publication Year: 1998

16/6/183 (Item 183 from file: 5)  
12747612 BIOSIS NO.: 199598215445  
Effect of Rhizobium meliloti inoculation on the yield and biochemical  
properties of \*alfalfa\*  
1994

16/6/184 (Item 184 from file: 5)  
11868546 BIOSIS NO.: 199396032962  
Influence of \*tillage\* on soybean (Glycine max) herbicide carryover to  
grass and legume forage crops in Missouri  
1993

16/6/185 (Item 185 from file: 50)  
0009287251 CAB Accession Number: 20073142785  
Effect of \*tillage\* packages and herbicides on energy and economics of  
wheat in transplanted rice ( Oryza sativa )-wheat ( Triticum aestivum )  
system.  
Publication Year: 2007

16/6/186 (Item 186 from file: 5)  
18760124 BIOSIS NO.: 200600105519

Effect of \*tillage\* practices and herbicides on weed dynamics and yield of wheat (*Triticum aestivum*) under transplanted rice (*Oryza sativa*)-wheat system in Vertisols  
2005

16/6/188 (Item 188 from file: 5)  
17406177 BIOSIS NO.: 200300364896  
Effect of \*tillage\* and rotation on organic carbon forms of chernozemic soils in Saskatchewan.  
2003

16/6/190 (Item 190 from file: 10)  
4830645 43791399 Holding Library: AGL

Influence of \*tillage\* and rotation systems on distribution of organic carbon associated with particle-size fractions in Chernozemic soils of Saskatchewan, Canada  
2006  
URL: <http://dx.doi.org/10.1007/s00374-005-0032-y>

16/6/191 (Item 191 from file: 50)  
0009065416 CAB Accession Number: 20063130118  
Effect of \*tillage\* and weed control methods on weeds and yield of rice-wheat and soybean-wheat cropping systems.  
Publication Year: 2005

16/6/192 (Item 192 from file: 5)  
13158968 BIOSIS NO.: 199698626801  
Effects of tall wheatgrass windbreaks on hay production of three \*alfalfa\* varieties at a semiarid location in Saskatchewan  
1995

16/6/193 (Item 193 from file: 50)  
0008952546 CAB Accession Number: 20053211665  
Effect of timothy sowing ratio on yield and nutritive value of \*alfalfa\* /timothy bi-crops.  
Book Title: Integrating efficient grassland farming and biodiversity. Proceedings of the 13th International Occasional Symposium of the European Grassland Federation, Tartu, Estonia, 29-31 August 2005  
Publication Year: 2005

16/6/194 (Item 194 from file: 10)  
3787830 22016449 Holding Library: AGL  
Influence of oat (*Avena sativa*) interseeding on weed suppression in the final year of an \*alfalfa\* (*\*Medicago\* sativa*) stand  
1999

16/6/195 (Item 195 from file: 10)  
3316013 93055163 Holding Library: AGL  
Effect of vegetation suppression on the establishment of sod-seeded \*alfalfa\* in the Aspen Parkland  
1992 Oct

16/6/196 (Item 196 from file: 50)  
0009349469 CAB Accession Number: 20073186074  
Effect of vineyard grass covering with \*alfalfa\* ( *\*Medicago\* sativa* )

on nitrogenous compound of grape berry and wine in grape cultivar cabernet sauvignon.

Publication Year: 2007

16/6/197 (Item 197 from file: 50)  
0007722982 CAB Accession Number: 19990704323

The effectiveness of oversowing of mountain meadows using different soil \*cultivation\* treatments.

Original Title: Skutecznośc podsiwu ak gorskich w zaleznosci od sposobu przygotowania gleby.

Publication Year: 1998

16/6/198 (Item 198 from file: 10)  
3238273 92072919 Holding Library: AGL

Effects of weed and invertebrate control on \*alfalfa\* establishment in oat stubble

1992 Jul

16/6/199 (Item 199 from file: 50)  
0008096908 CAB Accession Number: 20003018937

Influence of water stress on the nitrogen fixation of some lines of \*Medicago\* sativa .

Publication Year: 2000

16/6/200 (Item 200 from file: 10)  
4666967 43651175 Holding Library: AGL  
Effect of seeding rate on \*alfalfa\* stand longevity  
2004

16/6/201 (Item 201 from file: 50)  
0009453287 CAB Accession Number: 20083012296

Influence of soil \*cultivation\* and fertilizing on productivity and digestibility of lucerne forage.

Publication Year: 2006

16/6/202 (Item 202 from file: 203)  
02524298

The effect of soil \*cultivation\* on changes of its physical and chemical properties (Vplyv obrabania pody na zmeny jej fyzikalnych a chemickych vlastnosti)

2002

16/6/203 (Item 203 from file: 203)  
02525831

The influence of selected soil physical parameters on the \*alfalfa\* hay production (Vplyv fyzikalnych vlastnosti na produkciu lucerny pri rozdielnych systemoch zakladania porastu)

2002

16/6/204 (Item 204 from file: 203)  
02584550

The effect of salinity on the growth of \*Medicago\* polymorpha Linn.  
2003

16/6/205 (Item 205 from file: 50)  
0007563684 CAB Accession Number: 19980706691

Effect of soil preparation on \*alfalfa\* dry matter yield.

Original Title: Vplyv pripravy pody na urody lucrny siatej.  
 Ecological and biological aspects of fodder crop production. Refereed papers from an international research conference held at Nitra, Slovakia, 23 October 1997.  
 Publication Year: 1997

16/6/206 (Item 206 from file: 10)  
 3658870 20815229 Holding Library: AGL  
 The influence of soil \*tillage\* on the distribution of medic seeds in the soil, regeneration of medics and wheat yields in a medic wheat rotation  
 1998

16/6/207 (Item 207 from file: 203)  
 02427410  
 Effects of salt treatments on the production and chemical composition of salt wort (*Salicornia herbacea* L.), rhodesgrass [*Chloris gayana*] and \*alfalfa\* [*Medicago sativa*]  
 2000

16/6/209 (Item 209 from file: 143)  
 0868330 H.W. WILSON RECORD NUMBER: BBAI98022947  
 Influence of soil texture on \*alfalfa\* autotoxicity  
 19980100

16/6/210 (Item 210 from file: 10)  
 4677312 43937746 Holding Library: AGL  
 Effect of salt stress on the expression of NHX-type ion transporters in \*Medicago\* intertexta and *Melilotus indicus* plants  
 2007  
 URL: <http://dx.doi.org/10.1111/j.1399-3054.2007.00940.x>

16/6/211 (Item 211 from file: 5)  
 0019912099 BIOSIS NO.: 200700571840  
 Effect of salt stress on the expression of NHX-type ion transporters in \*Medicago\* intertexta and *Metilotus indicus* plants  
 2007

16/6/212 (Item 212 from file: 50)  
 0008433709 CAB Accession Number: 20033073813  
 The effectiveness of sewage sludge in soil recovery on flotation \*tilling\* tips.  
 Original Title: Rekultywacyjna efektywnosc osadow sciekowych na podozu wapna poflotacyjnego.  
 Publication Year: 2002

16/6/213 (Item 213 from file: 5)  
 17234642 BIOSIS NO.: 200300193361  
 Effect of iodine treatments on forage yields of \*alfalfa\*.  
 2003

16/6/214 (Item 214 from file: 5)  
 11202314 BIOSIS NO.: 199293045205  
 EFFECTS OF TWO CROPPING AND TWO \*TILLAGE\* SYSTEMS AND PESTICIDES ON PEANUT PEST MANAGEMENT  
 1991

16/6/215 (Item 215 from file: 10)

3246621 93001066 Holding Library: AGL  
 Effect of 2,4-D and dicamba residues on following crops in conservation  
 \*tillage\* systems  
 1992 Jan

16/6/216 (Item 216 from file: 50)  
 0007356264 CAB Accession Number: 19971904550  
 Effects of four \*cultivation\* systems for maize on nitrogen leaching. 1.  
 Field experiment.  
 Publication Year: 1997

16/6/217 (Item 217 from file: 50)  
 0007356263 CAB Accession Number: 19971904549  
 Effects of four \*cultivation\* systems for maize on nitrogen leaching. 2.  
 Model simulation.  
 Publication Year: 1997

16/6/218 (Item 218 from file: 10)  
 3603606 20588573 Holding Library: AGL  
 Eliminating the use of residual herbicides in corn/\*alfalfa\* rotations  
 1990

16/6/219 (Item 219 from file: 10)  
 3988515 23269827 Holding Library: AGL  
 Eliminating soil disturbance reduces post-\*alfalfa\* summer annual weed  
 populations  
 2001

16/6/220 (Item 220 from file: 5)  
 10645971 BIOSIS NO.: 199191028862  
 EMBRYOLOGY OF SOME PERENNIAL \*MEDICAGO\* FABACEAE SPECIES  
 1990

16/6/221 (Item 221 from file: 266)  
 00581976  
 IDENTIFYING NO.: 0405542 AGENCY CODE: AGRIC  
 ENHANCED DISEASE RESISTANCE AND IMPROVED METHODS OF PLANT SELECTION FOR  
 \*ALFALFA\* AND OTHER LEGUMES

16/6/222 (Item 222 from file: 156)  
 4042165 NLM Doc No: 16202815  
 Enhancement of lead uptake by \*alfalfa\* (\*Medicago\* sativa) using EDTA  
 and a plant growth promoter.  
 Oct 2005

16/6/223 (Item 223 from file: 143)  
 1376551 H.W. WILSON RECORD NUMBER: BBAI00050281  
 Enhancing pasture productivity with \*alfalfa\*: a review  
 20000700

16/6/224 (Item 224 from file: 5)  
 0019493452 BIOSIS NO.: 200700153193  
 Energy crop production on \*organic\* \*farms\* without livestock  
 ORIGINAL LANGUAGE TITLE: Energiepflanzenproduktion in viehlosen Biobetrieben  
 2006

16/6/225 (Item 225 from file: 10)  
 3595027 20581030 Holding Library: AGL  
 Energy requirements for conventional \*tillage\* following different crop rotations  
 1997

16/6/226 (Item 226 from file: 203)  
 02496558  
 Energetic evaluation of \*alfalfa\* growing in various systems of soil preparation and differentiated nutrition (Energeticke zhodnotenie pestovania lucrny siatej pri roznych systemoch pripravy pody a diferencovanej vyzive)  
 2002

16/6/227 (Item 227 from file: 50)  
 0007700044 CAB Accession Number: 19990702760  
 Erratum to 'Soybean yield as affected by crop rotations, deep \*tillage\* and irrigation layout on a hardsetting Alfisol'.  
 Publication Year: 1999

16/6/228 (Item 228 from file: 203)  
 02710260  
 2004  
 Evaluation And Comparison Of Integrated, Chemical And Mechanical Control Of Broadleaf Weeds In Seed \*Alfalfa\*

16/6/229 (Item 229 from file: 50)  
 0007094882 CAB Accession Number: 19951910770  
 Evaluation of forage and grain legumes, no-\*till\* and fertilizers to restore fertility degraded soils.  
 15th World Congress of Soil Science, Acapulco, Mexico, 10-16, July, 1994. Transactions, Volume 5a: Commission IV symposia.  
 Publication Year: 1994

16/6/230 (Item 230 from file: 50)  
 0009427399 CAB Accession Number: 20073231263  
 Evaluation of lucerne varieties for organic agriculture.  
 Book Title: Breeding and seed production for conventional and organic agriculture. Proceedings of the XXVI meeting of the EUCARPIA fodder crops and amenity grasses section, XVI meeting of the EUCARPIA \*Medicago\* spp group, Perugia, Italy, 2-7 September 2006  
 Publication Year: 2007

16/6/231 (Item 231 from file: 5)  
 0019679749 BIOSIS NO.: 200700339490  
 Evaluation of annual pasture legumes in northern New South Wales. 2. Trifolium and \*Medicago\* spp. and other legumes  
 2007

16/6/232 (Item 232 from file: 10)  
 3483257 20490910 Holding Library: AGL  
 Evaluation of weed control practices during spring and summer \*alfalfa\* establishment  
 1995 Jul

16/6/233 (Item 233 from file: 143)  
 0502330 H.W. WILSON RECORD NUMBER: BBAI94052894

Evaluation of sainfoin-\*alfalfa\* mixtures for forage production and compatibility at a semi-arid location in southern Saskatchewan  
19941000

16/6/234 (Item 234 from file: 5)  
0019620392 BIOSIS NO.: 200700280133  
Experimental \*cultivation\* of shiitake mushroom Lentinula edodes on two agricultural by-products from Guerrero, Mexico  
ORIGINAL LANGUAGE TITLE: Cultivo experimental del hongo shiitake, Lentinula edodes, sobre dos subproductos agricolas en Guerrero, Mexico  
2006

16/6/235 (Item 235 from file: 50)  
0009102273 CAB Accession Number: 20063146549  
Experiment on \*cultivating\* Sorghum sudanense in the lower reaches of the Tarim River.  
Publication Year: 2004

16/6/236 (Item 236 from file: 50)  
0008177350 CAB Accession Number: 20013091733  
Experiments with leguminous crops in a stockless \*organic\* \*farming\* system with sugar beets.  
Book Title: Designing and testing crop rotations for \*organic\* \*farming\*. Proceedings from an international workshop  
Publication Year: 1999

16/6/237 (Item 237 from file: 5)  
13517974 BIOSIS NO.: 199699152034  
Extent of RFLP variability in tetraploid populations of \*alfalfa\*, \*Medicago\* sativa  
1996

16/6/238 (Item 238 from file: 143)  
1768724 H.W. WILSON RECORD NUMBER: BBAI03110537  
Extraction of Subsoil Nitrogen by \*Alfalfa\*, \*Alfalfa\*-Wheat, and Perennial Grass Systems  
20010500

16/6/239 (Item 239 from file: 10)  
3503293 20509286 Holding Library: AGL  
Establishment of lucerne after maize in conservation \*tillage\* systems  
1994 Sep

16/6/240 (Item 240 from file: 50)  
0007983510 CAB Accession Number: 20003004891  
Establishing \*alfalfa\* on high clay soils after application of municipal solid waste.  
Publication Year: 2000

16/6/241 (Item 241 from file: 5)  
11813270 BIOSIS NO.: 199395115536  
Estimation of suitability of the Ascherson's cocksfoot (Dactylis aschersoniana Graebn.) for field \*cultivation\*  
1992

16/6/242 (Item 242 from file: 5)  
17406336 BIOSIS NO.: 200300365055  
[Efficiency of Gafsa phosphate associated with liming and gypsum and  
\*alfalfa\* \*Medicago\* sativa L. nutrient symptoms.]  
ORIGINAL LANGUAGE TITLE: Eficiencia do fosfato natural de Gafsa associado a  
calagem e gesso e sintomas nutricionais da alfafa, \*Medicago\* sativa L.  
2002

16/6/243 (Item 243 from file: 203)  
01816068  
[The effect of soil compaction on the production of \*alfalfa\*, perennial  
grasses and silage maize] (Uticaj sabijanja zemljista na proizvodnju  
lucerke, visegodisnjih trava i silokrmne kukuruza)  
1993  
The effect of soil compaction upon yield of agricultural cultures ( (Uticaj sabijanja zemljista na prinos poljoprivrednih kultura)

16/6/244 (Item 244 from file: 143)  
1273938 H.W. WILSON RECORD NUMBER: BBAI00057772  
Field response to selection in \*alfalfa\* for germination rate and seedling  
vigor at low temperatures  
20000900

16/6/245 (Item 245 from file: 5)  
11764369 BIOSIS NO.: 199395066635  
Phenolic accumulation and peroxidase activity in in vitro selected  
\*alfalfa\* callus cultures resistant to filtrate of Fusarium spp  
1992

16/6/246 (Item 246 from file: 5)  
11256972 BIOSIS NO.: 199293099863  
PHENOTYPIC RECURRENT SELECTION FOR 2N POLLEN AND 2N EGG PRODUCTION IN DIPLOID  
\*ALFALFA\*  
1991

16/6/247 (Item 247 from file: 5)  
14985511 BIOSIS NO.: 199900245171  
Phenotypic variation and germplasm discrimination in lucerne (\*Medicago\*  
sativa complex) as evidenced by multivariate analysis  
1999

16/6/248 (Item 248 from file: 5)  
14157750 BIOSIS NO.: 199799791810  
Phenylalanine ammonia-lyase activity in \*alfalfa\* suspension cultures  
treated with conidia and elicitors of Verticillium albo-atrum  
1997

16/6/249 (Item 249 from file: 5)  
15378478 BIOSIS NO.: 200000096791  
Foraging use of \*cultivated\* fields by the Houbara Bustard Chlamydotis  
undulata fuertaventurae Rothschild and Hartert, 1894 on Fuerteventura  
(Canary Islands)  
1999

16/6/250 (Item 250 from file: 50)  
0007146712 CAB Accession Number: 19950713861  
Formation and production of perennial grass stands depending on methods



of soil \*cultivation\*.

Publication Year: 1994

16/6/251 (Item 251 from file: 71)

00922874 1998168394

Fate of symbiotically-fixed sup 1sup 5Ninf 2 as influenced by method of  
\*alfalfa\* termination

PUBLICATION DATE: 19980000

16/6/253 (Item 253 from file: 10)

3729908 21969873 Holding Library: AGL

Fate of symbiotically-fixed 15N2 as influenced by method of \*alfalfa\*  
termination

1998

16/6/254 (Item 254 from file: 50)

0008504921 CAB Accession Number: 20033156584

Photosynthesis in \*alfalfa\* ( \*Medicago\* sativa L.) under phosphate  
suppression and resupply.

Original Title: Fotossintese em \*alfalfa\* ( \*Medicago\* sativa L.) sob  
supressao e ressuprimento de fosfato.

Publication Year: 2003

16/6/255 (Item 255 from file: 40)

00457693 ENVIROLINE NUMBER: 97-15303

Phytoremediation of Diesel-Contaminated Soil Using \*Alfalfa\*

Apr 28-May 1, 97

16/6/256 (Item 256 from file: 10)

3555000 20548811 Holding Library: AGL

Phytotoxicity of ryegrass and clover cover crops, and a lucerne alley  
crop for no-\*till\* vegetable production

1996

16/6/257 (Item 257 from file: 5)

12196046 BIOSIS NO.: 199497217331

Study of the phytoestrogen content of goat's rue (*Galega orientalis*),  
\*alfalfa\* (*Medicago sativa*) and white clover (*Trifolium repens*)

1993

16/6/258 (Item 258 from file: 50)

0007915330 CAB Accession Number: 20001612752

Physical mapping of rRNA genes in \*Medicago\* sativa and *M. glomerata* by  
fluorescent in situ hybridization.

Publication Year: 2000

16/6/259 (Item 259 from file: 266)

00441141

IDENTIFYING NO.: 0343975 AGENCY CODE: NSF

Phosphate Transport in the Arbuscular Mycorrhizal Symbiosis: Functional  
Analysis of a \*Medicago\* Truncatula Mycorrhiza-Specific Phosphate  
Transporter

16/6/260 (Item 260 from file: 5)

16728966 BIOSIS NO.: 200200322477

[The genus \*Medicago\* in agricultural systems and in safeguarding the  
environment: The role of annuals.]

ORIGINAL LANGUAGE TITLE: Il genere \*Medicago\* L. nei sistemi colturali e nella salvaguardia dell'ambiente: Il ruolo delle annuali  
2001

16/6/261 (Item 261 from file: 5)  
16322239 BIOSIS NO.: 200100494078  
Genetic diversity of indigenous Rhizobium leguminosarum bv. viciae isolates nodulating two different host plants during soil restoration with \*alfalfa\*  
2001

16/6/262 (Item 262 from file: 50)  
0007445003 CAB Accession Number: 19971611386  
Genetic diversity inventory and valuation of spontaneous species belonging to \*Medicago\* L. genus in Tunisia.  
Publication Year: 1996

16/6/263 (Item 263 from file: 50)  
0007444996 CAB Accession Number: 19971611379  
Genetic diversity, preservation and use of genetic resources of Mediterranean legumes: \*alfalfa\* and medics.  
Publication Year: 1996

16/6/264 (Item 264 from file: 50)  
0009427444 CAB Accession Number: 20073231320  
Genetic diversity and potential agronomic value of \*Medicago\* polymorpha L. populations collected in Sicily.  
Book Title: Breeding and seed production for conventional and organic agriculture. Proceedings of the XXVI meeting of the EUCARPIA fodder crops and amenity grasses section, XVI meeting of the EUCARPIA \*Medicago\* spp group, Perugia, Italy, 2-7 September 2006  
Publication Year: 2007

16/6/266 (Item 266 from file: 10)  
4740671 43981621 Holding Library: AGL  
Genetic and physical localization of an anthracnose resistance gene in \*Medicago\* truncatula  
2007  
URL: <http://dx.doi.org/10.1007/s00122-007-0645-7>

16/6/267 (Item 267 from file: 10)  
4689432 43883734 Holding Library: AGL  
Genetic Mapping Forage Yield, Plant Height, and Regrowth at Multiple Harvests in Tetraploid \*Alfalfa\* (\*Medicago\* sativa L.)  
2007  
URL: <http://dx.doi.org/10.2135/cropsci2006.07.0447>

16/6/268 (Item 268 from file: 203)  
02638542  
Genetic transformation of \*Medicago\* truncatula using system for direct somatic embryogenesis promoted by TDZ  
2005

16/6/269 (Item 269 from file: 5)  
13073579 BIOSIS NO.: 199598541412  
Genetic variability for morphology, growth and forage yield among perennial diploid and tetraploid lucerne populations (\*Medicago\* sativa L.)  
1995

16/6/270 (Item 270 from file: 10)  
3148910 92010235 Holding Library: AGL  
Genetic variation detectable with molecular markers among unadapted  
germ-plasm resources of \*cultivated\* peanut and related wild species  
1991 Dec

16/6/271 (Item 271 from file: 5)  
13620925 BIOSIS NO.: 199699254985  
Genetic variation for disease and nematode resistances and forage quality  
in perennial diploid and tetraploid lucerne populations (\*Medicago\* sativa  
L.)  
1996

16/6/272 (Item 272 from file: 50)  
0007444997 CAB Accession Number: 19971611380  
Genetic variation in the \*Medicago\* sativa complex.  
Publication Year: 1996

16/6/273 (Item 273 from file: 5)  
15594442 BIOSIS NO.: 200000312755  
Genetic variation for seed yield and its components in \*alfalfa\* (  
\*Medicago\* sativa L.) populations  
2000

16/6/274 (Item 274 from file: 143)  
2101238 H.W. WILSON RECORD NUMBER: BBAI03124033  
Genotypes of lucerne (\*Medicago\* sativa L.) show differential tolerance to  
manganese deficiency and toxicity when grown in bauxite residue sand  
20030200

16/6/275 (Item 275 from file: 5)  
15587300 BIOSIS NO.: 200000305613  
Gene expression of \*Medicago\* sativa inoculated with Sinorhizobium meliloti  
as modulated by the xenobiotics cadmium and fluoranthene  
2000

16/6/276 (Item 276 from file: 40)  
00554052 ENVIROLINE NUMBER: 98-12730  
Groundwater Quality Under Conventional and No \*Tillage\* : I. Nitrate,  
Electrical Conductivity, and pH  
Jul-Aug 98

16/6/277 (Item 277 from file: 50)  
0008241700 CAB Accession Number: 20023085915  
Growing processing tomatoes with less \*tillage\* in California.  
Publication Year: 2001

16/6/278 (Item 278 from file: 44)  
0000622511 IP ACCESSION NO: 4236064  
The growth and morphological variability of Anabaena thermalis Vouk under  
joint \*cultivation\* with seedlings of higher plants  
ORIGINAL TITLE: Rost i morfologicheskaya izmenchivost' Anabaena thermalis  
Vouk pri sovместnom vyrashchivanii s prорostkami vysshikh rastenii  
PUBLICATION DATE: 1995

16/6/279 (Item 279 from file: 50)

0009289250 CAB Accession Number: 20073112658  
 High efficient irrigation scheduling of the perennial \*cultivated\*  
 forage grasses.  
 Publication Year: 2006

16/6/280 (Item 280 from file: 266)  
 00583648  
 IDENTIFYING NO.: 0407539 AGENCY CODE: AGRIC  
 HIGH-THROUGHPUT REVERSE GENETICS IN \*MEDICAGO\* TRUNCATULA

16/6/281 (Item 281 from file: 5)  
 0019932446 BIOSIS NO.: 200700592187  
 Hydraulic conductivity and porosity under conventional and no-\*tillage\* and  
 the effect of three species of cover crop in northern France  
 2007

16/6/282 (Item 282 from file: 5)  
 10858618 BIOSIS NO.: 199192104389  
 THE USE OF HISTOCHEMICAL ANALYSIS AND STEM COLONIZATION FOR DISTINGUISHING  
 REACTIONS OF \*ALFALFA\* TO VERTICILLIUM WILT  
 1991

16/6/283 (Item 283 from file: 10)  
 4573037 43875528 Holding Library: AGL  
 Identification of Bacterial Groups Preferentially Associated with  
 Mycorrhizal Roots of \*Medicago\* truncatula  
 2007  
 URL: <http://aem.asm.org/contents-by-date.0.shtml>

16/6/284 (Item 284 from file: 5)  
 16881693 BIOSIS NO.: 200200475204  
 Identification and confirmation of aluminum tolerance QTL in diploid  
 \*Medicago\* sativa subsp. coerulea  
 2002

16/6/285 (Item 285 from file: 10)  
 4577415 43880615 Holding Library: AGL  
 Identification of Sources of Resistance to Phoma medicaginis Isolates in  
 \*Medicago\* truncatula SARDI Core Collection Accessions, and Multigene  
 Differentiation of Isolates  
 2006  
 URL: <http://dx.doi.org/10.1094/PHYTO-96-1330>

16/6/286 (Item 286 from file: 10)  
 4832624 43960331 Holding Library: AGL  
 Immediate Effects of Time and Method of \*Alfalfa\* Termination on Soil  
 Mineral Nitrogen, Moisture, Weed Control, and Seed Yield, Quality, and  
 Nitrogen Uptake  
 2007  
 URL: <http://www.tandf.co.uk/journals/titles/01904167.asp>

16/6/287 (Item 287 from file: 5)  
 15307507 BIOSIS NO.: 200000025820  
 Impact of Agrobacterium tumefaciens co-\*cultivation\* time and temperature  
 on T-DNA transfer and expression in plant cells  
 1997

16/6/289 (Item 289 from file: 50)  
0009229816 CAB Accession Number: 20073076583  
Impact of \*alfalfa\* mosaic virus subgroup I and II isolates on terpene secondary metabolism of *Lavandula vera* D.C., *Lavandula x alardii* and eight cultivars of *L. hybrida* Rev.  
Publication Year: 2006

16/6/290 (Item 290 from file: 41)  
0000305809 IP ACCESSION NO: 7159625  
Impact of Strip-\*till\* planting using Various Cover Crops on Insect Pests and Diseases of Peanuts  
BOOK TITLE: MAKING CONSERVATION \*TILLAGE\* CONVENTIONAL: BUILDING A FUTURE ON 25 YEARS OF RESEARCH.  
PUBLICATION DATE: 2002

16/6/291 (Item 291 from file: 266)  
00580419  
IDENTIFYING NO.: 0403586 AGENCY CODE: AGRIC  
IMPROVEMENT OF \*ALFALFA\* AND RELATED SPECIES

16/6/292 (Item 292 from file: 10)  
4095626 43615825 Holding Library: AGL  
Improvement of somatic embryogenesis in \*Medicago\* arborea  
2003  
URL: <http://www.kluweronline.com/issn/0167-6857/contents>

16/6/293 (Item 293 from file: 5)  
0019455942 BIOSIS NO.: 200700115683  
Independent action and contrasting phenotypes of resistance genes against spotted \*alfalfa\* aphid and bluegreen aphid in \*Medicago\* truncatula  
2007

16/6/294 (Item 294 from file: 10)  
3278687 93025322 Holding Library: AGL  
Infiltration rate of a sandy loam soil: effects of traffic, \*tillage\*, and plant roots  
1992 May

16/6/295 (Item 295 from file: 5)  
17487655 BIOSIS NO.: 200300444689  
Inferences from mitochondrial DNA patterns on the domestication history of \*alfalfa\* (\*Medicago\* sativa).  
2003

16/6/296 (Item 296 from file: 10)  
3895012 22300508 Holding Library: AGL  
Inhibition of ferric chelate reductase in \*alfalfa\* roots by cobalt, nickel, chromium, and copper  
2000

16/6/297 (Item 297 from file: 143)  
0499561 H.W. WILSON RECORD NUMBER: BBAI94050110  
Inorganic nitrogen supply and symbiotic dinitrogen fixation in \*alfalfa\*  
19940000

16/6/298 (Item 298 from file: 50)  
0007682642 CAB Accession Number: 19991001198

Integrated pest management in forage \*alfalfa\*.  
Publication Year: 1998

16/6/299 (Item 299 from file: 50)  
0008013965 CAB Accession Number: 20003031846  
Integration of weeds into pest management in \*alfalfa\* agroecosystems.  
Book Title: The BCPC Conference: Pests and diseases, Volume 3.  
Proceedings of an international conference held at the Brighton Hilton  
Metropole Hotel, Brighton, UK, 13-16 November 2000  
Publication Year: 2000

16/6/300 (Item 300 from file: 10)  
3762799 21993757 Holding Library: AGL  
Intercropping sorghum into \*alfalfa\* and reed canarygrass to increase  
biomass yield  
1998

16/6/301 (Item 301 from file: 10)  
4755076 43990681 Holding Library: AGL  
The interrelationship between the \*cultivation\* of crops and  
soil-strength dynamics  
2007  
URL: <http://dx.doi.org/10.1002/jpln.200625009>

16/6/302 (Item 302 from file: 5)  
11398756 BIOSIS NO.: 199294100597  
IN-VITRO \*CULTIVATION\* OF PLANT PARASITIC NEMATODES  
1992

16/6/303 (Item 303 from file: 5)  
14605611 BIOSIS NO.: 199800399858  
In vitro selection for osmotic tolerance in \*alfalfa\* (\*Medicago\* sativa L.)  
1996

16/6/304 (Item 304 from file: 50)  
0007694606 CAB Accession Number: 19992300805  
Investigation of genetic background of plant parasitism in the model  
system of \*alfalfa\* ( \*Medicago\* sativa ) and dodder ( Cuscuta trifolii ).  
Original Title: A novenyi parazitizmus genetikai hatterenek vizsgalata a  
lucerna ( \*Medicago\* sativa ) es a kis aranka ( Cuscuta trifolii )  
modellrendszerében.  
Publication Year: 1999

16/6/306 (Item 306 from file: 5)  
17343721 BIOSIS NO.: 200300301540  
Investigation of variations in NBS motifs in \*alfalfa\* (\*Medicago\* sativa),  
M. edgeworthii, and M. ruthenica.  
2003

16/6/307 (Item 307 from file: 50)  
0007370686 CAB Accession Number: 19971605978  
Insight on segregation distortions in two intraspecific crosses between  
annual species of \*Medicago\* (Leguminosae).  
Publication Year: 1997

16/6/308 (Item 308 from file: 10)  
3059069 91008040 Holding Library: AGL

In situ hybridization of beta-tubulin to \*alfalfa\* chromosomes  
1990 Nov

16/6/309 (Item 309 from file: 5)  
11932471 BIOSIS NO.: 199396096887  
Karyotype and C-banding in \*Medicago\* noeana Boiss., Leguminosae  
1993

16/6/310 (Item 310 from file: 50)  
0007600452 CAB Accession Number: 19980709619  
Lucerne: \*cultivation\*, processing and consumption.  
Original Title: La \*alfalfa\*: cultivo, transformacion y consumo.  
Publication Year: 1998

16/6/311 (Item 311 from file: 50)  
0006633281 CAB Accession Number: 19921973344  
Lucerne \*cultivation\* and rate of the microbial population of the soil.  
Original Title: Kultivace vojlesky a intenzita annosti microbni  
populace pudy.  
Publication Year: 1990

16/6/312 (Item 312 from file: 50)  
0006848044 CAB Accession Number: 19940703900  
Lucerne: factors affecting its production and utilization.  
Original Title: \*Alfalfa\*: factores que afectan su produccion y  
utilizacion.  
Publication Year: 1992

16/6/313 (Item 313 from file: 5)  
0019761215 BIOSIS NO.: 200700420956  
Lucerne management in an \*organic\* \*farming\* system under dry site conditions  
2007

16/6/314 (Item 314 from file: 50)  
0007444995 CAB Accession Number: 19971611378  
The lucerne in Spain. Characterization of the \*cultivated\* and  
spontaneous ecotypes.  
Publication Year: 1996

16/6/315 (Item 315 from file: 5)  
17905036 BIOSIS NO.: 200400275793  
Legume species and management for stockless \*organic\* \*farming\*  
2003

16/6/316 (Item 316 from file: 203)  
02076275  
[Algerian experience in the production field of \*Medicago\* and  
subterranean clover seeds] (Experience algerienne en matiere de production  
de semences de medics et de trefle souterrain)  
1995  
Sylvopastoral systems. Environmental, agricultural and economic  
sustainability (Systemes sylvopastoraux. Pour un environnement, une  
agriculture et une economie durables)

16/6/317 (Item 317 from file: 10)  
3791089 22018936 Holding Library: AGL  
Long-term influence of cropping systems, \*tillage\* methods, and N sources

on nitrate leaching  
1995

16/6/318 (Item 318 from file: 50)  
0007583340 CAB Accession Number: 19982302921  
Long-term \*tillage\* and rotation effects on soil seedbank  
characteristics.  
Publication Year: 1998

16/6/319 (Item 319 from file: 10)  
3381664 20408920 Holding Library: AGL  
Linkage mapping in diploid \*alfalfa\* (\*Medicago\* sativa)  
1994 Feb

16/6/320 (Item 320 from file: 10)  
4761528 43661780 Holding Library: AGL  
Large-scale assessment of symbiotic dinitrogen fixation by crops: soybean  
and \*alfalfa\* in the Mississippi River Basin  
2004  
URL: <http://hdl.handle.net/10113/8303>

16/6/321 (Item 321 from file: 6)  
2246693 NTIS Accession Number: MIC-102-05783/XAB  
Low disturbance injection of swine manure into \*alfalfa\* produced for  
dehy: Final report  
c2001

16/6/322 (Item 322 from file: 203)  
02448320  
1997  
\*Medicago\* and Trifolium germplasm collection and preservation  
strategies development (Kan phatthana withi kan kep raksa lae ruapruam  
chua phan phut ahan sat bang chanit (\*Medicago\* and Trifolium spp.))

16/6/323 (Item 323 from file: 203)  
02645495  
1999  
\*Medicago\* and trifolium germplasm collection and preservation  
strategies development

16/6/324 (Item 324 from file: 50)  
0007445006 CAB Accession Number: 19971611389  
\*Medicago\* truncatula : a legume model-plant.  
Publication Year: 1996

16/6/325 (Item 325 from file: 5)  
15887550 BIOSIS NO.: 200100059389  
Molecular analysis of genetic variation among \*alfalfa\* (\*Medicago\* sativa  
L.) and \*Medicago\* ruthenica clones  
2000

16/6/326 (Item 326 from file: 50)  
0007913654 CAB Accession Number: 20001612632  
The mielgas: wild Spanish populations of \*alfalfa\*. Results of ten years  
of researches.  
Lucerne and medics for the XXI Century. Proceedings XIII Eucarpia  
\*Medicago\* spp. Group Meeting, Perugia, Italy, 13-16 September 1999.



Publication Year: 2000

16/6/327 (Item 327 from file: 50)  
0006449775 CAB Accession Number: 19912312312  
Multiplication of *Pratylenchus brachyurus*, *P. zeae*, *Radopholus similis*  
*Tylenchorhynchus* sp. in monoxenic culture on \*alfalfa\* callus tissues.  
Original Title: Multiplicacao de *Pratylenchus brachyurus*, *P. zeae*,  
*Radopholus similis*, *Tylenchorhynchus* sp. em culturas monoxenicas em calos  
de alfafa.  
Publication Year: 1990

16/6/328 (Item 328 from file: 50)  
0008993560 CAB Accession Number: 20063031974  
Management of the \*alfalfa\* leaf-cutter bee, *Megachile rotundata*  
(Hymenoptera: Megachilidae), for \*alfalfa\* pollination in Mongolia.  
Original Title: Der Einsatz der Luzerne-Blattschneiderbiene, *Megachile*  
*rotundata* (Hymenoptera: Megachilidae), zur Bestaubung von Luzerne in der  
Mongolei.  
Book Title: Erforschung biologischer Ressourcen der Mongolei, Band 9  
Publication Year: 2005

16/6/329 (Item 329 from file: 266)  
00570202  
IDENTIFYING NO.: 0202036 AGENCY CODE: AGRIC  
Management of *Lygus* spp. (Hemiptera: Miridae) in \*Alfalfa\* Seed

16/6/330 (Item 330 from file: 143)  
2131034 H.W. WILSON RECORD NUMBER: BBAI07130183  
Managing Nitrogen Contaminated Soils: Benefits of N<sub>2</sub>-Fixing \*Alfalfa\*  
20070500

16/6/331 (Item 331 from file: 50)  
0008359728 CAB Accession Number: 20033003667  
Moon trifol - \*Medicago\* arborea L. in the flora of Croatia.  
Original Title: Drvenasta lucerna - \*Medicago\* arborea L. u Hrvatskoj  
flori.  
Publication Year: 2002

16/6/333 (Item 333 from file: 10)  
4872278 22294313 Holding Library: AGL  
Mapping of simple sequence repeat (SSR) DNA markers in diploid and  
tetraploid \*alfalfa\*  
2000  
URL: <http://hdl.handle.net/10113/14350>

16/6/334 (Item 334 from file: 50)  
0009427434 CAB Accession Number: 20073231310  
Morphology characterization of the \*alfalfa\* ecotype 'Ampurdan'.  
Book Title: Breeding and seed production for conventional and organic  
agriculture. Proceedings of the XXVI meeting of the EUCARPIA fodder crops  
and amenity grasses section, XVI meeting of the EUCARPIA \*Medicago\* spp  
group, Perugia, Italy, 2-7 September 2006  
Publication Year: 2007

16/6/335 (Item 335 from file: 5)  
19070960 BIOSIS NO.: 200600416355  
Morphologic and agronomic diversity of wild genetic resources of \*Medicago\*

sativa L. collected in Spain  
2006

16/6/336 (Item 336 from file: 203)  
02377304

Marker-assisted selection in lucerne. Construction of linkage maps and gene targeting [*\*Medicago\* sativa* L.] (Selezione assistita da marcatori molecolari in erba medica. Costruzione di mappe genetiche e mappaggio genico [*\*Medicago\* sativa* L.] )

1998

16/6/337 (Item 337 from file: 10)  
3709651 21807606 Holding Library: AGL

A method to measure genetic distance between allogamous populations of *\*alfalfa\** (*\*Medicago\* sativa*) using RAPD molecular markers

1998

16/6/338 (Item 338 from file: 10)  
4168017 43622083 Holding Library: AGL

Method and time of *\*alfalfa\** termination affects cereal growth and weed populations

Summary in French.

2003

16/6/339 (Item 339 from file: 40)  
00659861 ENVIROLINE NUMBER: 04-07578

Metal-Humic Complexes and Plant Micronutrient Uptake: a Study Based on Different Plant Species *\*Cultivated\** in Diverse Soil Types  
Jan 04

16/6/340 (Item 340 from file: 50)  
0009116763 CAB Accession Number: 20063195678

NaCl effect on *Sinorhizobium meliloti* strains in association with *\*alfalfa\** landraces from the pre-saharian regions of Morocco.

Original Title: Effet du Nacl sur des isolats de *Sinorhizobium meliloti* en association avec des ecotypes de luzerne ( *\*Medicago\* sativa* L.) des regions pre sahariennes du Maroc.

Publication Year: 2005

16/6/341 (Item 341 from file: 203)  
02387581

[Incorporation of *Vicia* and *\*Medicago\** in leguminous-cereal rotations]  
(Incorporacion de *Vicia* y *\*Medicago\** en rotaciones leguminosa-cereal)

1998

[Rotations and farming systems associations of maize in template zones]  
(Rotaciones y asociaciones de cultivos en sistemas de maiz en zonas templadas)

16/6/342 (Item 342 from file: 143)  
0968613 H.W. WILSON RECORD NUMBER: BBAI96010423  
Nodulation, biomass production, and nitrogen fixation in *\*alfalfa\** under drought  
19960000

16/6/343 (Item 343 from file: 10)  
3752869 21988874 Holding Library: AGL

Nitrogen dynamics under greenhouse conditions as influenced by method of

\*alfalfa\* termination. 1. Volatile N losses  
1998

16/6/344 (Item 344 from file: 10)  
3752871 21988879 Holding Library: AGL  
Nitrogen dynamics under growth chamber conditions as influenced by method  
of \*alfalfa\* termination. 2. Plant-available N release  
1998

16/6/345 (Item 345 from file: 143)  
0970903 H.W. WILSON RECORD NUMBER: BBAI97040060  
The nitrogen dynamics of 1-, 2- and 3-year stands of \*alfalfa\* in a cropping  
system  
19970615

16/6/346 (Item 346 from file: 143)  
0545866 H.W. WILSON RECORD NUMBER: BBAI95042193  
Nitrogen fixation and growth of one-year stands of non-dormant \*alfalfa\* in  
Manitoba  
19950700

16/6/347 (Item 347 from file: 5)  
10817279 BIOSIS NO.: 199192063050  
NUMBERS AND BIOMASS OF DIPTERA AND COLEOPTERA LARVAE IN THE SOIL UNDER RAPE  
AND \*ALFALFA\* FIELDS CROP  
1990

16/6/348 (Item 348 from file: 5)  
10618270 BIOSIS NO.: 199191001161  
A NUMERICAL TAXONOMIC ANALYSIS OF THE \*MEDICAGO\*-LITTORALIS AND \*MEDICAGO\*  
-TRUNCATULA COMPLEX  
1990

16/6/350 (Item 350 from file: 5)  
16703734 BIOSIS NO.: 200200297245  
[Nitrogen metabolism in \*alfalfa\* nodulated under phosphorus suppression and  
resupply.]  
ORIGINAL LANGUAGE TITLE: Metabolismo do nitrogenio em alfafa nodulada sob  
supressao e ressuprimento de fosforo  
2001

16/6/351 (Item 351 from file: 5)  
14004216 BIOSIS NO.: 199799638276  
Nitrogen requirements of corn (Zea mays L.) as affected by monocropping and  
intercropping with \*alfalfa\* (\*Medicago\* sativa)  
1996

16/6/352 (Item 352 from file: 5)  
18800724 BIOSIS NO.: 200600146119  
No \*tillage\* scarified - Spatial distribution preferential flows  
ORIGINAL LANGUAGE TITLE: Escarificado en siembra directa - Distribucion  
espacial de los flujos preferenciales  
2004

16/6/353 (Item 353 from file: 5)  
10181833 BIOSIS NO.: 199089099724

NO-\*TILL\* PASTURE RENOVATION AFTER SWARD SUPPRESSION BY HERBICIDES  
1990

16/6/354 (Item 354 from file: 10)  
3231749 92068304 Holding Library: AGL  
No-\*till\* vs. conventional \*tillage\* for late-planted corn following hay  
harvest  
1992 Apr

16/6/355 (Item 355 from file: 50)  
0009177058 CAB Accession Number: 20063220086  
Nutrient uptake and nodulation ability of \*alfalfa\* in an acid purple  
soil.  
Publication Year: 2006

16/6/356 (Item 356 from file: 50)  
0006683209 CAB Accession Number: 19930762386  
Nutrient uptake by perennial and annual grasses and legumes depending on  
the dose of mineral fertilizers and methods of soil \*tillage\*.  
Publication Year: 1991

16/6/357 (Item 357 from file: 10)  
3434868 20451761 Holding Library: AGL  
Nitrate leaching under furrow irrigation as affected by crop sequence and  
\*tillage\*  
1995 Jan

16/6/358 (Item 358 from file: 50)  
0006694340 CAB Accession Number: 19931977602  
Nitrate movement after ploughing up of legume-forage stands on \*organic\*  
\*farms\*.  
Original Title: Nitratverlagerung nach Umbruch von  
Leguminosen-Feldfutterbeständen in biologisch-dynamischen Betrieben.  
Publication Year: 1991

16/6/359 (Item 359 from file: 50)  
0007249777 CAB Accession Number: 19960708295  
Nitrate reductase activity in \*alfalfa\* plants supplied with increasing  
rates of mineral nitrogen and inoculated with different Rhizobium meliloti  
strains.  
Publication Year: 1996

16/6/360 (Item 360 from file: 5)  
13073985 BIOSIS NO.: 199598541818  
Nutritive value of some top feeds and \*cultivated\* fodders  
1994

16/6/361 (Item 361 from file: 5)  
13769706 BIOSIS NO.: 199799403766  
The nutritive value and yield of \*alfalfa\* in relation to nitrogen  
fertilization on sulphur industry reclaimed lands  
1996

16/6/362 (Item 362 from file: 40)  
00449903 ENVIROLINE NUMBER: 97-05602

Novel \*Alfalfa\* Cleans Fertilizer Spill  
Jan 97

16/6/363 (Item 363 from file: 5)  
0019787938 BIOSIS NO.: 200700447679  
A novel statistical method for assessing SSR variation in autotetraploid  
\*alfalfa\* (\*Medicago\* sativa L.)  
2007

16/6/365 (Item 365 from file: 5)  
16862609 BIOSIS NO.: 200200456120  
A new lodging tolerant and multiple resistant variety of \*alfalfa\* "Neo-  
tachiwakaba"  
2001

16/6/366 (Item 366 from file: 10)  
3602627 20587216 Holding Library: AGL  
A new \*Medicago\* truncatula line with superior in vitro regeneration,  
transformation, and symbiotic properties isolated through cell culture  
selection  
1997

16/6/367 (Item 367 from file: 10)  
3135427 92002080 Holding Library: AGL  
A new approach to direct somatic embryogenesis in \*Medicago\*  
1991

16/6/368 (Item 368 from file: 5)  
17603084 BIOSIS NO.: 200300559515  
Occurrence, inheritance and use of reproductive mutants in \*alfalfa\*  
improvement.  
2003

16/6/369 (Item 369 from file: 203)  
02432429  
Studies on breeding of \*alfalfa\* (\*Medicago\* sativa L.) cultivars  
adapted to Konsen district, eastern Hokkaido of Japan  
1998

16/6/370 (Item 370 from file: 5)  
13974524 BIOSIS NO.: 199799608584  
Studies on Coccinella septempunctata brucki mulsant as a biological agent  
for controlling \*alfalfa\* aphids  
1996

16/6/372 (Item 372 from file: 50)  
0009528732 CAB Accession Number: 20083098289  
Study on the characteristics of reproductive biology of \*alfalfa\*.  
Publication Year: 2008

16/6/373 (Item 373 from file: 50)  
0009043266 CAB Accession Number: 20063089686  
Study on the degrading process and vegetation succession of \*Medicago\*  
sativa grassland in North Loess Plateau, China.  
Publication Year: 2006

16/6/374 (Item 374 from file: 50)

0009122419 CAB Accession Number: 20063175642  
 Study on influence of sowing time in \*alfalfa\* variety Gloria and plant density in \*alfalfa\* variety Adonis upon nectarogenesis and honey production.  
 Original Title: Studiul influentei epocii de semanat la soiul de lucerna Gloria si a densitatii plantelor la soiul de lucerna Adonis, asupra nectarogenezei si a productiei de miere.  
 Publication Year: 1996

16/6/375 (Item 375 from file: 41)  
 0000305404 IP ACCESSION NO: 7150507  
 On farm conservation of \*alfalfa\* farmer's units of diversity (FUD) in Morocco  
 BOOK TITLE: MANAGING BIODIVERSITY IN AGRICULTURAL ECOSYSTEMS.  
 PUBLICATION DATE: 2001

16/6/376 (Item 376 from file: 50)  
 0008124412 CAB Accession Number: 20013153332  
 Study on the genetic diversity of wild \*Medicago\* falcata .  
 Publication Year: 2001

16/6/377 (Item 377 from file: 50)  
 0009534446 CAB Accession Number: 20083099128  
 Study on allelopathy of root, stem, and leaf aqueous extracts of different \*Medicago\* sativa varieties.  
 Publication Year: 2008

16/6/378 (Item 378 from file: 50)  
 0008221595 CAB Accession Number: 20023039505  
 Studies on integrated control of weeds in \*alfalfa\* field.  
 Publication Year: 2001

16/6/379 (Item 379 from file: 5)  
 17986420 BIOSIS NO.: 200400357209  
 Study on the productivity and mineral composition of mixed-seeded \*alfalfa\* (\*Medicago\* sativa L.) pastures  
 2004

16/6/380 (Item 380 from file: 5)  
 10629012 BIOSIS NO.: 199191011903  
 A STUDY ON THE VALUE OF \*ALFALFA\* I. THE STUDY ON THE CHANGE OF NUTRITIVE VALUE DUE TO PROCESSING OF \*ALFALFA\*  
 1990

16/6/382 (Item 382 from file: 5)  
 10286660 BIOSIS NO.: 199090071139  
 STUDIES ON VARIETAL ECOLOGY OF \*ALFALFA\* PLANTS 4. INFLUENCE OF PHOTOPERIODIC TREATMENTS ON SEEDLING GROWTH OF \*ALFALFA\* VARIETIES  
 1990

16/6/383 (Item 383 from file: 50)  
 0007696723 CAB Accession Number: 19991102649  
 On the selectivity and dispersion of \*alfalfa\* plant bug among its host plants in Eastern Henan cotton region.  
 Publication Year: 1998

16/6/384 (Item 384 from file: 143)

0439491 H.W. WILSON RECORD NUMBER: BBAI93038430  
Oat companion crop management in \*alfalfa\* establishment  
19930900

16/6/385 (Item 385 from file: 203)  
02638923  
2005  
Other insect pests of \*alfalfa\* and clover (Ostali stetni insekti lucerke  
i deteline)

16/6/386 (Item 386 from file: 5)  
12257100 BIOSIS NO.: 199497278385

Pollen morphology as a tool for determining interspecific relationships in  
the genus \*Medicago\*  
1993

16/6/387 (Item 387 from file: 10)  
3565080 20555934 Holding Library: AGL  
Planting date, fungicide, and cultivar effects on sclerotinia crown and  
stem rot severity in \*alfalfa\*  
1997

16/6/388 (Item 388 from file: 10)  
3548519 20543419 Holding Library: AGL  
Plant population dynamics in subterranean clover and murex medic swards.  
3. Effect of pod burial, summer grazing and autumn \*cultivation\* on  
emergence  
1996

16/6/389 (Item 389 from file: 5)  
12376586 BIOSIS NO.: 199497397871  
Plant regeneration from callus cultures of \*alfalfa\*  
1994

16/6/390 (Item 390 from file: 10)  
3810883 22027090 Holding Library: AGL  
Plant-available nitrogen supply as affected by method and timing of  
\*alfalfa\* termination  
1999

16/6/391 (Item 391 from file: 203)  
02578586  
Plants spontaneous alternative host of beneficent insects on an  
\*alfalfa\* crop (Plantas espont neas hospederas alternativas de insectos  
beneficiosos en un cultivo de \*alfalfa\*)  
2003  
[Conference 2003. Spanish Weed Science Society. Proceedings, Barcelona  
[Spain], 4th, 5th and 6th November, 2003] (Congreso 2003. Sociedad  
Espa ola de Malherbolog a. Actas, Barcelona, 4, 5 y 6 de noviembre de 2003)

16/6/392 (Item 392 from file: 10)  
4801489 43636009 Holding Library: AGL  
Plasmid transfer from Pseudomonas putida to the indigenous bacteria on  
\*alfalfa\* sprouts: characterization, direct quantification, and in situ  
location of transconjugant cells

2003

- 16/6/393 (Item 393 from file: 143)  
1838150 H.W. WILSON RECORD NUMBER: BBAI04169156  
Penetration of Photosynthetically Active and Ultraviolet Radiation into  
\*Alfalfa\* and Tall Fescue Canopies  
20041100
- 16/6/394 (Item 394 from file: 5)  
11275004 BIOSIS NO.: 199293117895  
PRODUCTIVITY OF \*CULTIVATED\* DRAINED SODDY-PODZOLIC SOILS FIRST  
COMMUNICATION SELECTING CROPS AND OPTIMIZING THEIR NUTRITION IN VARIOUS  
SYSTEMS OF AGRICULTURAL USE OF SODDY-PODZOLIC GLEY SOIL  
1991
- 16/6/395 (Item 395 from file: 143)  
0663114 H.W. WILSON RECORD NUMBER: BBAI97004500  
Productivity, and composition of smooth and meadow brome grass mixtures with  
\*alfalfa\* under frequent cutting management  
19961000
- 16/6/396 (Item 396 from file: 50)  
0006747617 CAB Accession Number: 19930767478  
Productivity of drained dernopodzolic soils under \*cultivation\*. 1.  
Selecting crops and optimizing their nutrition under different systems of  
agricultural utilization of gleyed dernopodzolic soil.  
Publication Year: 1991
- 16/6/397 (Item 397 from file: 50)  
0006570409 CAB Accession Number: 19920755300  
Productivity and feeding value of irrigated lucerne depending on  
practices of primary soil \*tillage\* and fertilizer rates.  
Publication Year: 1990
- 16/6/398 (Item 398 from file: 203)  
01748196  
[Productivity of \*alfalfa\* and Festuca arundinacea cultivars in mixture  
and pure] (Produttivita' di cultivar di medica e di Festuca arundinacea in  
miscuglio ed in purezza)  
1992
- 16/6/399 (Item 399 from file: 5)  
13738975 BIOSIS NO.: 199799373035  
The productivity of natural and \*cultivated\* (artificial) coenoses in  
semi-desert of North-West Caspian Lowland  
1996
- 16/6/400 (Item 400 from file: 50)  
0007515020 CAB Accession Number: 19981604100  
Production of plant-regenerants in a culture in vitro in annual species  
of \*alfalfa\*.  
Publication Year: 1996
- 16/6/401 (Item 401 from file: 143)  
0350164 H.W. WILSON RECORD NUMBER: BBAI91054270  
Productivity of wheat and \*alfalfa\* under intercropping  
19911000



16/6/402 (Item 402 from file: 203)

02652553  
Performance of a new \*alfalfa\* variety "Lucerne 2002" for green forage yield and quality  
2003

16/6/403 (Item 403 from file: 5)  
0019667938 BIOSIS NO.: 200700327679  
Performance of short-lived perennial grasses grown with and without \*alfalfa\* at a semiarid location in southern Saskatchewan  
2007

16/6/404 (Item 404 from file: 10)  
4831088 43806118 Holding Library: AGL  
Profitability of Various Corn, Soybean, Wheat, and \*Alfalfa\* Cropping Systems  
2003  
URL: <http://hdl.handle.net/10113/11875>

16/6/406 (Item 406 from file: 5)  
19341052 BIOSIS NO.: 200700000793  
Preliminary evaluation of diverse lucerne (\*Medicago\* sativa sspp.) germplasm to identify new material for livestock and cropping based farming systems in Australia  
2006

16/6/407 (Item 407 from file: 144)  
14886943 PASCAL No.: 01-0034519  
Partner Farm concept : A participatory approach to collaboration between specialised \*organic\* \*farms\*  
Organic agriculture faces its development : the future issues  
L'agriculture biologique face a son developpement : les enjeux futurs :  
Lyon, 6-8 decembre 1999  
2000

16/6/408 (Item 408 from file: 50)  
0006716922 CAB Accession Number: 19930764733  
Peroxidase of cultured \*alfalfa\* cells.  
Publication Year: 1993

16/6/409 (Item 409 from file: 5)  
12312244 BIOSIS NO.: 199497333529  
Peroxidase activities and contents of phenolic acids in embryogenic and nonembryogenic \*alfalfa\* cell suspension cultures  
1994

16/6/410 (Item 410 from file: 50)  
0006404842 CAB Accession Number: 19910744883  
The presence of an enzyme that converts indole-3-acetamide into IAA in wild and \*cultivated\* rice.  
Publication Year: 1991

16/6/411 (Item 411 from file: 203)  
02658952  
2005

[Perspective directions of \*alfalfa\* breeding in Belarus]

- 16/6/412 (Item 412 from file: 5)  
0020227417 BIOSIS NO.: 200800274356  
Prospection of viral diseases of soybeans in several production areas in Argentina and different \*tillage\* systems  
ORIGINAL LANGUAGE TITLE: Prospeccion de enfermedades virales del cultivo de soja en distintas areas de produccion de Argentina y bajo distintos sistemas de labranza  
2007
- 16/6/413 (Item 413 from file: 5)  
13867311 BIOSIS NO.: 199799501371  
Parasitoids and hyperparasitoids associated with *Acyrtosiphon pisum* (Harris) and *Acyrtosiphon kondoi* Shinji (Homoptera: Aphididae) in \*alfalfa\* (\*Medicago\* sativa L.) in Albany, California-USA  
1996
- 16/6/414 (Item 414 from file: 5)  
12543622 BIOSIS NO.: 199598011455  
Pathological relationship of *Meloidogyne hapla* and *Phytophthora megasperma* f. sp. *medicaginis* in twelve \*Medicago\* sativa L. cultivars  
1994
- 16/6/416 (Item 416 from file: 10)  
3320758 20338443 Holding Library: AGL  
Potential of trispecies bridge crosses and random amplified polymorphic DNA markers for introgression of \*Medicago\* daghestanica and *M. pironae* germplasm into \*alfalfa\* (*M. sativa*)  
1993 Jun
- 16/6/417 (Item 417 from file: 203)  
02543282  
Possibilities of accelerated evaluation of \*alfalfa\* winterhardiness under Latvia conditions (*Lucernas ziemcietibas paatrinatas novertesanas iespeja Latvijas apstaklos*)  
2003
- 16/6/418 (Item 418 from file: 5)  
19207163 BIOSIS NO.: 200600552558  
Qualitative land suitability evaluation for the growth of onion, potato, maize, and \*alfalfa\* on soils of the Khalat pushan research station  
2006
- 16/6/419 (Item 419 from file: 203)  
02629679  
Quality and yield from \*alfalfa\* after applying of organo-mineral amendmets on heavy metal polluted soil (*Dobiv i kachestvo na lyutserna, poluchena sled meliorativni vazdejstviya na zamarsena s tezhki metali pochva*)  
2005
- 16/6/420 (Item 420 from file: 10)  
3633626 20612540 Holding Library: AGL  
Quantitative comparison of volatile compounds among seven \*Medicago\* Spp. accessions  
1996

16/6/421 (Item 421 from file: 5)  
15415554 BIOSIS NO.: 200000133867  
Quantitative genetic analysis of erect glandular trichome density in diploid  
\*alfalfa\*  
2000

16/6/422 (Item 422 from file: 10)  
4578589 43881981 Holding Library: AGL  
Quantitative trait loci and candidate gene mapping of aluminum tolerance  
in diploid \*alfalfa\*  
2007  
URL: <http://dx.doi.org/10.1007/s00122-006-0488-7>

16/6/423 (Item 423 from file: 5)  
12256211 BIOSIS NO.: 199497277496  
Reclamation of sands by crop \*cultivation\* near oases in Turkmenistan  
1994

16/6/424 (Item 424 from file: 50)  
0008922974 CAB Accession Number: 20053180498  
The recovery of mineral-N applied to mixed stands of *Dactylis glomerata*  
L. and \*Medicago\* sativa L.  
Book Title: Optimal forage systems for animal production and the  
environment. Proceedings of the 12th Symposium of the European Grassland  
Federation, Pleven, Bulgaria, 26-28 May 2003  
Publication Year: 2003

16/6/425 (Item 425 from file: 5)  
0019534052 BIOSIS NO.: 200700193793  
Ridge-furrow planting of \*alfalfa\* (\*Medicago\* sativa L.) for improved  
rainwater harvest in rainfed semiarid areas in Northwest China  
2007

16/6/428 (Item 428 from file: 10)  
3517407 20517419 Holding Library: AGL  
RFLP linkage map of an \*alfalfa\* meiotic mutant based on an F1 population  
1996 Mar

16/6/429 (Item 429 from file: 50)  
0007887179 CAB Accession Number: 20001610656  
Registration of CADL 98 \*alfalfa\* germplasm.  
Publication Year: 2000

16/6/430 (Item 430 from file: 50)  
0006508944 CAB Accession Number: 19921626950  
Registration of W2 x iso-1 and W4 x iso-1 isogenic populations of  
diploid and tetraploid \*alfalfa\* germplasm.  
Publication Year: 1991

16/6/431 (Item 431 from file: 50)  
0007828121 CAB Accession Number: 20001905120  
Relationships between growth of \*alfalfa\* and sulphur levels in selected  
soils of Misr (Egypt).  
Publication Year: 1995, publ. 1999

16/6/432 (Item 432 from file: 5)  
18477876 BIOSIS NO.: 200510172376

Relationship between amino acid concentration and aphid (Hemiptera:  
Aphididae) abundance on \*Alfalfa\* (\*Medicago\* sativa L.)

2005

16/6/433 (Item 433 from file: 76)  
0001710083 IP ACCESSION NO: 5992689  
Relationship of disease resistance and stand persistence in \*alfalfa\*  
cultivars from the 1940's to the 1990's  
PUBLICATION DATE: 2004

16/6/434 (Item 434 from file: 10)  
3775940 22005046 Holding Library: AGL  
Relationship of rainfall, cultural practices, soil and plant nutrients,  
and seedling survival with root disease and parasitic nematode numbers in  
annual \*Medicago\* spp. pastures  
1999

16/6/435 (Item 435 from file: 5)  
13795074 BIOSIS NO.: 199799429134  
The role of weeds in \*cultivated\* and virgin soils on activity and  
perpetuation of *Fusarium oxysporum* f. sp. *melonis* in Fars Province  
1996

16/6/436 (Item 436 from file: 50)  
0007056219 CAB Accession Number: 19950708478  
The relative sustainability of alternative, conventional, and reduced-  
\*till\* farming systems.  
Publication Year: 1995

16/6/437 (Item 437 from file: 5)  
16787982 BIOSIS NO.: 200200381493  
Removal of phenol by \*alfalfa\* plants (\*Medicago\* sativa L.) grown in  
hydroponics and its effect on some physiological parameters  
2002

16/6/438 (Item 438 from file: 5)  
15732035 BIOSIS NO.: 200000450348  
Use of RAPD and microsatellite (SSR) variation to assess genetic  
relationships among populations of tetraploid \*alfalfa\*, \*Medicago\* sativa  
2000

16/6/439 (Item 439 from file: 10)  
3742433 21982585 Holding Library: AGL  
Root recolonization of previous root channels in corn and \*alfalfa\*  
rotations  
1998

16/6/440 (Item 440 from file: 5)  
16149820 BIOSIS NO.: 200100321659  
Rotation and \*tillage\* effects on soil organic carbon sequestration in a  
typic Hapludalf in southern Ontario  
2001

16/6/442 (Item 442 from file: 10)

3470982 20479224 Holding Library: AGL  
 Root exuded non-gene inducing signals limit the nodulation capacity of  
 different \*alfalfa\* varieties with Rhizobium meliloti  
 1995

16/6/443 (Item 443 from file: 10)  
 3517501 20517943 Holding Library: AGL  
 Root-zone mineral nitrogen changes as affected by crop sequence and  
 \*tillage\*  
 1994 Sep

16/6/444 (Item 444 from file: 143)  
 1288069 H.W. WILSON RECORD NUMBER: BBAI00050408  
 Reexamining the relationship between fall dormancy and winter hardiness in  
 \*alfalfa\*  
 20000700

16/6/445 (Item 445 from file: 143)  
 0740523 H.W. WILSON RECORD NUMBER: BBAI93010439  
 Ryegrass companion crops for \*alfalfa\* establishment: I. Forage yield and  
 \*alfalfa\* suppression  
 19930100

16/6/446 (Item 446 from file: 143)  
 0740524 H.W. WILSON RECORD NUMBER: BBAI93010444  
 Ryegrass companion crops for \*alfalfa\* establishment: II. Forage quality in  
 the seeding year  
 19930100

16/6/447 (Item 447 from file: 203)  
 01784345  
 [Some results of studies on \*cultivated\* fodders]  
 1991  
 [Summaries of reports to the Research Conference for 30th Anniversary of  
 the Research Institute of Animal Husbandry]

16/6/449 (Item 449 from file: 50)  
 0007917698 CAB Accession Number: 20000709830  
 Results of the experimentation and \*cultivation\* of lucerne in Albania.  
 Publication Year: 2000

16/6/450 (Item 450 from file: 5)  
 18063991 BIOSIS NO.: 200400434780  
 Responses of the fructose-1,6-bisphosphatase and glutamate dehydrogenase  
 activities of \*alfalfa\* to boron, gypsum, and limestone amendments of soil  
 2004

16/6/451 (Item 451 from file: 10)  
 3700171 21806040 Holding Library: AGL  
 Response of \*alfalfa\* to inoculation with Penicillium bilaii (Provide)  
 1998

16/6/452 (Item 452 from file: 10)  
 3828758 22040024 Holding Library: AGL  
 Response of overseeded \*alfalfa\* and bermudagrass to \*alfalfa\* row  
 spacing and nitrogen rate  
 1999

16/6/453 (Item 453 from file: 71)  
01365306 2000043192  
Response of overseeded \*alfalfa\* and bermudagrass to \*alfalfa\* row sparing  
and nitrogen rate

16/6/454 (Item 454 from file: 40)  
00703146 ENVIROLINE NUMBER: 06-17375  
Responses of Soil Water, Nitrogen, and Organic Matter to the \*Alfalfa\* Crop  
Rotation in Semiarid Loess Area of China  
2006

16/6/455 (Item 455 from file: 50)  
0009138959 CAB Accession Number: 20063185400  
Researches about the influence of some fertilising system on some fodder  
plants \*cultivated\* on reddish-brown soil from Moara Domneasca.  
Original Title: Cercetari privind influenta sistemului de fertilizare  
asupra unor plante furajere \*cultivate\* pe solul brun-roscat de la Moara  
Domneasca.  
Publication Year: 1997

16/6/456 (Item 456 from file: 203)  
02124407  
Research concerning the development of root system in different plants  
\*cultivated\* on a saline soil during the amelioration process (Cercetari  
privind dezvoltarea sistemului radicular al unor plante de cultura pe un  
sol saraturat in curs de ameliorare)  
1995

16/6/457 (Item 457 from file: 50)  
0009122431 CAB Accession Number: 20063175604  
Research on chemical fertilisers and the lead as polluting of fodder  
plants \*cultivated\* on reddish-brown soil at Moara Domneasca.  
Original Title: Cercetari privind influenta ingraisaimintelor chimice  
si a plumbului ca poluant la plantele furajere \*cultivate\* pe solul brun  
roscat de la Moara Domneascai.  
Publication Year: 1998

16/6/458 (Item 458 from file: 50)  
0007385990 CAB Accession Number: 19970706077  
Resource-saving methods for basic \*tillage\* of lucerne plots on southern  
chernozem before sowing soft winter wheat in irrigated rotations in South  
Ukraine.  
Nauchnoe obespechenie agropromyshlennogo kompleksa.  
Publication Year: 1996

16/6/459 (Item 459 from file: 50)  
0007483833 CAB Accession Number: 19981001649  
A subject store for disease resistance of selected \*cultivated\* plant  
species.  
Original Title: Ein Sachspeicher zur Krankheitsresistenz bei  
ausgewählten Kulturpflanzen-arten.  
Publication Year: 1997

16/6/460 (Item 460 from file: 143)  
1827953 H.W. WILSON RECORD NUMBER: BBAI04165723

Screening for Salinity Tolerance in \*Alfalfa\*: A Repeatable Method  
20041100

16/6/461 (Item 461 from file: 10)  
4011978 23287349 Holding Library: AGL  
Seedbed preparation, timing of seeding, fertility and root pathogens  
affect establishment and yield of \*alfalfa\*  
2002

16/6/462 (Item 462 from file: 40)  
00607300 ENVIROLINE NUMBER: 01-14271  
Sudangrass Uses Water at Rates Similar to \*Alfalfa\*, Depending on Location  
Jul-Aug 01

16/6/463 (Item 463 from file: 144)  
11300074 PASCAL No.: 94-0120149  
Seed and seedling dynamics over four consecutive years from a single seed  
set of six annual medics (\*Medicago\* spp) in North Syria  
1993

16/6/464 (Item 464 from file: 143)  
0477814 H.W. WILSON RECORD NUMBER: BBAI94028250  
Sod-seeding \*alfalfa\* in spring into established crested wheatgrass in  
southwest Saskatchewan  
19940400

16/6/465 (Item 465 from file: 50)  
0007697361 CAB Accession Number: 19990702413  
Sugarbeet \*cultivation\* with limited inputs in conditions of protection  
of underground water sources.  
Original Title: Pestovanie cukrovej repy pri obmedzenych vstupoch v  
podmienkach ochrany podzemnych zdrojov vody.  
Publication Year: 1998

16/6/466 (Item 466 from file: 10)  
3285181 93029924 Holding Library: AGL  
Shrinkage of bare and \*cultivated\* soil  
1992 Jul

16/6/467 (Item 467 from file: 10)  
4867285 44058459 Holding Library: AGL  
Short Cuts For Planting \*Alfalfa\*  
2008  
URL: <http://cropwatch.unl.edu/>

16/6/468 (Item 468 from file: 266)  
00437984  
IDENTIFYING NO.: 0321460 AGENCY CODE: NSF  
Sequencing the Gene Space of the Model Legume, \*Medicago\* Truncatula

16/6/469 (Item 469 from file: 5)  
0019534034 BIOSIS NO.: 200700193775  
Soil biophysical responses by macroaggregates to \*tillage\* of two soil types  
BOOK TITLE: Advances in Geoecology  
2006

16/6/470 (Item 470 from file: 5)

19193031 BIOSIS NO.: 200600538426  
 Soil chemical changes following manure application on irrigated \*alfalfa\*  
 and rainfed timothy in southern Alberta  
 2006

16/6/471 (Item 471 from file: 5)  
 10811802 BIOSIS NO.: 199192057573  
 SELECTION OF \*ALFALFA\* CLONES RESISTANT TO ANALOGUES OF AMINO ACIDS AND  
 STREPTOMYCIN  
 1990

16/6/472 (Item 472 from file: 50)  
 0007371899 CAB Accession Number: 19970704888  
 Selection and utilization of \*cultivated\* fodder trees and shrubs in  
 Mediterranean extensive livestock production systems.  
 The optimal exploitation of marginal Mediterranean areas by extensive  
 ruminant production systems. Proceedings of an international symposium  
 organized by HSAP and EAAP and sponsored by EU(DGVI), FAO and CIHEAM,  
 Thessaloniki, Greece, 18-20 June, 1994.  
 Publication Year: 1996

16/6/473 (Item 473 from file: 50)  
 0009451305 CAB Accession Number: 20083021662  
 Soil decontamination of 2,4,6-trinitrotoluene by \*alfalfa\* ( \*Medicago\*  
 sativa ).  
 Publication Year: 2007

16/6/474 (Item 474 from file: 50)  
 0007337320 CAB Accession Number: 19970702567  
 Soil factors limiting growth of lucerne in four soils of the X Region.  
 II. Soil acidity.  
 Original Title: Factores de suelo limitantes del crecimiento de la  
 \*alfalfa\* en cuatro suelos de la X Region. II. Acidez del suelo.  
 Publication Year: 1995

16/6/475 (Item 475 from file: 5)  
 18758934 BIOSIS NO.: 200600104329  
 Soil quality responses to \*alfalfa\* watered with a field micro-catchment  
 technique in the Loess Plateau of China  
 2006

16/6/476 (Item 476 from file: 5)  
 15988651 BIOSIS NO.: 200100160490  
 Soil and \*alfalfa\* response after amelioration of subsoil acidity in a fine  
 sandy loam Podzol in Prince Edward Island  
 2000

16/6/477 (Item 477 from file: 10)  
 4366428 43757472 Holding Library: AGL  
 Soil microbial characteristics and mineral nitrogen availability as  
 affected by olive oil waste water applied to \*cultivated\* soil  
 2005

16/6/478 (Item 478 from file: 5)  
 14651703 BIOSIS NO.: 199800445950  
 Soil mites (Acari) of ecotones between a shelterbelt and \*cultivated\*  
 fields in the agricultural landscape near Turew, Poland



1998

16/6/479 (Item 479 from file: 143)  
1629864 H.W. WILSON RECORD NUMBER: BBAI03110028  
Soil Nitrogen Mineralization in Mixtures of Eastern Gamagrass with  
\*Alfalfa\* and Red Clover  
20010700

16/6/480 (Item 480 from file: 143)  
1424312 H.W. WILSON RECORD NUMBER: BBAI93019817  
Soil properties associated with \*alfalfa\* winter survival at Kamloops,  
British Columbia  
19930200

16/6/482 (Item 482 from file: 5)  
15677514 BIOSIS NO.: 200000395827  
Soil organic carbon and <sup>13</sup>C abundance as related to \*tillage\*, crop  
residue, and nitrogen fertilization under continuous corn management in  
Minnesota  
2000

16/6/484 (Item 484 from file: 5)  
11942712 BIOSIS NO.: 199396107128  
Salt tolerance variability of wild \*alfalfa\* during germination  
1993

16/6/485 (Item 485 from file: 143)  
1791363 H.W. WILSON RECORD NUMBER: BBAI04152806  
Soil water balance simulation of \*alfalfa\* (\*Medicago\* sativa L.) in the  
semiarid Chinese Loess Plateau  
20040915

16/6/486 (Item 486 from file: 10)  
3785612 22012126 Holding Library: AGL  
Soil water dynamics after \*alfalfa\* as influenced by crop termination  
technique  
1999

16/6/487 (Item 487 from file: 5)  
19000897 BIOSIS NO.: 200600346292  
Soil water and \*alfalfa\* yields as affected by alternating ridges and  
furrows in rainfall harvest in a semiarid environment  
2006

16/6/488 (Item 488 from file: 143)  
0570057 H.W. WILSON RECORD NUMBER: BBAI96012793  
Soil solution chemistry and \*alfalfa\* response to CaCO<sub>3</sub> and MgCO<sub>3</sub> on an  
acidic Gleysol  
19960200

16/6/489 (Item 489 from file: 10)  
4329513 43692251 Holding Library: AGL  
Soil carbon and nitrogen changes as influenced by \*tillage\* and cropping  
systems in some Iowa soils  
2005

16/6/490 (Item 490 from file: 5)

19338611 BIOSIS NO.: 200600684006  
Soil carbon and nitrogen sequestration following the conversion of cropland  
to \*alfalfa\* forage land in northwest China  
2007

16/6/492 (Item 492 from file: 143)  
1970596 H.W. WILSON RECORD NUMBER: BBAI06154984  
Soil carbon pool and effects of soil fertility in seeded \*alfalfa\* fields  
on the semi-arid Loess Plateau in China  
20060800

16/6/493 (Item 493 from file: 5)  
14419582 BIOSIS NO.: 199800213829  
Somaclonal variability of morphological and biochemical parameters in  
regenerated \*alfalfa\* plants  
1997

16/6/494 (Item 494 from file: 143)  
1893633 H.W. WILSON RECORD NUMBER: BBAI05157597  
Simulated Aspen Understory Microclimate Effects on \*Alfalfa\* Growth  
20050900

16/6/495 (Item 495 from file: 50)  
0007444992 CAB Accession Number: 19971611375  
Summary of research on \*Medicago\* at the National Institute of Agronomic  
Research, Tunisia (INRAT).  
Original Title: Synthese des travaux de recherche realises sur les  
\*Medicago\* a l'Institut National de la Recherche Agronomique de Tunisie  
(INRAT).  
Publication Year: 1996

16/6/496 (Item 496 from file: 5)  
19196554 BIOSIS NO.: 200600541949  
Somatic embryogenesis and Agrobacterium mediated genetic transformation in  
Indian accessions of lucerne (\*Medicago\* sativa L.)  
2006

16/6/498 (Item 498 from file: 5)  
13446974 BIOSIS NO.: 199699081034  
The supply of phosphorus from native, inorganic phosphorus pools in  
continuously \*cultivated\* Mexican agroecosystems  
1996

16/6/499 (Item 499 from file: 50)  
0008859130 CAB Accession Number: 20053115475  
Saponins of \*Medicago\* sativa as the natural inductor of laccase from  
Trametes versicolor .  
Publication Year: 2005

16/6/500 (Item 500 from file: 5)  
17989944 BIOSIS NO.: 200400360733  
Suppression of silver-leaf bitter apple (Solanum elaeagnifolium Cav.) by  
\*cultivated\* pasture crops under dry-land conditions: a preliminary study  
2004

16/6/501 (Item 501 from file: 5)  
17354397 BIOSIS NO.: 200300311886  
Spatial and temporal pattern of colonization of Nabidae (Heteroptera) in  
\*alfalfa\* (\*Medicago\* sativa).  
2003

16/6/502 (Item 502 from file: 50)  
0006336973 CAB Accession Number: 19911618236  
Sources of resistance to \*alfalfa\* gallfly in lucerne.  
Publication Year: 1990

16/6/503 (Item 503 from file: 50)  
0009403582 CAB Accession Number: 20073273922  
Surveys of false chinch bug, *Nysius raphanus* (Howard) (Hemiptera:  
Lygaeidae) and their movement on \*cultivated\* crops and non-\*cultivated\*  
habitats throughout growing season in Colorado.  
Publication Year: 2006

16/6/504 (Item 504 from file: 71)  
03241584 2006059666  
Surveys of *Lygus* spp. and their movement on \*cultivated\* crops and non-  
\*cultivated\* habitats throughout growing season in Colorado

16/6/505 (Item 505 from file: 50)  
0007062192 CAB Accession Number: 19952308930  
Survey of virus diseases of wild and \*cultivated\* legumes in the coastal  
region of Syria.  
Publication Year: 1994

16/6/506 (Item 506 from file: 203)  
02523998  
Suitability of different legume/grass swards for \*organic\* \*farming\*  
2002  
International Scientific Conference "Scientific Aspects of \*Organic\*  
\*Farming\*". Proceedings of the conference held in Jelgava, Latvia, March  
21-22, 2002 (Biologiskas lauksaimniecibas zinatniskie aspekti. Konferences  
materiali, Latvija, Jelgava, 21.-22.marts, 2002)

16/6/507 (Item 507 from file: 5)  
14518593 BIOSIS NO.: 199800312840  
Structuration of \*alfalfa\* genetic diversity using agronomic and  
morphological characteristics: Relationship with RAPD markers  
1998

16/6/508 (Item 508 from file: 50)  
0007797440 CAB Accession Number: 19990709893  
Use of strip cropping and \*alfalfa\* to reduce NO SUB 3 -N leaching to  
shallow groundwater.  
ASAE/CSAE-SCGR Annual International Meeting, Toronto, Ontario, Canada,  
18-21 July, 1999.  
Publication Year: 1999

16/6/509 (Item 509 from file: 50)  
0006593943 CAB Accession Number: 19920758078  
Strip position, \*tillage\* , and water regime effects on a strip  
intercropping rotation.  
Publication Year: 1992

16/6/510 (Item 510 from file: 10)  
3323032 20355842 Holding Library: AGL  
Seventeen years of cropping systems and \*tillage\* affect velvetleaf  
(*Abutilon theophrasti*) seed longevity  
1993 Jan

16/6/511 (Item 511 from file: 10)  
3499564 20503783 Holding Library: AGL  
Sustaining productivity of a Vertisol at Warra, Queensland, with  
fertilisers, no-\*tillage\*, or legumes. 1. Organic matter status  
1995

16/6/512 (Item 512 from file: 10)  
4745497 43951936 Holding Library: AGL  
Threecornered \*Alfalfa\* Hopper (Hemiptera: Membracidae): Seasonal  
Occurrence, Girdle Distribution, and Response to Insecticide Treatment on  
Peanut in South Carolina  
2007  
URL: [http://dx.doi.org/10.1603/0022-0493\(2007\)100\[1229:TAHHMS\]2.0.CO;2](http://dx.doi.org/10.1603/0022-0493(2007)100[1229:TAHHMS]2.0.CO;2)

16/6/513 (Item 513 from file: 5)  
16843617 BIOSIS NO.: 200200437128  
\*Tillage\* and chlorpyrifos treatment effects on peanut arthropods: An  
incidence of severe burrower bug injury  
2001

16/6/514 (Item 514 from file: 266)  
00558875  
IDENTIFYING NO.: 0187199 AGENCY CODE: AGRIC  
\*Tillage\* and Crop Rotations for Eastern South Dakota

16/6/515 (Item 515 from file: 266)  
00553508  
IDENTIFYING NO.: 0157659 AGENCY CODE: AGRIC  
\*TILLAGE\* , CROPPING SEQUENCES, AND OTHER PRACTICES TO ENHANCE  
AGRICULTURAL SUSTAINABILITY

16/6/516 (Item 516 from file: 50)  
0008377119 CAB Accession Number: 20033007911  
\*Tillage\* effect and duration of prairies on the physical condition in  
Vertic Argiudol soil in Argentina.  
Original Title: Efecto de la labranza y duracion de las praderas sobre  
la condicion fisica de un suelo Argiudol Vertico de Argentina.  
Publication Year: 2002

16/6/517 (Item 517 from file: 5)  
11941779 BIOSIS NO.: 199396106195  
\*Tillage\* effects on near-surface soil hydraulic properties  
1993

16/6/518 (Item 518 from file: 76)  
0001229503 IP ACCESSION NO: 4296902  
\*Tillage\* effects on water runoff and soil erosion after sod  
PUBLICATION DATE: 1998

16/6/519 (Item 519 from file: 10)

3653289 20627197 Holding Library: AGL  
 \*Tillage\* effect on soil water content and corn yield in a strip  
 intercropping system  
 1997

16/6/520 (Item 520 from file: 5)  
 16035730 BIOSIS NO.: 200100207569  
 \*Tillage\* effect on soil water content and soybean (Glycine max) yield in a  
 strip intercropping system  
 2001

16/6/521 (Item 521 from file: 10)  
 3285217 93029960 Holding Library: AGL  
 \*Tillage\* - and traffic-induced changes in macroporosity and macropore  
 continuity: air permeability assessment  
 1992 Jul

16/6/522 (Item 522 from file: 5)  
 16218911 BIOSIS NO.: 200100390750  
 Temporal effects on the composition of a population of Sinorhizobium  
 meliloti associated with \*Medicago\* sativa and Melilotus alba  
 2001

16/6/523 (Item 523 from file: 50)  
 0009427425 CAB Accession Number: 20073231301  
 Temperate forage legume and grass genetic resources: capitalizing on the  
 U.S. germplasm system.  
 Book Title: Breeding and seed production for conventional and organic  
 agriculture. Proceedings of the XXVI meeting of the EUCARPIA fodder crops  
 and amenity grasses section, XVI meeting of the EUCARPIA \*Medicago\* spp  
 group, Perugia, Italy, 2-7 September 2006  
 Publication Year: 2007

16/6/524 (Item 524 from file: 156)  
 3593609 NLM Doc No: 10898396  
 Total arsenic, lead, and cadmium levels in vegetables \*cultivated\* at the  
 Andean villages of northern Chile.  
 Jun 8 2000

16/6/525 (Item 525 from file: 5)  
 0020046717 BIOSIS NO.: 200800093656  
 Undersowing wheat with different living mulches in a no-\*till\* system. I.  
 Yield analysis  
 2007

16/6/526 (Item 526 from file: 5)  
 0020046718 BIOSIS NO.: 200800093657  
 Undersowing wheat with different living mulches in a no-\*till\* system. II.  
 Competition for light and nitrogen  
 2007

16/6/527 (Item 527 from file: 5)  
 16340530 BIOSIS NO.: 200100512369  
 Updating and extending genetic characterization and classification of  
 phytoplasmas from wild and \*cultivated\* plants in southern Italy  
 2001

16/6/528 (Item 528 from file: 71)  
03331441 2006110223  
Urease activity as affected by \*cultivation\* and soil depth: A kinetic approach

16/6/529 (Item 529 from file: 266)  
00574506  
IDENTIFYING NO.: 0207579 AGENCY CODE: AGRIC  
Using association mapping to identify markers for cell wall constituents and biomass yield in \*alfalfa\*

16/6/530 (Item 530 from file: 5)  
0020096500 BIOSIS NO.: 200800143439  
Variability of morphological traits in natural populations of \*Medicago\* truncatula Gaertn in Morocco  
ORIGINAL LANGUAGE TITLE: Variabilite des caracteres morphologiques des populations naturelles de \*Medicago\* truncatula Gaertn. an Maroc  
2007

16/6/531 (Item 531 from file: 76)  
0001075393 IP ACCESSION NO: 3889516  
Virus diseases of ornamental shrubs. VII. \*Alfalfa\* mosaic virus (AMV) and a carlavirus infecting Ruscus hypoglossum  
PUBLICATION DATE: 1994

16/6/532 (Item 532 from file: 10)  
4076424 23339636 Holding Library: AGL  
Variation among and within Italian \*alfalfa\* ecotypes by means of bio-agronomic characters and amplified fragment length polymorphism analyses  
2003

16/6/533 (Item 533 from file: 10)  
3633627 20612541 Holding Library: AGL  
Variation in aphid alarm pheromone content among glandular and eglandular-haired \*Medicago\* accessions  
1996

16/6/534 (Item 534 from file: 5)  
13055814 BIOSIS NO.: 199598523647  
Variation in generative cell plastid nucleoids and male fertility in \*Medicago\* sativa  
1995

16/6/535 (Item 535 from file: 50)  
0008243442 CAB Accession Number: 20023053798  
Viruses on \*cultivated\* forage legumes in Syria.  
Publication Year: 2001

16/6/536 (Item 536 from file: 10)  
3319812 20337472 Holding Library: AGL  
Weed control in oat (Avena sativa)-\*alfalfa\* (\*Medicago\* sativa) and effect on next year corn (Zea mays) yield  
1992 Oct

16/6/537 (Item 537 from file: 6)  
1907080 NTIS Accession Number: MIC-95-04349

Weed control for row-cropped \*alfalfa\*: Final research report  
c1995

16/6/538 (Item 538 from file: 266)  
00573309  
IDENTIFYING NO.: 0206170 AGENCY CODE: AGRIC  
Weed Management in Reduced-\*tillage\* Agriculture

16/6/539 (Item 539 from file: 266)  
00552232  
IDENTIFYING NO.: 0014360 AGENCY CODE: AGRIC  
Weeds in \*Cultivated\* Agronomic Row Crops and Their Management

16/6/540 (Item 540 from file: 203)  
02639246  
2005  
Weed in \*alfalfa\* and clover fields and their control (Korovi u lucerki  
i detelini i njihovo suzbijanje)

16/6/541 (Item 541 from file: 10)  
3762066 21990423 Holding Library: AGL  
Weed seedbanks and corn growth following continuous corn or \*alfalfa\*  
1998

16/6/542 (Item 542 from file: 203)  
02111270  
Weed seeds in \*alfalfa\* seed [in the Vojvodina Province [Yugoslavia]] (Seme korova u semenu lucerke Vojvodine [Yugoslavia])  
1995

16/6/543 (Item 543 from file: 10)  
3918059 23212918 Holding Library: AGL  
Weed suppression by annual legume cover crops in no-\*tillage\* corn  
2001

16/6/544 (Item 544 from file: 10)  
3913743 23211260 Holding Library: AGL  
Wheat stem maggot in spring wheat-\*alfalfa\* intercrops with different  
crop management intensities  
2000

16/6/545 (Item 545 from file: 50)  
0008230004 CAB Accession Number: 20023041348  
Ways of intensification of fodder grass \*cultivation\* on irrigated  
lands.  
Publication Year: 2002

16/6/546 (Item 546 from file: 5)  
15124985 BIOSIS NO.: 199900384645  
Winter wheat pests and their natural enemies under \*organic\* \*farming\*  
system in Slovakia: Effect of ploughing and previous crop  
1999

16/6/547 (Item 547 from file: 143)  
1629977 H.W. WILSON RECORD NUMBER: BBAI03110154

Weather Impacts on Maize, Soybean, and \*Alfalfa\* Production in the Great  
Lakes Region, 1895-1996  
20010900

16/6/548 (Item 548 from file: 5)  
14740353 BIOSIS NO.: 199900000013  
Water quality in an irrigated sandy soil: Ridge \*tillage\* in rotated corn  
and soybean compared with full-width \*tillage\* in continuous corn  
1998

16/6/549 (Item 549 from file: 50)  
0008252890 CAB Accession Number: 20023065874  
Water management of irrigation for \*alfalfa\* in a Red-Yellow Latosol  
(Hapludox).  
Original Title: Manejo da agua na irrigacao da alfafa num Latossolo  
Vermelho-Amarelo.  
Publication Year: 2002

16/6/550 (Item 550 from file: 203)  
02212190  
1997  
[Yugoslav varieties and hybrids of the \*cultivated\* plants] (  
Jugoslovenske sorte i hibridi poljoprivrednog bilja)

16/6/551 (Item 551 from file: 50)  
0006492792 CAB Accession Number: 19920750696  
Yield of a crop rotation with lucerne in relation to fertilizers and  
\*tillage\* methods.  
Publication Year: 1990

16/6/552 (Item 552 from file: 5)  
13006163 BIOSIS NO.: 199598473996  
Yields of \*alfalfa\* varieties selected for Aphanomyces resistance in Kentucky  
1995

16/6/553 (Item 553 from file: 10)  
3631976 20610835 Holding Library: AGL  
Yield and nitrogen uptake of rotated corn in a ridge \*tillage\* system  
1997

16/6/554 (Item 554 from file: 143)  
1630120 H.W. WILSON RECORD NUMBER: BBAI03110355  
Zone of Autotoxic Influence around Established \*Alfalfa\* Plants  
20020900

16/6/555 (Item 555 from file: 203)  
02158200  
[Synthesis of research activities on \*Medicago\* at the "Institut  
National de la Recherche Agronomique" of Tunisia] (Synthese des travaux de  
recherche realises sur les \*Medicago\* a l'Institut National de la Recherche  
Agronomique de Tunisie)  
1996  
The Genus \*Medicago\* in the Mediterranean Region: Current Situation and  
Prospects in Research (Le Genre \*Medicago\* en Mediterranee : Bilan et  
Perspectives de la Recherche)

16/6/556 (Item 556 from file: 50)



0008058472 CAB Accession Number: 20013068616

First observations regarding the nitrate content under the root zone of various \*cultivations\*.

Original Title: Prime osservazioni sulla concentrazione di N nitrico sotto la zona radicale in sistemi colturali diversi.

Publication Year: 2001

16/6/557 (Item 557 from file: 10)

3158678 92014087 Holding Library: AGL

C-banding of \*alfalfa\* chromosomes: standard karyotype and analysis of a somaclonal variant

1991 Jul

16/6/558 (Item 558 from file: 50)

0008996361 CAB Accession Number: 20063058932

Carbon and N mineralization as affected by soil \*cultivation\* and crop residue in a calcareous wetland ecosystem in Central Iran.

Publication Year: 2006

16/6/559 (Item 559 from file: 10)

4414426 43777021 Holding Library: AGL

Carbon and N mineralization as affected by soil \*cultivation\* and crop residue in a calcareous wetland ecosystem in Central Iran

2006

S3        31057    GLYPHOSATE  
 S4        817567    CONTAMINATION  
 S5        8467700    AIR OR WATER OR SOIL OR SOILS OR GROUNDWATER OR SEDIMENT? ?  
 S6        28645322    PY=1926:1989  
           S17    20807    S3 NOT S6  
           S18       463    S17 AND S4 AND S5  
           S19       229    RD S18    (unique items)  
           S20       229    S19 NOT (S15 OR S10)

21/6/1        (Item 1 from file: 10)  
 4712857    43957306    Holding Library: AGL  
 The Absence of \*Glyphosate\* Residues in Wet \*Soil\* and the Adjacent  
 Watercourse after a Forestry Application in New Brunswick  
 2007

21/6/2        (Item 2 from file: 5)  
 12298959    BIOSIS NO.: 199497320244  
 Accumulation of 2,4-D and \*glyphosate\* in fish and \*water\* hyacinth  
 1994

21/6/3        (Item 3 from file: 40)  
 00256363    ENVIROLINE NUMBER: 94-01661  
 Additive Effects of Herbicide Combinations on Aquatic Non-Target Organisms  
 May 11-15, 93

21/6/4        (Item 4 from file: 40)  
 00673626    ENVIROLINE NUMBER: 05-01954  
 Adsorption and Cosorption of Cadmium and \*Glyphosate\* on Two \*Soils\* with  
 Different Characteristics  
 Dec 04

21/6/5        (Item 5 from file: 40)  
 00270394    ENVIROLINE NUMBER: 95-00813  
 Adsorption and Desorption of \*Glyphosate\* in Some European \*Soils\*  
 1994

21/6/6        (Item 6 from file: 5)  
 14259404    BIOSIS NO.: 199800053651  
 Adsorption of \*glyphosate\* on the clay mineral montmorillonite: Effect of  
 Cu(II) in solution and adsorbed on the mineral  
 1997

21/6/7        (Item 7 from file: 5)  
 13509621    BIOSIS NO.: 199699143681  
 Adsorption of atrazine, simazine, and \*glyphosate\* in \*soils\* of the  
 Gnangara Mound, Western Australia  
 1996

21/6/8        (Item 8 from file: 266)  
 00585843  
 IDENTIFYING NO.: 0409955    AGENCY CODE: AGRIC  
 AUGMENTATIVE BIOHERBICIDE STRATEGIES FOR CONTROL OF INVASIVE WEEDS

21/6/9        (Item 9 from file: 144)  
 17772232    PASCAL No.: 06-0366995  
 Agricultural pesticide residues in farm ditches of the Lower Fraser  
 valley, British Columbia, Canada

2006

21/6/10 (Item 10 from file: 266)  
00576322

IDENTIFYING NO.: 0209768 AGENCY CODE: AGRIC  
Agroforestry/Riparian in Central PlainsSDTDPXBTAT

21/6/11 (Item 11 from file: 5)  
18426425 BIOSIS NO.: 200510120925  
Amphibian communities in stormwater detention ponds along roads of Southeast France.  
ORIGINAL LANGUAGE TITLE: Communautés d'amphibiens des bassins d'eau de pluie autoroutiers du Sud-Est de la France  
2004

21/6/12 (Item 12 from file: 144)  
14969679 PASCAL No.: 01-0122867  
Analytical methods to determine phosphonic and amino acid group-containing pesticides  
2001

21/6/13 (Item 13 from file: 144)  
16277748 PASCAL No.: 03-0440897  
Analysis of \*glyphosate\* and glufosinate by capillary electrophoresis-mass spectrometry utilising a sheathless microelectrospray interface  
Electrophoresis in tubes, capillaries and microchips: with recognition of Stellan Hjerten

2003

21/6/14 (Item 14 from file: 144)  
18585668 PASCAL No.: 08-0171496  
Analysis of \*glyphosate\* and aminomethylphosphonic acid by capillary electrophoresis with electrochemiluminescence detection  
2008

21/6/15 (Item 15 from file: 50)  
0008149478 CAB Accession Number: 20013178221  
Analysis of \*glyphosate\* and its metabolite, aminomethylphosphonic acid, in agricultural products by HPLC.  
Publication Year: 2001

21/6/16 (Item 16 from file: 156)  
3855988 NLM Doc No: 13129785  
Analysis of \*glyphosate\* residues in cereals using liquid chromatography-mass spectrometry (LC-MS/MS).  
Aug 2003

21/6/17 (Item 17 from file: 10)  
4667778 43705267 Holding Library: AGL  
Applicability of the quantification of genetically modified organisms to foods processed from maize and soy  
2005

21/6/18 (Item 18 from file: 266)  
00570535

IDENTIFYING NO.: 0202606 AGENCY CODE: AGRIC  
Application of solid-phase microextraction (SPME) fibres in monitoring  
organic contaminants in the Sugar Creek watershed

21/6/19 (Item 19 from file: 5)  
16010870 BIOSIS NO.: 200100182709  
Behavior of \*glyphosate\* and aminomethylphosphonic acid (AMPA) in \*soils\*  
and \*water\* of reservoir Radeburg II catchment (Saxony/Germany)  
2001

21/6/20 (Item 20 from file: 156)  
3986138 NLM Doc No: 15719990  
Black-bellied whistling duck (*Dendrocygna autumnalis*) brain  
cholinesterase characterization and diagnosis of anticholinesterase  
pesticide exposure in wild populations from Mexico.  
Feb 2005

21/6/21 (Item 21 from file: 41)  
0000276470 IP ACCESSION NO: 6398588  
Black-bellied whistling duck (*Dendrocygna autumnalis*) brain cholinesterase  
characterization and diagnosis of anticholinesterase pesticide exposure in  
wild populations from Mexico  
PUBLICATION DATE: 2005

21/6/22 (Item 22 from file: 266)  
00579953  
IDENTIFYING NO.: 0402726 AGENCY CODE: AGRIC  
BIOLOGICALLY BASED INTEGRATED MANAGEMENT OF AQUATIC RIPARIAN &  
TERRESTRIAL INVASIVE WEEDS

21/6/23 (Item 23 from file: 5)  
16713456 BIOSIS NO.: 200200306967

Between-row mowing+banded herbicide to control annual weeds and reduce  
herbicide use in no-till soybean (*Glycine max*) and corn (*Zea mays*)  
2001

21/6/24 (Item 24 from file: 156)  
4186445 NLM Doc No: 17432331  
Coca and poppy eradication in Colombia: environmental and human health  
assessment of aerially applied \*glyphosate\*.  
2007

21/6/25 (Item 25 from file: 156)  
3909262 NLM Doc No: 15095878  
Chemical and biomonitoring to assess potential acute effects of Vision  
herbicide on native amphibian larvae in forest wetlands.  
Apr 2004

21/6/26 (Item 26 from file: 5)  
0019634137 BIOSIS NO.: 200700293878  
Chronic exposure to sub-lethal concentration of a \*glyphosate\*-based  
herbicide alters hormone profiles and affects reproduction of female *Jundia*  
(*Rhamdia quelen*)  
2007

21/6/27 (Item 27 from file: 41)  
0000284790 IP ACCESSION NO: 6408160  
Cold-climate vegetative buffer zones as pesticide-filters for surface runoff  
BOOK TITLE: Diffuse Pollution and Basin Management  
PUBLICATION DATE: 2005

21/6/28 (Item 28 from file: 10)  
4808049 43988906 Holding Library: AGL  
Combination of a pesticide exposure and a bacterial challenge: In vivo  
effects on immune response of Pacific oyster, *Crassostrea gigas* (Thunberg)  
2007  
URL: <http://dx.doi.org/10.1016/j.aquatox.2007.06.002>

21/6/29 (Item 29 from file: 10)  
4428862 43791928 Holding Library: AGL  
A Comparative Risk Assessment of Genetically Engineered, Mutagenic, and  
Conventional Wheat Production Systems \h [electronic resource]  
2005  
URL: <http://dx.doi.org/10.1007/s11248-005-1411-8>

21/6/30 (Item 30 from file: 41)  
0000283465 IP ACCESSION NO: 6018242  
Comparative Toxicity of \*Glyphosate\*-Based Herbicides: Aqueous and  
\*Sediment\* Porewater Exposures  
PUBLICATION DATE: 2004

21/6/31 (Item 31 from file: 76)  
0001934389 IP ACCESSION NO: 6282264  
A Comparison of Two Factorial Designs, a Complete 3 x 3 Factorial and a  
Central Composite Rotatable Design, for Use in Binomial Response  
Experiments in Aquatic Toxicology  
PUBLICATION DATE: 2004

21/6/32 (Item 32 from file: 41)  
0000283023 IP ACCESSION NO: 5982416  
Concentrations of \*Glyphosate\* and AMPA in \*Sediment\* Following Operational  
Applications of Rodeo to Control Smooth Cordgrass in Willapa Bay, Washington,  
USA  
PUBLICATION DATE: 2003

21/6/33 (Item 33 from file: 5)  
17261508 BIOSIS NO.: 200300220227  
Condensation nucleation light scattering detection with ion chromatography  
for direct determination of \*glyphosate\* and its metabolite in \*water\*.  
2003

21/6/34 (Item 34 from file: 50)  
0007890582 CAB Accession Number: 20001910170  
\*Contamination\* of the 'Afgedamde Maas' with pesticides and fertilizers:  
a survey of pollutants.  
Original Title: Belasting van de 'Afgedamde Maas' door  
bestrijdingsmiddelen en meststoffen: een inventarisatie van  
probleemstoffen.  
Rapport - DLO Staring Centrum, Instituut voor Onderzoek van het  
Landelijk Gebied  
Publication Year: 1999

21/6/35 (Item 35 from file: 245)  
062384  
Contaminant Minimum-Dose Threshold Concentrations for \*Water\* Quality  
Sensors 2005

21/6/36 (Item 36 from file: 50)  
0007646438 CAB Accession Number: 19982304307  
\*Contamination\* in irrigation \*water\* wells by some herbicides in the  
Comunidad Valenciana (Spain) citrus areas.  
Comptes-rendus 6eme symposium Mediterranee EWRS, Montpellier, France,  
13-15 Mai, 1998.  
Publication Year: 1998

21/6/37 (Item 37 from file: 5)  
15650274 BIOSIS NO.: 200000368587  
\*Contamination\* and persistence of endophyte-free ryegrass pastures  
established by spray-drilling, and intensively grazed by dairy cows in  
the Waikato region of New Zealand  
2000

21/6/38 (Item 38 from file: 5)  
0019722894 BIOSIS NO.: 200700382635  
Contribution by urban and agricultural pesticide uses to \*water\*  
\*contamination\* at the scale of the Marne watershed  
2007

21/6/39 (Item 39 from file: 76)  
0001300211 IP ACCESSION NO: 4451086  
Control and spread of alligator weed Alternanthera philoxeroides (Mart.)  
Griseb., in Australia: lessons for other regions  
PUBLICATION DATE: 1998

21/6/40 (Item 40 from file: 10)  
4762045 43835166 Holding Library: AGL  
The Current Status and Environmental Impacts of \*Glyphosate\*-Resistant  
Crops  
2006  
URL: <http://hdl.handle.net/10113/7373>

21/6/41 (Item 41 from file: 156)  
4122526 NLM Doc No: 16899736  
The current status and environmental impacts of \*glyphosate\*-resistant  
crops: a review.  
Sep-Oct 2006

21/6/42 (Item 42 from file: 41)  
0000232344 IP ACCESSION NO: 5560184  
A Critical Assessment of the Potential Wildlife Toxicity of \*Glyphosate\* in  
Ontario with Consideration for Endocrine Disruption  
PUBLICATION DATE: [nd]

21/6/43 (Item 43 from file: 50)  
0008525642 CAB Accession Number: 20033178639  
Criteria for evaluation of the leaching potential of herbicides used in  
Parana.  
Original Title: Critérios para avaliação do potencial de lixiviação dos  
herbicidas comercializados no Estado do Parana.

Publication Year: 2003

21/6/44 (Item 44 from file: 41)  
0000131017 IP ACCESSION NO: 3637806  
Cu(II)-\*glyphosate\* system: A study by anodic stripping voltammetry and the influence on Cu adsorption by montmorillonite  
PUBLICATION DATE: 1994

21/6/45 (Item 45 from file: 5)  
11989701 BIOSIS NO.: 199497010986  
Degradation behavior of the pesticides \*glyphosate\* and diflubenuron in \*water\*  
1993

21/6/46 (Item 46 from file: 50)  
0007695082 CAB Accession Number: 19991903184  
Degradation of selected pesticide active ingredients and commercial formulations in \*water\* by the photo-assisted Fenton reaction.  
Publication Year: 1999

21/6/48 (Item 48 from file: 40)  
00407146 ENVIROLINE NUMBER: 93-03079  
Degradation of 14C-\*Glyphosate\* in Saskatchewan \*Soils\*  
Apr 93

21/6/49 (Item 49 from file: 50)  
0008031115 CAB Accession Number: 20013036493  
The Danish EPA's assessment and approval of \*glyphosate\*.  
Original Title: Miljøstyrelsens vurdering og godkendelse af glyphosat.  
Publication Year: 2001

21/6/50 (Item 50 from file: 40)  
00450457 ENVIROLINE NUMBER: 97-07406  
Direct Surface Analysis of Pesticides on \*Soil\* , Leaves, Grass, and Stainless Steel by Static Secondary Ion Mass Spectrometry  
Feb 97

21/6/51 (Item 51 from file: 50)  
0007309926 CAB Accession Number: 19972300189  
Determination of chlorthal-dimethyl residues in tubers of saffron (Crocus sativus L.) by HPLC.  
Publication Year: 1996

21/6/52 (Item 52 from file: 144)  
14022673 PASCAL No.: 99-0211073  
Bestimmung von Glyphosat und Aminomethylphosphonsäure (AMPA) in Wasser : Methodik und erste Ergebnisse aus Schleswig-Holstein  
(Determination of \*glyphosate\* and aminomethyl-phosphonic acid (AMPA) in \*water\* : Methodology and first results from Schleswig-Holstein)  
1999

21/6/53 (Item 53 from file: 10)  
3940838 23231085 Holding Library: AGL  
Determination of \*glyphosate\* and aminomethylphosphonic acid in crops by capillary gas chromatography with mass-selective detection: collaborative study

2001

21/6/54 (Item 54 from file: 10)  
3492502 20498090 Holding Library: AGL  
Determination of \*glyphosate\* and (aminomethyl)phosphonic acid in \*soil\*,  
plant and animal matrices, and \*water\* by capillary gas chromatography with  
mass-selective detection  
1994 Dec

21/6/55 (Item 55 from file: 10)  
3850189 22067295 Holding Library: AGL  
Determination of \*glyphosate\* residues in plants by precolumn  
derivatization and coupled-column liquid chromatography with fluorescence  
detection  
2000

21/6/57 (Item 57 from file: 5)  
10739215 BIOSIS NO.: 199191122106  
DETERMINATION OF THE HERBICIDE \*GLYPHOSATE\* AND ITS METABOLITE  
AMINOMETHYLPHOSPHONIC ACID BY GAS CHROMATOGRAPHY WITH FLAME PHOTOMETRIC  
DETECTION  
1991

21/6/58 (Item 58 from file: 144)  
14890245 PASCAL No.: 01-0038092  
Development of California Public Health Goals (PHGs) for chemicals in  
drinking \*water\*  
2000

21/6/59 (Item 59 from file: 5)  
15153153 BIOSIS NO.: 199900412813  
Development of an ultrasensitive enzyme immunoassay for the analysis of  
\*glyphosate\* in community \*water\* systems  
1999

21/6/60 (Item 60 from file: 50)  
0008450312 CAB Accession Number: 20033076771  
Development of the analytical method of residual pesticides in sugar  
(Part V). Determination of \*glyphosate\* on the residual pesticide in sugar  
using HPLC with fluorescence detection.  
Publication Year: 2002

21/6/61 (Item 61 from file: 266)  
00580602  
IDENTIFYING NO.: 0403876 AGENCY CODE: AGRIC  
DEVELOPMENT OF \*WATER\* MANAGEMENT TECHNOLOGY AND EFFICIENT CROPPING  
SYSTEMS FOR MID SOUTH

21/6/62 (Item 62 from file: 41)  
0000207816 IP ACCESSION NO: 5125928  
Dynamics of \*glyphosate\* and aminomethylphosphonic acid in a forest \*soil\*  
in Galicia, north-west Spain  
PUBLICATION DATE: 2001



21/6/63 (Item 63 from file: 10)  
 3473279 20480240 Holding Library: AGL  
 Dissipation of \*glyphosate\* and aminomethylphosphonic acid in North  
 American forests  
 1994 Aug

21/6/64 (Item 64 from file: 76)  
 0000890954 IP ACCESSION NO: 9308651  
 Dissipation of \*Glyphosate\* and Aminomethylphosphonic Acid in \*Water\* and  
 \*Sediments\* of Boreal Forest Ponds  
 PUBLICATION DATE: 1993

21/6/65 (Item 65 from file: 266)  
 00565351  
 IDENTIFYING NO.: 0196167 AGENCY CODE: AGRIC  
 Ecotoxicological Effects of Contaminants in Aquatic Ecosystems

21/6/66 (Item 66 from file: 40)  
 00256355 ENVIROLINE NUMBER: 94-01653  
 Ecotoxic Effects of Four Herbicides (\*Glyphosate\*, Alachlor, Chlortoluron  
 and Isoproturon) on the Algae *Chlorella pyrenoidosa* Chick.  
 May 11-15, 93

21/6/67 (Item 67 from file: 156)  
 4029382 NLM Doc No: 16041711  
 Efficacy and fate of \*glyphosate\* on Swedish railway embankments.  
 Sep 2005

21/6/68 (Item 68 from file: 203)  
 01540489  
 Effect of cover crops on weed infestation in maize (Wirkung von  
 Bodendeckern auf die Verunkrautung in Mais)  
 1990

21/6/69 (Item 69 from file: 40)  
 00549458 ENVIROLINE NUMBER: 98-08240  
 Effects of Edifenphos and \*Glyphosate\* on the Immune Response and Protein  
 Biosynthesis of Bolti Fish (*Tilapia nilotica*)  
 1998

21/6/70 (Item 70 from file: 10)  
 4765054 43961216 Holding Library: AGL  
 Effects of dredging an agricultural drainage ditch on \*water\* column  
 herbicide concentration, as predicted by fluvium techniques  
 2007  
 URL: <http://hdl.handle.net/10113/7540>

21/6/71 (Item 71 from file: 5)  
 14426245 BIOSIS NO.: 199800220492  
 Effect of flow rate on the adsorption and desorption of \*glyphosate\*,  
 simazine and atrazine in columns of sandy \*soils\*  
 1998

21/6/72 (Item 72 from file: 41)  
 0000256512 IP ACCESSION NO: 6535626  
 Influence of phosphate on the mobility of pesticide \*glyphosate\* in

different \*soils\*

PUBLICATION DATE: 2005

21/6/73 (Item 73 from file: 156)

4123894 NLM Doc No: 16174533

Effect of \*glyphosate\* herbicide on acetylcholinesterase activity and metabolic and hematological parameters in piava (*Leporinus obtusidens*).

Oct 2006

21/6/74 (Item 74 from file: 5)

14244856 BIOSIS NO.: 199800039103

Effect of \*glyphosate\* on the development of *Pseudosuccinea columella* snails

1997

21/6/75 (Item 75 from file: 156)

087578 NLM Doc No: NTIS/02971767 Sec. Source ID: NTIS/PB93121309

Effect of \*Glyphosate\* and Nitrpyrin on Selected Bacterial Populations in Continuous-Flow Culture.

1992

21/6/76 (Item 76 from file: 203)

01913428

Effects of agricultural pesticides on freshwater plankton communities in enclosures

1994

\*Contamination\* of pesticides from agricultural and industrial areas to \*soil\* and \*water\*

21/6/77 (Item 77 from file: 40)

00384147 ENVIROLINE NUMBER: 91-03252

Effects of the Herbicide \*Glyphosate\* on Nitrification in Four \*Soils\* from Atlantic Canada

Jun 90

21/6/78 (Item 78 from file: 40)

00411820 ENVIROLINE NUMBER: 93-07764

Influence of Herbicides on Transformations of Urea Nitrogen in \*Soil\*

1993

21/6/79 (Item 79 from file: 76)

0001878085 IP ACCESSION NO: 7017766

Effects of the Herbicides Roundup and Avans on *Euglena gracilis*

PUBLICATION DATE: 2006

21/6/80 (Item 80 from file: 50)

0009086731 CAB Accession Number: 20063129307

Effect of heavy metals and herbicides on immune capacities in Pacific oyster, *Crassostrea gigas*.

Publication Year: 2006

21/6/81 (Item 81 from file: 5)

10835626 BIOSIS NO.: 199192081397

EFFECT OF ALFALFA MEDICAGO-SATIVA ROOTS ON MOVEMENT OF ATRAZINE AND ALACHLOR THROUGH \*SOIL\*

1991

21/6/82 (Item 82 from file: 5)

14172459 BIOSIS NO.: 199799806519  
 Influence of natural organic matter on the sorption of biocides onto  
 goethite, II. \*Glyphosate\*  
 1997

21/6/83 (Item 83 from file: 10)  
 4877763 44045213 Holding Library: AGL  
 Effects of pesticides on community composition and activity of \*sediment\*  
 microbes - responses at various levels of microbial community organization  
 2008  
 URL: <http://dx.doi.org/10.1016/j.envpol.2007.07.003>

21/6/84 (Item 84 from file: 203)  
 01913429  
 Effects of pesticides on different zooplankton taxa in mesocosm  
 experiments  
 1994  
 \*Contamination\* of pesticides from agricultural and industrial areas to  
 \*soil\* and \*water\*

21/6/85 (Item 85 from file: 50)  
 0006767860 CAB Accession Number: 19932339123  
 The effect of reduced cultivation, ploughing and herbicides on the  
 occurrence of volunteer cereal grains in winter wheat and barley.  
 Publication Year: 1993

21/6/86 (Item 86 from file: 41)  
 0000247993 IP ACCESSION NO: 6177718  
 Effect of Root Death and Decay on Dissipation of Polycyclic Aromatic  
 Hydrocarbons in the Rhizosphere of Yellow Sweet Clover and Tall Fescue  
 PUBLICATION DATE: 2005

21/6/87 (Item 87 from file: 5)  
 18111717 BIOSIS NO.: 200500018782  
 Effects of thiophanate-methyl and \*glyphosate\* on asexual and sexual  
 reproduction in the rotifer *Brachionus calyciflorus* Pallas  
 2004

21/6/88 (Item 88 from file: 50)  
 0008273313 CAB Accession Number: 20013105423  
 Effect of \*soil\* \*contamination\* of \*glyphosate\* solution on *Cyperus*  
*esculentus* L.  
 Original Title: Efecto de la contaminacion con suelo de la solucion  
 herbicida de glifosato en el control de *Cyperus esculentus* L.  
 Publication Year: 2001

21/6/90 (Item 90 from file: 50)  
 0008575008 CAB Accession Number: 20043013531  
 The effect of spray particle size and distribution on drift and efficacy  
 of herbicides.  
 Publication Year: 2004

21/6/91 (Item 91 from file: 10)  
 3822916 22044822 Holding Library: AGL  
 Effects of 2,4-D, \*glyphosate\* and paraquat on growth, photosynthesis and  
 chlorophyll-a synthesis of *Scenedesmus quadricauda* Berb 614  
 2000

21/6/92 (Item 92 from file: 156)  
 3969653 NLM Doc No: 15660608  
 Elicitation of expert judgments of uncertainty in the risk assessment of  
 herbicide-tolerant oilseed crops.  
 Dec 2004

21/6/93 (Item 93 from file: 41)  
 0000179563 IP ACCESSION NO: 4365091  
 Environmental degradation of polyacrylamides. II. Effects of environmental  
 (outdoor) exposure  
 PUBLICATION DATE: 1997

21/6/94 (Item 94 from file: 156)  
 4029385 NLM Doc No: 16041722  
 Environmental fate of herbicides trifluralin, metazachlor, metamitron and  
 sulcotrione compared with that of \*glyphosate\*, a substitute broad spectrum  
 herbicide for different \*glyphosate\*-resistant crops.  
 Sep 2005

21/6/95 (Item 95 from file: 266)  
 00566742  
 IDENTIFYING NO.: 0197733 AGENCY CODE: AGRIC  
 Environmental Impacts of Forest Herbicides

21/6/96 (Item 96 from file: 50)  
 0009336000 CAB Accession Number: 20073199982  
 Environmental impacts of transgenic herbicide-resistant crops.  
 Publication Year: 2007

21/6/97 (Item 97 from file: 50)  
 0009297831 CAB Accession Number: 20073132555  
 Enzymatic activity of \*soil\* contaminated with triazine herbicides.  
 Publication Year: 2007

21/6/98 (Item 98 from file: 144)  
 15180463 PASCAL No.: 01-0345076  
 ETUDE DES EFFETS D'APPLICATIONS REPETEES DE CUIVRE SUR L'ACTIVITE ET LA  
 DIVERSITE DE LA MICROFLORE DES SOLS  
 (EFFECTS OF REPEATED APPLICATIONS OF COPPER ON ACTIVITY AND DIVERSITY OF  
 \*SOIL\* MICROFLORA) 2000-04; 2000

21/6/99 (Item 99 from file: 266)  
 00571835  
 IDENTIFYING NO.: 0204294 AGENCY CODE: AGRIC  
 Evaluating the physical and biological availability of pesticides and  
 pharmaceuticals in agricultural contexts

21/6/100 (Item 100 from file: 5)  
 12254744 BIOSIS NO.: 199497276029  
 Evaluation of the mobility of C-14-labelled pesticides in \*soils\* by thin  
 layer chromatography using a linear analyser  
 1994

21/6/101 (Item 101 from file: 41)  
 0000271841 IP ACCESSION NO: 5401917  
 Evolution of the pesticide \*contamination\* of rivers in the Ile-de-France

ORIGINAL TITLE: Evolution de la \*contamination\* des cours d'eau par les  
pesticides en Ile-de-France  
PUBLICATION DATE: 2002

21/6/103 (Item 103 from file: 156)  
135511 NLM Doc No: NTIS/02990874 Sec. Source ID: NTIS/PB96199559  
Evaluation and Selection of Analytical Methods for Lawn-Applied  
Pesticides.  
1996

21/6/104 (Item 104 from file: 5)  
17702823 BIOSIS NO.: 200400083580  
Estimation of \*soil\* phosphate adsorption capacity by means of a pedotransfer  
function.  
2004

21/6/105 (Item 105 from file: 156)  
4247005 NLM Doc No: 18186337  
Facilitated transport of diuron and \*glyphosate\* in high copper vineyard  
\*soils\*.  
Dec 1 2007

21/6/106 (Item 106 from file: 50)  
0009519762 CAB Accession Number: 20083103461  
Fate and behavior of chlorpyrifos and \*glyphosate\* at a field level in  
Apalta catchment I. Experimental phase.  
Book Title: Environmental fate and ecological effects of pesticides  
Publication Year: 2007

21/6/107 (Item 107 from file: 50)  
0008038106 CAB Accession Number: 20013047631  
Fate of foodborne bacterial pathogens in pesticide products.  
Publication Year: 2001

21/6/108 (Item 108 from file: 76)  
0000659569 IP ACCESSION NO: 9009606  
Fate of \*Glyphosate\* in a Canadian Forest Watershed: 1. Aquatic Residues  
and Off-Target Deposit Assessment  
PUBLICATION DATE: 1990

21/6/109 (Item 109 from file: 76)  
0000659568 IP ACCESSION NO: 9009607  
Fate of \*Glyphosate\* in a Canadian Forest Watershed: 2. Persistence in  
Foliage and \*Soils\*  
PUBLICATION DATE: 1990

21/6/110 (Item 110 from file: 5)  
15002412 BIOSIS NO.: 199900262072  
Fate of agrochemical residues, associated with malt and hops, during brewing  
1999

21/6/111 (Item 111 from file: 266)  
00569638  
IDENTIFYING NO.: 0201364 AGENCY CODE: AGRIC  
Fate and Impact of Gene Migration from Transgenic Creeping Bentgrass  
Production Fields

21/6/112 (Item 112 from file: 50)  
0007874396 CAB Accession Number: 20002302163  
Features of using herbicides on hillsides with radiation technogenic  
\*contamination\*.  
Publication Year: 1998

21/6/114 (Item 114 from file: 50)  
0008773324 CAB Accession Number: 20053018188  
\*Glyphosate\*.  
Publication Year: 2004

21/6/115 (Item 115 from file: 41)  
0000254603 IP ACCESSION NO: 6445337  
\*Glyphosate\* degradation as a \*soil\* health indicator for heavy metal  
polluted \*soils\*  
PUBLICATION DATE: 2005

21/6/116 (Item 116 from file: 156)  
4046638 NLM Doc No: 15951002  
\*Glyphosate\* adsorption in \*soils\* compared to herbicides replaced with  
the introduction of \*glyphosate\* resistant crops.  
Nov 2005

21/6/117 (Item 117 from file: 156)  
4194300 NLM Doc No: 17411011  
\*Glyphosate\* and AMPA analysis in sewage sludge by LC-ESI-MS/MS after  
FMOC derivatization on strong anion-exchange resin as solid support.  
May 15 2007

21/6/118 (Item 118 from file: 50)  
0007602637 CAB Accession Number: 19982303244  
\*Glyphosate\* and AMPA in \*soil\*.  
Original Title: Glyphosat og AMPA i jord.  
Publication Year: 1998

21/6/119 (Item 119 from file: 144)  
13306543 PASCAL No.: 98-0030824  
Glyphosat in der Ruhr Analytik und Ergebnisse  
(\*Glyphosate\* in the River Ruhr : Analytical methods and results)  
1997

21/6/120 (Item 120 from file: 50)  
0007654813 CAB Accession Number: 19982304440  
\*Glyphosate\* (roundup).  
Publication Year: 1998

21/6/121 (Item 121 from file: 41)  
0000284387 IP ACCESSION NO: 6237719  
\*Glyphosate\*, other herbicides, and transformation products in Midwestern  
streams, 2002  
PUBLICATION DATE: 2005

21/6/123 (Item 123 from file: 10)  
4734257 43973929 Holding Library: AGL  
\*Glyphosate\* translocation from plants to \*soil\* - does this constitute a  
significant proportion of residues in \*soil\*  
2007

URL: <http://dx.doi.org/10.1007/s11104-007-9387-1>

- 21/6/124 (Item 124 from file: 50)  
0009420995 CAB Accession Number: 20073254671  
\*Glyphosate\*: worldwide situation and consequences for Switzerland.  
Original Title: Le \*glyphosate\* : bilan de la situation mondiale et  
analyse de quelques consequences malherbologiques pour la Suisse.  
Publication Year: 2007
- 21/6/125 (Item 125 from file: 5)  
10777895 BIOSIS NO.: 199192023666  
\*GLYPHOSATE\* SKIN BINDING ABSORPTION RESIDUAL TISSUE DISTRIBUTION AND SKIN  
DECONTAMINATION  
1991
- 21/6/126 (Item 126 from file: 40)  
00454948 ENVIROLINE NUMBER: 97-12226  
The Use of \*Glyphosate\* as the Sole Source of Phosphorus or Carbon for the  
Selection of \*Soil\* -Borne Fungal Strains Capable to Degrade This  
Herbicide  
Jun 97
- 21/6/127 (Item 127 from file: 50)  
0007188280 CAB Accession Number: 19962300674  
\*Glyphosate\*, part 2: human exposure and ecological effects.  
Publication Year: 1995
- 21/6/129 (Item 129 from file: 40)  
00401824 ENVIROLINE NUMBER: 92-12357  
Genotoxic Effect Induced by Herbicides Atrazine \*Glyphosate\* in Plants of  
Vicia faba Grown in Different \*Soils\*  
Aug 12, 92
- 21/6/131 (Item 131 from file: 50)  
0008262277 CAB Accession Number: 20023068082  
Grass crops as weeds.  
Original Title: Kulturgraesser som ukrudt.  
Publication Year: 2002
- 21/6/132 (Item 132 from file: 41)  
0000241958 IP ACCESSION NO: 5955581  
Does grassland farming pose a threat to \*groundwater\*? A comparative study  
of leaching from pasture and cut sward  
ORIGINAL TITLE: Kuormittaako nurmiviljely pohjavettae? Vertailussa  
saeiloerehunurmi ja laidun  
PUBLICATION DATE: 2003
- 21/6/133 (Item 133 from file: 144)  
17570367 PASCAL No.: 06-0158103  
Gestion des \*sediments\* de l'assainissement pluvial : analyse des risques  
sanitaires lies aux hydrocarbures aromatiques polycycliques et aux  
pesticides. Application aux \*sediments\* des bassins de retention/infiltration  
2005; 2005
- 21/6/134 (Item 134 from file: 76)  
0002004298 IP ACCESSION NO: 7588470

Highway stormwater detention ponds in the Mediterranean region: Functioning and Biodiversity Evaluation of \*water\* quality and its impact on aquatic animal communities.

ORIGINAL TITLE: Les bassins d'eau pluviale autoroutiers en region  
Mediterraneenne: Fonctionnement et Biodiversite Evaluation de l'impact de  
la pollution routiere sur les communautes animales aquatiques  
PUBLICATION DATE: 2005

21/6/135 (Item 135 from file: 156)  
051526 NLM Doc No: NTIS/02930158 Sec. Source ID: NTIS/PB2004107408  
Herbicides and their Transformation Products in Source-\*Water\* Aquifers  
Tapped by Public-Supply Wells in Illinois, 2001-02.  
2003

21/6/136 (Item 136 from file: 144)  
16308784 PASCAL No.: 03-0473017  
Behandlung versiegelter Flaechen - moegliche Quelle fuer die Belastung  
von Oberflaechengewaessern mit Pflanzenschutzmitteln  
((Herbicide treatment of urban areas: a possible source of surface  
\*water\* \*contamination\*) )  
2002

21/6/137 (Item 137 from file: 266)  
00555433  
IDENTIFYING NO.: 0179283 AGENCY CODE: AGRIC  
Herbicides: Evaluations in Ornamental Plant Production and Sorption to  
\*Soils\* and Potting Media

21/6/138 (Item 138 from file: 5)  
14984208 BIOSIS NO.: 199900243868  
Hydrotalcites and organo-hydrotalcites as sorbents for removing pesticides  
from \*water\*  
1999

21/6/139 (Item 139 from file: 40)  
00271764 ENVIROLINE NUMBER: 95-00267  
Hydrogen-Bonding Interactions Between the Herbicide \*Glyphosate\* and  
\*Water\*-Soluble Humic Substances  
Nov 94

21/6/140 (Item 140 from file: 5)  
10523939 BIOSIS NO.: 199141036565  
IMPACT OF AN ORGANOPHOSPHATE HERBICIDE \*GLYPHOSATE\* ON PERIPHYTON  
COMMUNITIES DEVELOPED IN EXPERIMENTAL STREAMS  
1991

21/6/141 (Item 141 from file: 50)  
0007439093 CAB Accession Number: 19971911804  
Improvement of floodplain and swampy farmlands polluted by  
radionuclides.  
Publication Year: 1996

21/6/142 (Item 142 from file: 5)  
12917671 BIOSIS NO.: 199598385504  
Improved method for the determination of \*glyphosate\* in \*water\*  
1995



21/6/143 (Item 143 from file: 266)  
00581669  
IDENTIFYING NO.: 0405209 AGENCY CODE: AGRIC  
IMPROVING SURFACE \*WATER\* QUALITY WITH ALTERNATIVE CROPPING SYSTEMS AT  
FIELD AND WATERSHED SCALES

21/6/144 (Item 144 from file: 266)  
00559286  
IDENTIFYING NO.: 0187864 AGENCY CODE: AGRIC  
Integrated management of winter annual grass weeds in eastern Washington  
dryland crop systems

21/6/145 (Item 145 from file: 50)  
0008999163 CAB Accession Number: 20063034647  
Interactions of calcium ions with weakly acidic active ingredients slow  
cuticular penetration: a case study with \*glyphosate\*.  
Publication Year: 2004

21/6/146 (Item 146 from file: 10)  
4057470 23319018 Holding Library: AGL  
Investigation of the herbicide \*glyphosate\* and the plant growth  
regulators chlormequat and mepiquat in cereals produced in Denmark  
2001

21/6/147 (Item 147 from file: 266)  
00581807  
IDENTIFYING NO.: 0405357 AGENCY CODE: AGRIC  
IRRIGATION SYSTEMS AND PRECISION MGMT STRATEGIES TO CONSERVE \*WATER\* AND  
PROTECT \*WATER\* QUALITY

21/6/148 (Item 148 from file: 10)  
4311076 43682641 Holding Library: AGL  
Leaching of \*glyphosate\* and amino-methylphosphonic acid from Danish  
agricultural field sites  
2005

21/6/150 (Item 150 from file: 10)  
4380835 43767826 Holding Library: AGL  
Leaching of \*glyphosate\* and AMPA under two \*soil\* management practices  
in Burgundy vineyards (Vosne-Romanee, 21-France)  
2005

21/6/151 (Item 151 from file: 156)  
3704936 NLM Doc No: 11767144  
Liquid chromatography/electrospray ionization/isotopic dilution mass  
spectrometry analysis of n-(phosphonomethyl) glycine and mass spectrometry  
analysis of aminomethyl phosphonic acid in environmental \*water\* and  
vegetation matrixes.  
Nov-Dec 2001

21/6/152 (Item 152 from file: 10)  
4076684 23339900 Holding Library: AGL  
Long-term fate of \*glyphosate\* associated with repeated Rodeo  
applications to control smooth cordgrass (*Spartina alterniflora*) in Willapa  
Bay, Washington  
2001

21/6/153 (Item 153 from file: 10)  
 3580847 20569385 Holding Library: AGL  
 Levels of the herbicide \*glyphosate\* in well \*water\*  
 1996

21/6/154 (Item 154 from file: 10)  
 4830223 43762243 Holding Library: AGL  
 Mobility and leaching of \*glyphosate\*: a review  
 2005  
 URL: <http://www.interscience.wiley.com/jpages/1526-498X/>

21/6/155 (Item 155 from file: 41)  
 0000130126 IP ACCESSION NO: 3626776  
 Mobility of pesticides in \*soils\*. Influence of \*soil\* properties and  
 pesticide structure  
 PUBLICATION DATE: 1994

21/6/156 (Item 156 from file: 10)  
 3917726 23212368 Holding Library: AGL  
 Mobility of \*soil\* nitrogen and microbial responses following the sudden  
 death of established turf  
 2000

21/6/158 (Item 158 from file: 156)  
 3906684 NLM Doc No: 15074680  
 Modeling the kinetics of the competitive adsorption and desorption of  
 \*glyphosate\* and phosphate on goethite and gibbsite and in \*soils\*.  
 Mar 15 2004

21/6/159 (Item 159 from file: 156)  
 4106835 NLM Doc No: 16532367  
 Molecular identification and expression of differentially regulated genes  
 of the European flounder, *Platichthys flesus*, submitted to pesticide  
 exposure.  
 May-Jun 2006

21/6/161 (Item 161 from file: 266)  
 00581493  
 IDENTIFYING NO.: 0405012 AGENCY CODE: AGRIC  
 MANAGEMENT PRACTICES TO REDUCE MOVEMENT OF AGRO-CHEMICALS TO SURFACE AND  
 GROUND WATERS IN NC U.S.

21/6/162 (Item 162 from file: 50)  
 0007288434 CAB Accession Number: 19962302846  
 Managing riparian weeds.  
 Publication Year: 1995

21/6/163 (Item 163 from file: 10)  
 4114916 43627974 Holding Library: AGL  
 Mineralization of \*glyphosate\* in compost-amended \*soil\* under controlled  
 conditions  
 2004

21/6/164 (Item 164 from file: 50)  
 0007481024 CAB Accession Number: 19982300753  
 Mineralization of [ SUP 14 C]\*glyphosate\* and its plant-associated  
 residues in arable \*soils\* originating from different farming systems.

Publication Year: 1997

21/6/165 (Item 165 from file: 266)  
00586447

IDENTIFYING NO.: 0410786 AGENCY CODE: AGRIC  
MAINTAINING \*SOIL\* RESOURCES FOR EFFECTIVE CONSERVATION AND HERBICIDE  
MANAGEMENT IN MID-SOUTH CROP PRODUCTION

21/6/166 (Item 166 from file: 76)  
0000642511 IP ACCESSION NO: 2291643  
Method for the determination of residues of the herbicide \*glyphosate\* and  
its principal metabolite, aminomethylphosphonic acid, in plant materials by  
nitrogen-selective gas chromatography.  
PUBLICATION DATE: 1990

21/6/167 (Item 167 from file: 144)  
17616792 PASCAL No.: 06-0206716  
Matrix solid-phase dispersion extraction and determination by  
high-performance liquid chromatography with fluorescence detection of  
residues of \*glyphosate\* and aminomethylphosphonic acid in tomato fruit  
2005

21/6/168 (Item 168 from file: 10)  
4875387 44014513 Holding Library: AGL  
Mycotoxin occurrence and *Aspergillus flavus* \*soil\* propagules in a corn  
and cotton \*glyphosate\*-resistant cropping systems  
2007  
URL: <http://hdl.handle.net/10113/14128>

21/6/169 (Item 169 from file: 50)  
0007090253 CAB Accession Number: 19952310514  
Misguided herbicides?  
Publication Year: 1994

21/6/170 (Item 170 from file: 266)  
00556809

IDENTIFYING NO.: 0183498 AGENCY CODE: AGRIC  
Measuring Chronic Exposure to Biotoxins and Chemicals

21/6/171 (Item 171 from file: 10)  
4791979 44013354 Holding Library: AGL  
Measurement and modelling of \*glyphosate\* fate compared with that of  
herbicides replaced as a result of the introduction of \*glyphosate\*  
-resistant oilseed rape  
2008  
URL: <http://dx.doi.org/10.1002/ps.1519>

21/6/172 (Item 172 from file: 156)  
3706586 NLM Doc No: 11775355  
[Analysis of \*glyphosate\* and its metabolite, aminomethylphosphonic acid,  
in agricultural products by HPLC]  
Oct 2001

21/6/173 (Item 173 from file: 245)  
058269  
Non-Point Pollution of the Paris Metropolitan Area Rivers by Pesticides:

21/6/174 (Item 174 from file: 10)  
4667266 43667148 Holding Library: AGL  
N and P leaching and microbial \*contamination\* from intensively managed  
pasture and cut sward on sandy \*soil\* in Finland  
2004

21/6/175 (Item 175 from file: 266)  
00583844  
IDENTIFYING NO.: 0407750 AGENCY CODE: AGRIC  
NARCOTIC CROP CONTROL STRATEGIES

21/6/176 (Item 176 from file: 41)  
0000256437 IP ACCESSION NO: 6520431  
Novel AroA with High Tolerance to \*Glyphosate\*, Encoded by a Gene of  
Pseudomonas putida 4G-1 Isolated from an Extremely Polluted Environment in  
China  
PUBLICATION DATE: 2005

21/6/177 (Item 177 from file: 5)  
18765565 BIOSIS NO.: 200600110960  
Occurrence of pesticides in surface \*water\* originating from agricultural  
areas  
ORIGINAL LANGUAGE TITLE: Auftreten von pflanzenschutzmitteln in  
oberflachengewassern mit landwirtschaftlich gepragten einzugsgebieten  
2002

21/6/178 (Item 178 from file: 5)  
0019504572 BIOSIS NO.: 200700164313  
On-line \*water\* quality parameters as indicators of distribution system  
\*contamination\*  
2007

21/6/179 (Item 179 from file: 50)  
0008303067 CAB Accession Number: 20023125349  
Optimization and performance evaluation of the analysis of \*glyphosate\*  
and AMPA in \*water\* by HPLC with fluorescence detection.  
Publication Year: 2002

21/6/180 (Item 180 from file: 50)  
0008736772 CAB Accession Number: 20043192199  
The use of organic wastes for \*soil\*-covering of vineyards.  
Publication Year: 2004

21/6/181 (Item 181 from file: 50)  
0009070643 CAB Accession Number: 20063118595  
Pedotransfer function for estimation of phosphate adsorption capacity on  
a wide range of \*soils\*.  
Book Title: \*Soil\* abiotic and biotic interactions and the impact on  
the ecosystem and human welfare  
Publication Year: 2005

21/6/182 (Item 182 from file: 50)  
0008514625 CAB Accession Number: 20033162509  
Proceedings of the Third International Conference on Fungi: Hopes and  
Challenges III - \*Soil\* Microbiology, Cairo, Egypt, 30 October - I

November, 2002.

Publication Year: 2003

- 21/6/183 (Item 183 from file: 5)  
10729576 BIOSIS NO.: 199191112467  
PRECONCENTRATION OF HYDROPHILIC AND HYDROPHOBIC PESTICIDES FROM AQUEOUS  
SOLUTIONS AND EXTRACTION OF RESIDUES USING THE POLYMERIC SORBENT WOFATIT  
Y 77 II. EXTENSION OF THE STUDIES TO HYDROPHOBIC PESTICIDES AQUEOUS  
EXTRACTION OF PESTICIDES FROM PLANT MATERIAL AND \*SOIL\*  
1991
- 21/6/184 (Item 184 from file: 50)  
0008179168 CAB Accession Number: 20023016228  
Predicted impact of transgenic, herbicide-tolerant corn on drinking  
\*water\* quality in vulnerable watersheds of the mid-western USA.  
Publication Year: 2002
- 21/6/185 (Item 185 from file: 50)  
0007293118 CAB Accession Number: 19962302930  
The progress and development of herbicides for weed management in the  
tropics.  
Publication Year: 1996
- 21/6/186 (Item 186 from file: 245)  
061374  
Parameters for Rapid Contaminant Detection in a \*Water\* Distribution  
System 2005
- 21/6/187 (Item 187 from file: 50)  
0009482834 CAB Accession Number: 20083046039  
The potential of \*contamination\* of \*groundwater\* by pesticides in  
Dourados river watershed, MS - Brazil.  
Original Title: Potencial de contaminacao da agua subterranea por  
pesticidas na Bacia do Rio Dourados, MS.  
Publication Year: 2007
- 21/6/188 (Item 188 from file: 144)  
15337493 PASCAL No.: 02-0024181  
Potential of microcolumn liquid chromatography and capillary  
electrophoresis with flame photometric detection for determination of polar  
phosphorus-containing pesticides  
2001
- 21/6/189 (Item 189 from file: 50)  
0006865552 CAB Accession Number: 19942306110  
The Poa species: problems and management in Danish arable fields.  
Brighton crop protection conference, weeds. Proceedings of an  
international conference, Brighton, UK, 22-25 November 1993.  
Publication Year: 1993
- 21/6/190 (Item 190 from file: 156)  
4021689 NLM Doc No: 16020099  
Pesticide \*contamination\* inside farm and nonfarm homes.  
Jul 2005
- 21/6/191 (Item 191 from file: 266)  
00559251

IDENTIFYING NO.: 0187809    AGENCY CODE: AGRIC  
PESTICIDE DEGRADATION BY MICROBES UNDER MODIFIED \*SOIL\* CONDITONS

21/6/192        (Item 192 from file: 40)  
00613077    ENVIROLINE NUMBER: 02-01376  
Pesticide Influence on \*Soil\* Enzymatic Activities  
Nov 01

21/6/193        (Item 193 from file: 5)  
17728323    BIOSIS NO.: 200400099080  
Pesticide use among farmers in the Amazon basin of Ecuador.  
2003

21/6/194        (Item 194 from file: 5)  
0019839745    BIOSIS NO.: 200700499486  
Pesticides in the Rhone river delta (France): Basic data for a field-based  
exposure assessment  
2007

21/6/195        (Item 195 from file: 50)  
0008829851    CAB Accession Number: 20053072254  
Pesticides applied in eucalyptus and coconut palm plantations:  
preliminary analysis.  
Original Title: Risco de contaminacao de aguas por pesticidas aplicados  
em plantacoes de eucaliptos e coqueiros: analise preliminar.  
Publication Year: 2001

21/6/196        (Item 196 from file: 156)  
3793706    NLM Doc No: 12549246  
Pesticide use and practices in an Iowa farm family pesticide exposure  
study.  
Nov 2002

21/6/197        (Item 197 from file: 50)  
0008182786    CAB Accession Number: 20023008378  
Postcolumn fluorogenic labeling for the HPLC analysis of \*glyphosate\*  
and AMPA in matrix oil.  
Book Title: Cutting-edge technologies for sustained competitiveness:  
Proceedings of the 2001 PIPOC International Palm Oil Congress, Chemistry  
and Technology Conference, Kuala Lumpur, Malaysia, 20-22 August 2001  
Publication Year: 2001

21/6/198        (Item 198 from file: 266)  
00553082  
IDENTIFYING NO.: 0138596    AGENCY CODE: AGRIC  
REDUCING THE POTENTIAL FOR ENVIRONMENTAL \*CONTAMINATION\* BY PESTICIDES  
AND OTHER ORGANIC CHEMICALS

21/6/199        (Item 199 from file: 50)  
0006800727    CAB Accession Number: 19942300979  
Red rice ( Oryza sativa ): competition studies for management decisions.  
Publication Year: 1993

21/6/200        (Item 200 from file: 144)  
14014409    PASCAL No.: 99-0202198  
Rapid determination of \*glyphosate\* in cereal samples by means of

pre-column derivatisation with 9-fluorenylmethyl chloroformate and  
coupled-column liquid chromatography with fluorescence detection  
1999

21/6/201 (Item 201 from file: 266)  
00580396  
IDENTIFYING NO.: 0403552 AGENCY CODE: AGRIC  
REPLACEMENT OF HERBICIDES AND METHYL BROMIDE BY MICROBIOLOGICAL CONTROL  
OF WEEDS

21/6/202 (Item 202 from file: 5)  
10823495 BIOSIS NO.: 199192069266  
RATE CONSTANTS FOR DIRECT REACTIONS OF OZONE WITH SEVERAL DRINKING \*WATER\*  
CONTAMINANTS  
1991

21/6/203 (Item 203 from file: 156)  
4202286 NLM Doc No: 17562462  
Review of potential environmental impacts of transgenic \*glyphosate\*  
-resistant soybean in Brazil.  
Jun-Jul 2007

21/6/204 (Item 204 from file: 50)  
0007770016 CAB Accession Number: 19990707697  
Ryegrass \*contamination\* of endophyte-free dairy pastures after  
spray-drilling in autumn.  
Publication Year: 1997, publ. 1998

21/6/205 (Item 205 from file: 41)  
0000146309 IP ACCESSION NO: 3842414  
Residue detections in \*soil\* and shallow \*groundwater\* after long-term  
herbicide applications in southern Alberta  
PUBLICATION DATE: 1995

21/6/206 (Item 206 from file: 144)  
13693513 PASCAL No.: 98-0447752  
Risque de \*contamination\* des eaux souterraines par l'herbicide  
glyphosate : situation en 1997  
(Risk of \*contamination\* of groundwaters by the herbicide \*glyphosate\* :  
situation in 1997)  
1998

21/6/207 (Item 207 from file: 41)  
0000165998 IP ACCESSION NO: 4221706  
Solubility products of six metal-\*glyphosate\* complexes in \*water\* and  
forestry \*soils\*, and their influence on \*glyphosate\* toxicity to plants  
PUBLICATION DATE: 1997

21/6/208 (Item 208 from file: 50)  
0007733213 CAB Accession Number: 19992301379  
Simultaneous determination of residual phosphorus-containing amino acid  
herbicides in agricultural products by HPLC.  
Publication Year: 1999

21/6/209 (Item 209 from file: 76)  
0000865915 IP ACCESSION NO: 3002901  
Simple determination of \*glyphosate\* and its metabolite

(aminomethylphosphonic acid) in fruits and vegetables by high performance liquid chromatography with fluorescence detection.

PUBLICATION DATE: 1992

21/6/210 (Item 210 from file: 10)  
3502465 20508316 Holding Library: AGL  
Simple and rapid determination of the herbicides \*glyphosate\* and glufosinate in river \*water\*, \*soil\* and carrot samples by gas chromatography with flame photometric detection  
1996 Mar01

21/6/211 (Item 211 from file: 5)  
18478035 BIOSIS NO.: 200510172535  
Specific contributions of decaying alfalfa roots to nitrate leaching in a Kalamazoo loam \*soil\*  
2005

21/6/212 (Item 212 from file: 41)  
0000169421 IP ACCESSION NO: 4290693  
Spatial analysis of herbicide decay rates in Louisiana  
PUBLICATION DATE: 1997

21/6/213 (Item 213 from file: 40)  
00555411 ENVIROLINE NUMBER: 98-14200  
Sorption of \*Glyphosate\* and Cu(II) on a Natural Fulvic Acid Complex: Mutual Influence  
Sep 98

21/6/214 (Item 214 from file: 50)  
0006715474 CAB Accession Number: 19932333696  
Survey of farm wells for pesticides, Ontario, Canada, 1986 and 1987.  
Publication Year: 1990

21/6/216 (Item 216 from file: 245)  
039761 SM190142  
Standard Methods for the Examination of \*Water\* and Wastewater, 19th Edition: Section 6651 \*Glyphosate\* Herbicide 19th Edition, 1995

21/6/217 (Item 217 from file: 266)  
00580993  
IDENTIFYING NO.: 0404418 AGENCY CODE: AGRIC  
SUSTAINABILITY OF \*SOIL\* RESOURCES IN WEED AND CROP MANAGEMENT SYSTEMS IN MID SOUTH AGRICULTURE

21/6/218 (Item 218 from file: 144)  
16975920 PASCAL No.: 05-0036049  
ToF-SIMS as an alternative tool for the qualitative and quantitative analysis of polar herbicides  
Secondary ion mass spectrometry SIMS XIV: Proceedings of the Fourteenth International Conference on Secondary Ion Mass Spectrometry and Related Topics, San Diego, California, USA, September 14-19, 2003  
2004

21/6/219 (Item 219 from file: 5)  
14469051 BIOSIS NO.: 199800263298  
Time effects of three contaminants on the durability and permeability of a solidified sand



1998

21/6/220 (Item 220 from file: 50)  
0009194289 CAB Accession Number: 20073037476  
Trace element mobilization in \*soils\* by \*glyphosate\*.  
Publication Year: 2006

21/6/221 (Item 221 from file: 156)  
3937673 NLM Doc No: 15312724  
Transfer of hexazinone and \*glyphosate\* through undisturbed \*soil\*  
columns in \*soils\* under Christmas tree cultivation.  
Oct 2004

21/6/222 (Item 222 from file: 50)  
0007788265 CAB Accession Number: 19992302381  
Toxicity of herbicides for *Spirodela punctata* (G.F.W. Meyer) Thompson  
and *Salvinia minima* Baker (aquatic macrophytes).  
Original Title: Toxicidade de herbicidas para as macrofitas aquáticas  
*Spirodela punctata* (G.F.W. Meyer) Thompson e *Salvinia minima* Baker.  
Publication Year: 1996

21/6/223 (Item 223 from file: 203)  
02579069  
Toxicity of three \*glyphosate\* formulations to *Aphanius iberus* (  
Toxicidad de tres formulaciones de glifosato sobre *Aphanius iberus*)  
2003  
[Conference 2003. Spanish Weed Science Society. Proceedings, Barcelona  
[Spain], 4th, 5th and 6th November, 2003] (Congreso 2003. Sociedad  
Española de Malherbología. Actas, Barcelona, 4, 5 y 6 de noviembre de 2003)

21/6/224 (Item 224 from file: 5)  
18916129 BIOSIS NO.: 200600261524  
Urban contributions of \*glyphosate\* and its degradate AMPA to streams in the  
United States  
2006

21/6/225 (Item 225 from file: 50)  
0008928506 CAB Accession Number: 20053161843  
Urban areas - source of pesticide-\*contamination\* of surface \*water\*?  
Book Title: Second International Symposium on plant health in urban  
horticulture, Berlin, Germany, 27-29 August, 2003  
Publication Year: 2003

21/6/226 (Item 226 from file: 144)  
17115056 PASCAL No.: 05-0182167  
Vadose zone processes and chemical transport : Leaching of \*glyphosate\*  
and amino-methylphosphonic acid from danish agricultural field sites  
2005

21/6/227 (Item 227 from file: 76)  
0001714809 IP ACCESSION NO: 5982533  
As the Worm Turns: *Eisenia fetida* Avoids \*Soil\* Contaminated by a  
\*Glyphosate\*-Based Herbicide  
PUBLICATION DATE: 2004

21/6/228 (Item 228 from file: 245)  
063711

\*Water\* Quality Sensor Responses to Injected Contaminants in a  
Chloraminated Pipe Loop 2006

21/6/229 (Item 229 from file: 50)  
0008549430 CAB Accession Number: 20033205509  
[ SUP 14 C]-\*glyphosate\* : uptake into Echiochloa crusgalli following  
pre-emergent application.  
Book Title: The BCPC International Congress: Crop Science and  
Technology, Volumes 1 and 2. Proceedings of an international congress held  
at the SECC, Glasgow, Scotland, UK, 10-12 November 2003  
Publication Year: 2003

## Supplemental Searches

The USDA Economic Research Service website (<http://www.ers.usda.gov/>) was searched for all  
articles pertaining to:

- alfalfa
- tillage
- biotechnology

**Appendix K. Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa**

# **Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa**

## **Executive Summary**

This report analyses the potential impact on the economics of alfalfa farming due to the introduction of glyphosate-tolerant (GT) alfalfa into the market. It does so by reviewing the existing literature on alfalfa costs and returns, as well as on the potential impacts of GT alfalfa adoption. Based on this literature, scenarios of returns with GT alfalfa are constructed and described, where possible. Additional considerations are made regarding the potential long-term economic consequences of increased glyphosate resistance of weeds.

The report finds that alfalfa forage farmers aiming at maximizing returns during the time horizon of an alfalfa life stand would likely benefit financially from the adoption of GT alfalfa due to potential improvements in forage quality with reduced herbicide costs. The impact of GT alfalfa adoption for seed production is not as clear, given its dependence on conditions established by breeder company – producer contracts.

The increased returns expected for GT alfalfa farming in the short run may or may not persist in the long run, depending on market considerations (including technological fees), limitations to crop rotation imposed by the adoption of GT alfalfa, and cost impacts of any possible increased weed resistance over time.

A final analysis ranking counties based on the likely benefits of GT alfalfa adoption is presented at the end of this report and should be interpreted within the limited scope of this report.

## 1.0 Introduction

### 1.1 Objective, Scope, and Organization of Report

This report analyses the potential impact on the economics of alfalfa farming of the introduction of glyphosate-tolerant (GT) alfalfa into the market. By “economics of alfalfa” farming we refer to the costs of production and yields and their implications for farm income. Our analysis is restricted to looking at individual farms: we do not aggregate farmers to draw inferences on supply. This analysis – as well as demand considerations – is left for the remaining socioeconomic Technical Reports. In particular, the Technical Report *Economic and Social Impacts to Organic Farmers of Deregulation of Roundup Ready Alfalfa* (appendix S) will also include the impacts on farmers of conventional alfalfa.

Below we explain the methodology – assumptions, scenarios and limitations – upon which this analysis is based. Section 2 focuses on the production of alfalfa hay and section 3 on the production of alfalfa seeds. In both of these sections, we assume no glyphosate resistance in weeds. This assumption is relaxed in section 4 where we consider the impacts of increased glyphosate resistance of weeds on both hay and seed production, as well as on crops with which alfalfa is rotated on the farm.

### 1.2 Methodology

Alfalfa farming for forage and for seed are analyzed separately, the former in section 2, the latter in section 3. These are the two main – and quite distinct – cropping systems for alfalfa.

In section 2, we start with a brief description of alfalfa farming for forage, its cost factors and its value for the farmer. We then review the existing cost studies of alfalfa farming and identify the main factors affecting economic returns for alfalfa farmers. We then review the literature on the possible differences between conventional alfalfa farming and GT alfalfa farming, regarding those cost and return factors. The same methodology is adopted in section 3 regarding alfalfa farming for seed.

In section 2 we go a step further and build scenarios for GT alfalfa costs using some of the cost studies identified for conventional alfalfa. As alfalfa farming conditions vary considerably throughout the United States, these scenarios assume all conditions of the base conventional cost studies remain the same, except a few major changes previously identified as likely to occur in GT farming. The results are offered as an illustration of potential differences in costs and returns for the farmer under specific situations. We did not build similar scenarios in section 3. To do so would require investigation in greater depths into breeder company and seed grower agreements.

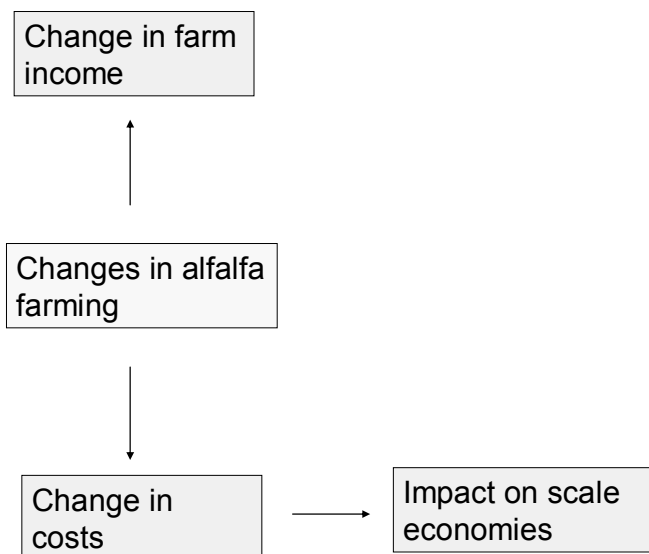
Sections 2 and 3 look at economic impacts to farmers when they plan with the time horizon of the life of an alfalfa stand, and assume no weed resistance occurs within this time horizon. Section 4 raises a few considerations regarding economic impacts beyond this time horizon and regarding weed resistance to glyphosate and its potential growth on alfalfa farms, whether in

alfalfa fields or in crops rotated with alfalfa. These considerations are based on the existing literature and on the analyses done in sections 2 and 3.

In appendix K-3 of this technical report, we present county level analysis identifying those counties that would most likely benefit from GT alfalfa deregulation, based solely on the short-term cost-return considerations made in section 2, and not incorporating considerations that will be dealt with in later Technical Reports (e.g. demand considerations, beyond the scope of the present report). It transposes, to the extent possible, the analysis done in this report to the county level.

### 1.2.1 Assumptions

Cause-effect relationships assumed in our analysis of the potential socioeconomic impacts of GT alfalfa on alfalfa farming stem from two potential sources of physical impacts. The first is the availability of a new variety of alfalfa with its own traits and implications for costs and farm income. The figure below illustrates the impact of the availability of this new variety, showing also potential implications for scale economies.



**Figure K-1: Changes in alfalfa farming**

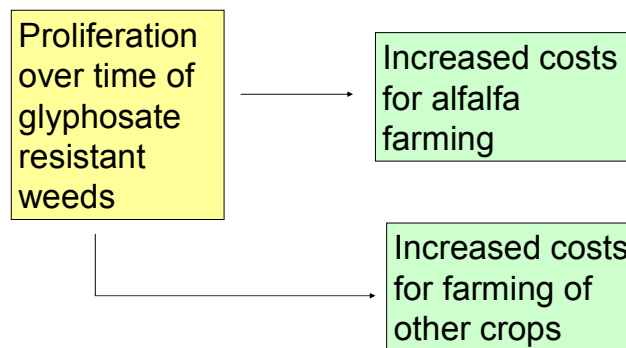
Change in alfalfa farming may imply more or less use of various inputs and higher or lower yields of alfalfa hay and seed. This leads to changes in the costs of producing alfalfa and potential impacts on economies of scale. It also results in changes in farm income.

Changes in costs of producing alfalfa could also have implications for the use of labor. We have not included analysis of this here for two reasons: a) the literature and cost studies we found

largely omit information on the use of farmers own or family labor; b) we found little to no reference on changes in the use of own or hired labor in the adoption of GT alfalfa.

For this analysis we assume no growth in glyphosate resistant weeds has yet followed from the increased use of glyphosate.

The second source of change in alfalfa farming is the growth in glyphosate-tolerant weeds that is expected from the increased use of glyphosate over time. This has implications not only for alfalfa farming but also for farming of other crops rotated with alfalfa, so we include the analysis of impacts on other crops as well.



**Figure K-2: Proliferation of glyphosate resistant weeds**

### *1.2.2 Data and Information Sources*

Most of the information on alfalfa production comes from documents published by university cooperative extension services. Some of these documents are peer-reviewed before publishing and others were presented at specialized conferences. Other sources of information and data include academic journals, producer associations, specialized internet portals and magazines and government official data sources.

## 2.0 Changes in Alfalfa Farming for Forage

### 2.1 Conventional Alfalfa Farming For Forage

Harvested acreage of alfalfa hay (dry) was in 2007 almost 21.7 million acres generating some 72.6 million tons of hay at an average yield of 3.35 tons per acre (USDA NASS, 2008)<sup>39</sup>. Statistics for acreage of alfalfa used as haylage (alfalfa baled at a higher moisture content than dry hay) are not available for all states except in the Agricultural Census, but based on the 2007 census and more recent USDA NASS data available for 18 states, haylage acreage should account for an additional 10%-15% in alfalfa acreage grown for forage. It is the fourth crop in acreage in the United States (USDA NASS, 2008; 2009).

Alfalfa is grown for forage in almost all of the U.S. states and farming conditions vary considerably depending on climate, rainfall, soil fertility, weed and disease prevalence, whether it is seeded in fall or in spring, for dairy or other use, among other factors. In a study conducted between 1988 and 2002 on pesticide use in alfalfa, Hower et al (1999) differentiate between four distinct regions of alfalfa farming: North Central, West, Northeast and South. The North Central region presented the highest acreage of alfalfa followed by the West. Together these two regions had 90% of the alfalfa acreage in the country. The West, however, presented the highest yields, relatively high prices, most seeding done in fall and relatively high rates of insecticide and herbicide use, while the North Central region presented the lowest yields, lowest prices, most seeding done in spring and the lowest rates of insecticide and herbicide use. According to this report, only 8.1% of alfalfa hay acreage in the North Central region was treated with herbicides, while in the West 50% of acreage was treated with herbicides..

Rogan and Fitzpatrick (2004) follow the regionalization adopted by the USDA-Plant Variety Protection Office and the National Alfalfa and Miscellaneous Legume Variety Review Board that divides alfalfa production in seven regions: Southeast, East Central, North Central, Great Planes, South West, Winterhardy Intermountain and Moderately Winterhardy Intermountain. More than half of the alfalfa forage acreage is grown in the North Central region. This region tends to use winterhardy varieties, harvest 2-5 times a year, has yields lower than national average and often uses companion crops to control weeds during establishment of alfalfa. A similar characterization is done of the East Central region. In contrast, in the Southwest region some non-dormant varieties are used allowing for 8-11 harvests a year Rogan and Fitzpatrick (2005). In some locations in California, yields can reach 14 tons/ acre (Klonsky et al, 2007)

Klonsky et al (2007) characterize alfalfa as being a relatively low risk crop, valued by farmers for its cash flow properties, often harvested many times a year, while waiting for the harvest of other crops. It is also valued as a rotational crop since it has beneficial properties on the soil (Putnam et al, 2007).

Klonsky et al. (2007) summarize average costs from various cost studies done for alfalfa by the University of California-Davis, in collaboration with the UC Cooperative Extension, for several

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<sup>39</sup> This includes alfalfa hay mixtures.



parts of California. Throughout the state, major sources of variation in costs are irrigation and land values. Harvesting costs also vary considerably depending on the number of harvests per year allowed by the local climate. Putnam et al (2007) consider the limitation of water supply as being the main determinant factor of the future of alfalfa production in California.

### *2.1.1 Cost Studies*

There are several cost studies done by university cooperative extension services available both for production of alfalfa hay and alfalfa haylage.

The University of Nevada conducted multiple cost studies for alfalfa hay production. A 1998 study in Humboldt County (Kettle et al., 1999b) found costs associated with 500 acres of alfalfa hay using center pivot irrigation. The study found irrigation power to be the highest cost component (22.3%) of total variable costs of production. Chemical weed control accounted for 10.7 percent of total operating costs. These figures differed only slightly from a 1996 cost study for costs associated with 960 acres of alfalfa (Myer et al., 1997). The study also found irrigation to be the highest cost component (26.8%), and found slightly lower costs associated with chemical weed control (9.2%).

A 2006 study conducted in Pershing County, Nevada (Brezeale et al., 2006) calculated costs for alfalfa hay stand establishment and production for farms with 750 acres of alfalfa cultivation. For stand establishment, the study results show no component accounting for a significant amount of the operating costs; fuel and lube, fertilizer, and maintenance together accounted for 42 percent of total operating costs. Herbicide use during stand establishment comprised 4.8 percent of operating costs. For hay production, the study shows maintenance (19.6%), fuel and lube (18.9%), hired labor (17.9%), and operator labor (16.4%) accounting for more than 70 percent of operating costs. Herbicide use accounts for 7.5% of operating costs during production.

A 2003 Ohio State University Extension alfalfa haylage production budget (The Ohio State University Extension, 2003) estimated costs for different yields of alfalfa haylage for a four year stand. The study found chemical use (Bathryoid, Poast, and Butyrac) to be the highest cost component of operating costs. The proportion of the budget in chemical use decreased with yield; for a yield of 8 tons/ acre chemical use accounted for 21.9 percent of operating costs, for a yield of 13 tons/ acre chemical use accounted for 18.1 percent of operating costs. A 2007 Virginia Cooperative Extension alfalfa haylage cost study (Virginia Cooperative Extension, 2007) found fertilizer use to be the highest operating cost component (41.4%) of operating costs for a 9 ton yield. Herbicide use accounted for 14.6 percent of total operating costs.

We detail two other cost studies below, one for California, the other for Wisconsin, in an attempt to better illustrate some of the varying local conditions in alfalfa production.

The most recent cost study we found comes from the University of California Cooperative Extension with sample costs for establishing and producing conventional alfalfa in a 50 acre extension in the San Joaquin Valley (Frate et al., 2008). Table K-1 below summarizes the costs for establishing alfalfa. Total cultural (land preparation and plant growing) costs include land preparation, fertilizers, planting and irrigation. Cash overhead costs are the costs for insurance,

office expenses and taxes. Non-cash costs are capital recovery costs for land, the irrigation system and the equipment. The seeding rate is assumed to be 30 lbs/acre. We show the line items for seeds and herbicides, more details are found in the publication.

**Table K-1. Establishment Costs, \$/ acre**

|                                       |        |
|---------------------------------------|--------|
| Seeds                                 | 90.00  |
| Herbicides                            | 32.00  |
| Other                                 | 314.00 |
| TOTAL CULTURAL COSTS                  | 436.00 |
| Interest on operating capital @ 6.75% | 10.00  |
| TOTAL OPERATING COSTS/ ACRE           | 446.00 |
| Cash overhead costs                   | 85.00  |
| CASH COSTS/ACRE                       | 531.00 |
| Non-cash costs/ acre                  | 294.00 |
| TOTAL COSTS/ACRE                      | 825.00 |

Source: Frate et al., 2008

Table K-2 shows how establishment costs per acre vary with changes in seed and herbicide costs. The first column shows the increase assumed for seed costs or for herbicide costs. The second and third columns show the impact on establishment costs when it is seed costs that increase 10%, 20%, 30% or 40%, and the fourth and fifth columns show the impact on establishment costs when it is herbicide costs that face a similar increase.

Table K-2 shows that seed costs have a greater weight than herbicide costs in determining total establishment costs, under the conditions of the US Cooperative Extension Study.

**Table K-2. Sensitivity of Establishment Costs to Changes in Seed and Herbicide Costs**

| Percent increase in input costs | Establishment costs when seed costs increase |          | Establishment costs when herbicide costs increase |          |
|---------------------------------|----------------------------------------------|----------|---------------------------------------------------|----------|
|                                 | \$                                           | % change | \$                                                | % change |
| 0                               | 825.0                                        |          | 825.0                                             |          |
| 10%                             | 834.0                                        | 1.09%    | 828.2                                             | 0.39%    |
| 20%                             | 843.0                                        | 2.18%    | 831.4                                             | 0.78%    |
| 30%                             | 852.0                                        | 3.27%    | 834.6                                             | 1.16%    |
| 40%                             | 861.0                                        | 4.36%    | 837.8                                             | 1.55%    |

Source: based on previous table

Table K-3 incorporates establishment costs into total costs of producing alfalfa by assuming annual cost recovery of cash establishment costs spread over a 4 year life of stand. Cultural costs now include herbicides, insecticides, fertilization and irrigation. Income from alfalfa hay sales is also incorporated and seven harvests are assumed in a year. The UC Cooperative Extension study assumed a yield of 8 tons/ acre, average of yields between 5 and 11 tons/ acre obtained under these conditions in the San Joaquin Valley. The table shows positive returns over operating costs, but negative returns when overhead and capital costs are included.

**Table K-3. Total Production Costs and Returns, \$/ acre**

|                                             |          |
|---------------------------------------------|----------|
| Sales (8 tons/acre at \$185/ton of premium) | 1,480    |
| Herbicides                                  | 71.00    |
| Other cultural costs                        | 294.00   |
| Harvest costs (7x)                          | 310.00   |
| Interest on operating capital @ 6.75%       | 10.00    |
| Total operating costs/ acre                 | 685.00   |
| Return over operating costs                 | 795.00   |
| Cash overhead costs                         | 165.00   |
| Annual cost recovery: alfalfa establishment | 147.00   |
| Annual cost recovery: other                 | 549.00   |
| Total costs/acre                            | 1,546.00 |
| Return over total costs                     | -66.00   |

Source: Frate et al., 2008

Table K-4 shows how returns per acre vary with changes in seed and herbicide costs, as well as changes in yields or hay prices. As in table K-2, the first column represents the percent increase assumed if a given factor is affecting returns. In this case: seed costs, herbicide costs or the yield multiplied by the price of alfalfa hay. The remaining columns show the impact on returns when the percent increase assumed is applied to seed costs, herbicide costs, yields or the price of alfalfa hay.

The table shows that the influence of herbicide costs now surpasses that of seeds on total costs, since now herbicides are also used during production. The table also shows, however, that under the conditions of the US Cooperative Extension Study, yields and hay prices are far more important than seed and herbicide costs in determining returns.

**Table K-4. Sensitivity of Returns to Changes in Costs, Yields and Hay Prices**

| Percent increase | Seed costs |          | Herbicide costs |          | Yields or Hay prices |          |
|------------------|------------|----------|-----------------|----------|----------------------|----------|
|                  | \$         | % change | \$              | % change | \$                   | % change |
| 0%               | -66        |          | -66             |          | -66                  |          |
| 10%              | -68.49     | 3.77%    | -73.99          | 12.11%   | 82                   | 224.24%  |
| 20%              | -70.49     | 6.80%    | -81.97          | 24.20%   | 230                  | 448.48%  |
| 30%              | -73.48     | 11.33%   | -89.96          | 36.30%   | 378                  | 672.73%  |
| 40%              | -75.97     | 15.11%   | -97.94          | 48.39%   | 526                  | 896.97%  |

Source: based on previous table

The Integrated Pest and Crop Management Portal of the University of Wisconsin Plant Sciences outreach programs posts a “Roundup Ready Alfalfa Calculator” elaborated by Dan Undersander (<http://ipcm.wisc.edu/WCMNews/tabid/53/EntryID/208/Default.aspx>). Table K-5 shows the results of this calculator for conventional hay, as presented on the website. We include the results for Roundup Ready alfalfa further below. Values are those that the portal feels “are accurate estimates of the costs, use patterns, and yield throughout Wisconsin.” However the numbers are not supposed to be representative of every farmer, and the calculator is offered so that each farmer can plug in their numbers and see the results.

**Table K-5. Establishment and Production Cost of Conventional Alfalfa, units/acre**

|                                                  |          |
|--------------------------------------------------|----------|
| Seed cost/ 50 lb bag (\$)                        | \$200.00 |
| Pounds of seed per acre                          | 12       |
| Technology fee/bag (\$/bag)                      | \$0.00   |
| Yield in seeding year (t/a DM)                   | 3.50     |
| Herbicide cost (\$/acre/application)             | \$20.00  |
| Herbicide application cost (\$/acre)             | \$10.00  |
| Number of herbicide applications                 | 1        |
| Value of ease of roundup use (\$/acre)           | \$0.00   |
| Yield depression from pursuit/raptor (t/a DM)    | 0.30     |
| Expected stand life (yrs including seeding year) | 3        |
| Value of hay (per ton DM)                        | \$100.00 |
| Fixed costs per acre per year                    | \$180.00 |
| Harvesting costs per acre per harvest            | \$35.00  |
| Number of harvests                               | 2        |
| Seeding Year Production Costs/Results            |          |
| Seed cost (prorated + tech fee) per acre*        | \$16.00  |
| Total seed and herbicide cost per ton of hay     | \$14.38  |
| Total cost per ton of hay seeding year           | \$85.80  |
| Profit per acre - seeding year                   | \$49.69  |

Source: Integrated Pest Crop Management, University of Wisconsin

The University of Wisconsin portal also presents some sensitivity analysis. We extend their analysis to include herbicide costs and the price of alfalfa hay, since these variables may potentially differ between conventional and GT alfalfa, as argued in section 2.2 below. We use the numbers for the seeding year above to have an idea of the changes in profit for percent changes in seed costs, herbicide costs and the price of hay. Table K-6 shows the results for a conventional alfalfa hay field. The first column represents the percent increase assumed in a given factor affecting returns. The remaining columns show the impact on per acre profit when the percent increase assumed is applied to seed costs, herbicide costs or the price of alfalfa hay.

**Table K-6. Sensitivity of Profit per Acre to Costs and Prices**

| % increase | seed costs | herbicide costs | price of alfalfa hay |
|------------|------------|-----------------|----------------------|
| 0          | 49.69      | 49.69           | 49.69                |
| 10         | 47.94      | 47.50           | 84.69                |
| 20         | 46.19      | 45.31           | 119.69               |
| 30         | 44.44      | 43.13           | 154.69               |
| 40         | 42.69      | 40.94           | 189.69               |

Source: Elaborated from numbers in table above.

While a 40% increase in seed costs and herbicide costs have a less than proportional impact on profit, a 40% increase in alfalfa hay prices will more than triple the profit per acre. What this means is that reductions in the costs of herbicides are less important in the farmer's choice of adopting GT alfalfa or conventional alfalfa for hay than the possibility of obtaining higher quality alfalfa hay.

As percentage changes in yield also seem to have a high impact on returns, it could be argued that farmers of conventional alfalfa face a trade off between pursuing higher yields of alfalfa of lower quality, by harvesting a shared alfalfa-weed mix, or pursuing higher prices of alfalfa with lesser weed content. In fact, it seems that differences in prices between high quality and low quality alfalfa hay are highest in times of average low prices (Holin, 2008). In those seasons it may be worth favoring quality over yield. In years when average prices are high, favoring yields may pay off.

### *2.1.2 Scale Economies*

Some insight on the potential link between alfalfa varieties and economies of scale is provided by the exercise below in which we compare costs for a 300 acre alfalfa hay farm with those of a 50 acre alfalfa hay farm, under similar circumstances, as made possible by two studies from the University of California Cooperative Extension (Frate et al., 2008; Mueller et al. 2008).

The University of California Cooperative Extension Service produced a similar study to that of the 50 acre farm in San Joaquin Valley for a 300 acre farm in the same region (Mueller et al., 2008). Most of the assumptions are the same such as seeding rate and price received per ton of premium hay; other aspects were adapted to production on a larger scale. These include:

- yields are assumed to be 9 tons/ acre, where the additional ton (compared to the 8 tons/ acre of the 50 acre farm) is the equivalent in haylage of 3.03 green tons with 30% dry matter. This additional ton is sold at \$46.67 (roughly the difference between hay and harvest costs, divided by three);
- land preparation costs are lower per acre, making establishment costs per acre lower in the 300 acre farm than in the 50 acre farm;
- insurance and property taxes are higher for the entire farm, but lower per acre.
- the life of stands is assumed to be three years instead of four.

Table K-7 below summarizes the total costs and returns for establishing and producing alfalfa on a 300 acre farm in the San Joaquin Valley, as compared to a 50 acre farm in the same region.

**Table K-7. Total Production Costs and Returns, \$/ acre**

|                                             | <b>300 acre farm</b> | <b>50 acre farm</b> |
|---------------------------------------------|----------------------|---------------------|
| <i>Sales</i>                                | <i>1620a</i>         | <i>1480</i>         |
| Herbicides                                  | 71.00                | 71.00               |
| Other cultural costs                        | 294.00               | 294.00              |
| Harvest costs (7x hay; 2x haylage)          | 322.00b              | 310.00              |
| Interest on operating capital @ 6.75%       | 11.00                | 10.00               |
| <i>Total operating costs/ acre</i>          | <i>708.00</i>        | <i>685.00</i>       |
| <b>Return over operating costs</b>          | <b>912.00</b>        | <b>795.00</b>       |
| Cash overhead costs                         | 122.00c              | 165.00              |
| Annual cost recovery: alfalfa establishment | 173.00d              | 147.00              |
| Annual cost recovery: other                 | 359.00e              | 549.00              |
| <i>Total costs/acre</i>                     | <i>1,362.00</i>      | <i>1,546.00</i>     |
| <b>Return over total costs</b>              | <b>258.00</b>        | <b>-66.00</b>       |

Source: Mueller et al., 2008. a. Eight tons hay, one ton haylage; b. Seven hay harvests, two haylage; c. Lower liability insurance and property taxes per acre; d. Establishment costs/ acre are actually lower for 300 acre farm thanks to reduced land preparation costs, but divided over shorter three year life of stand; e. Lower land cost recovery.

Even with a shorter life of stand and higher operating costs per acre, returns per acre are higher for the 300 acre farm due to: a) lower overhead and capital recovery costs, including lower land preparation costs in establishing alfalfa stands (economies of scale on the size of land); and b) increased yields. In the 50 acre and 300 acre studies compared above, the higher per acre land preparation costs for the 50 acre farm seem to originate from a greater reliance of custom operators.

What this analysis suggests is that any alfalfa variety that is more demanding of land preparation will likely be more attractive to larger farmers, while alfalfa varieties that allow for less expense in land preparation, may be more accessible to smaller farmers than other varieties.

## 2.2 GT Alfalfa Hay Farming

Evidence of farming distinctions between GT alfalfa and conventional alfalfa come mostly from field trials and from those farmers that planted alfalfa during the window in which it was deregulated, between June of 2005 and March of 2007. During this period over 300,000 acres of GT alfalfa are estimated to have been planted (Putnam, 2007). Much of this latter type of evidence is anecdotal, in that it is based on the observation of one or a few GT alfalfa fields.

Canevari (2007) presents a small (non-random) survey with 24 growers in addition to a few consultants, seed and marketing dealers, and university faculty where the main aspect of GT alfalfa observed was the control of weeds with glyphosate, generally to the satisfaction of the users. According to this paper, GT alfalfa would reduce the costs of herbicides while improving the quality of alfalfa hay (lesser weed content). Miller et al (2006) refers to field trials done at the University of Wyoming and University of Nebraska and suggest the main features of GT alfalfa are its “ease of use, flexibility, and broad spectrum weed control.”

Individual farmers that had experimented with GT alfalfa after initial deregulation and that sent comments to APHIS’ Notice of Intent to prepare an Environmental Impact Statement provide

additional reports, including that of possible increase in yields (due to lesser stunting caused by use of other herbicides) and reduction in herbicide costs.

Reduced seeding rates or increased life of stands would have relevant impacts on costs because establishment costs would be reduced (per year of production). Van Deynze et al. (2004) suggested GT alfalfa could potentially increase the life of alfalfa stands but we have not found studies verifying this.

Given the economic relevance for alfalfa farming of yields and alfalfa hay quality evidenced in the cost studies reviewed above, we reviewed the literature for evidence of differences in those particular traits between GT alfalfa and non- GT alfalfa.

### 2.2.1 Differences in Yield

Alfalfa hay yield is influenced by a wide range of factors, including seed variety, proper planting and establishment, climate, soil and moisture conditions, and weed and insect control (Dixon et al. 2005). Hundreds of alfalfa varieties have been developed for use in North America. These varieties are adapted to the various major alfalfa production zones, and contain genes selected for high yield and resistance to diseases, insects, and nematodes (Van Deynze et al. 2004).

The focus here is on evaluating any systematic differences in yield between GT and conventional alfalfa varieties, holding constant the other factors that may influence yield. Rigorous assessment of the yields of different alfalfa varieties under actual farming conditions is generally not available. Instead, forage agronomists usually evaluate different varieties in the context of controlled variety trials at agricultural experiment stations (Mueller 2008).

Comparative yield data from a number of variety trials across the United States are given in Table K-8. These results were selected for illustrative purposes, and do not necessarily represent the yield outcomes that would result from individual cultivar comparisons, or other locations and growing seasons.

**Table K-8. Comparative Variety Trial Yield Results**

| Variety Trial Location and Date                | Average Annual Yield, All GT Alfalfa Varieties (Tons/Acre) | Average Annual Yield, All Varieties (Tons/Acre) |
|------------------------------------------------|------------------------------------------------------------|-------------------------------------------------|
| Illinois (Freeport), 2007 <sup>1</sup>         | 6.10                                                       | 6.17                                            |
| Iowa (Ames), 2007 <sup>2</sup>                 | 4.61                                                       | 4.64                                            |
| Kansas (Thomas Co.), 2007 <sup>3</sup>         | 8.22                                                       | 8.41                                            |
| Nebraska (Havelock), 2006 <sup>4</sup>         | 5.04                                                       | 5.12                                            |
| New York (Cobleskill), 2006 <sup>5</sup>       | 2.6                                                        | 2.9                                             |
| South Dakota (Brookings Co), 2006 <sup>6</sup> | 3.81                                                       | 3.86                                            |
| Wisconsin (Lancaster), 2006 <sup>7</sup>       | 4.77                                                       | 4.07                                            |

1. Source: <http://vt.cropsci.uiuc.edu/forage.html>

2. Source: <http://www.croptesting.iastate.edu/alfalfa/results/2007-alfalfa.xls>

3. Source: <http://kscroptests.agron.ksu.edu/07/07alf/7a-thi6.asp?Loc=thi6>

4. Source: <http://varietytest.unl.edu/alfalfa/2006/Roundup-Havelock2006table06.xls>

5. Source: <http://plbrgen.cals.cornell.edu/programsandprojects/departamental/foragetest/alfalfa06.htm>

6. Source: [http://plantsci.sdstate.edu/forages/Alfalfa%20Trials/SD\\_Alfalfa\\_Trials.html](http://plantsci.sdstate.edu/forages/Alfalfa%20Trials/SD_Alfalfa_Trials.html)

7. Source: <http://www.uwex.edu/CES/crops/RRAlfalfa07.htm>

As revealed in table K-8 above, variety trial results do not indicate any systematic hay yield advantage or disadvantage for GT alfalfa hay cultivars. Dr. Daniel Putnam, a leading alfalfa

research agronomist at UC-Davis, has been conducting variety trial testing of GT and other alfalfa cultivars throughout California. Putnam (2008) notes that in general, the yield performance of GT alfalfa cultivars (as a group) are no different than what could be expected from similar conventional lines of equal fall dormancy characteristics. Moreover, he notes that there are differences between conventional varieties that are due to fall dormancy, and due to the superiority of individual cultivars within a dormancy group, but the range of variation observed in conventional cultivars is similar to the range of variation observed in GT cultivars (Putnam 2008).

Looking beyond comparative yield analysis under controlled variety trial conditions, a key factor influencing alfalfa hay yield under actual farming conditions is weed control during stand establishment (Dillehay and Curran 2006). Weed management in alfalfa is critical during stand establishment to ensure a successful plant population. Alfalfa seedlings establish slowly and are very sensitive to competition for limited resources (Dillehay and Curran 2006). Weed infestation during the establishment of an alfalfa hay crop increases weed seed reserves and decreases seedling vigor in an alfalfa stand (Van Deynze et al. 2004). Thus controlling weeds during the establishment year reduces stress on alfalfa, increases seedling weight and leaf numbers, and ultimately increases yields the following year (Stout et al. 1992). Van Deynze et al. (2004) note that weed control has an even more important impact on the forage quality of alfalfa hay, an issue that will be addressed in the next section.

One of the major incentives to plant GT alfalfa is to control weeds during establishment (Van Deynze et al. 2004). A weed management system in which glyphosate is applied at the proper alfalfa growth stage during stand establishment provides more than 95 percent control of nearly all weeds (Van Deynze et al. 2004; Dillehay and Curran 2006). By way of comparison, Dillehay and Curran (2006) found somewhat weaker weed control using other herbicides such as Buctril, Butyrac, Pursuit, and Raptor. Application of glyphosate at the seedling stage will also normally cause a three to seven percent seedling mortality rate, due to the normal occurrence of a small number of GT alfalfa seeds lacking the gene for glyphosate tolerance. This is not considered a problem in actual practice, however, as it is common for more than 40 percent of seeds sown to fail to establish prior to the first or second cutting in a normal process of self thinning (Van Deynze et al. 2004).

The application of herbicides may also cause crop injury and seedling mortality. Van Deynze et al. (2004) and Dillehay and Curran (2006) found that glyphosate applications caused little to no alfalfa injuries that were evident by the time of the first cutting. By way of comparison, Van Deynze et al. (2004) report that Raptor and Pursuit plus Buctril tank mix treatments resulted in higher injury ratings, usually of less than 20 percent. Rankin (undated) assumes a 6.67 percent conventional alfalfa hay yield reduction for crop injury based on conventional weed management systems. Rankin cites evidence from Wisconsin of no significant difference in total season yield between GT alfalfa with a glyphosate weed management system and conventional alfalfa hay production, but notes virtually the entire yield from the GT alfalfa system was alfalfa, while at least some of the yield from the conventional system was weeds.



Taken together, the evidence suggests that there is no intrinsic yield advantage in GT alfalfa cultivars over conventional cultivars. The evidence suggests a potential yield advantage for GT alfalfa using the glyphosate weed management system, particularly during stand establishment.

### *2.2.2 Differences in Quality*

The forage quality of alfalfa is based on a large number of factors that are ultimately linked to its utility as an animal feed (Baker and Ball 1998). Federal quality guidelines currently use percentage of crude protein and acid detergent fiber, relative feed value, and an evaluation of color, molds or weeds present (McWilliams et al. 2005). Alfalfa is then placed in five quality categories: supreme, premium, good, fair and low. Some states have adopted additional quality grading regulations. Dairy cattle and horses both tend to have high forage quality requirements (Van Deynze et al. 2004). Most weeds are lower in forage quality or palatability than alfalfa, and forage with high weed content can adversely affect milk production as well as animal growth and health (Van Deynze et al. 2004).

As noted in the preceding subsection, Van Deynze et al. (2004), Dillehay and Curran (2006), and Rankin (undated) all report better weed control in GT alfalfa using the glyphosate weed management system. Glyphosate controls a broader spectrum of weeds and is more efficacious than most currently available herbicides and herbicide combinations during the critical stand establishment stage of alfalfa production (Van Deynze et al. 2004; Dillehay and Curran 2006), and induces less crop injury in established stands (Van Deynze et al. 2004).

Conventional alfalfa hay varies in terms of weed content, and so it is difficult to make direct comparisons between GT and conventional alfalfa hay from a weed content standpoint. Quality grading assigns penalties based on weed and other contaminant content. Cummings et al. (2004) utilized an alfalfa hay pricing system in which each 15 percentage point increase in weed content above a benchmark 5 percent level resulted in a 10 percent reduction in the price of the alfalfa hay. Van Deynze et al. (2004) note that pure alfalfa hay is usually worth 20 to 50 percent more than weedy hay. Putnam (2008) argues that while the relative weed-free nature of GT alfalfa tends to give it a quality edge over conventional alfalfa, one cannot systematically attribute higher quality to GT alfalfa over conventional alfalfa, since sometimes conventional weed control systems can be quite effective.

The limited evidence presented here suggests that while there is the potential for higher quality forage from GT alfalfa, one cannot systematically assume higher quality attributable to GT alfalfa over conventionally produced alfalfa.

### *2.2.3 Scenarios*

Based on the review above, we use the cost studies previously mentioned and ask what would happen under the same assumptions but with the use of GT seed, glyphosate, and under various scenarios of alfalfa hay quality. No differences in yield are assumed between GT alfalfa and non-GT alfalfa, and no additional differences in management systems are assumed.

These scenarios should not be interpreted as likely differentials in costs and returns between conventional and non-GT alfalfa in any particular setting, since the differences in management

systems between the two varieties are likely to involve other factors not taken into consideration in the scenarios (such as the time spent by farmers with weed control) and the impact of the deregulation of GT alfalfa on the prices paid for alfalfa of various qualities is ignored (this will be analyzed in a future Technical Report, since it is not part of the scope of the present report). However, given the importance of differences in seed, herbicide use and potentially in alfalfa forage quality between conventional and GT alfalfa, we feel these scenarios provide a useful illustration of what the potential cost and return implications may be of adoption of GT alfalfa for forage.

A note on removal costs: removal of GT alfalfa stands can be done both through mechanical and chemical methods and one source describes plowing as possibly the most common method for alfalfa stand removal (Orloff and Putam, No Year). When herbicides are used for removal, glyphosate seems to be the most common (Canevari 2004). However, glyphosate cannot be used to remove GT alfalfa stands.

Differences in removal costs of alfalfa stands are not considered in this exercise, because they are also not included in the cost studies used as comparison. Glyphosate as an herbicide in the removal of alfalfa stands apparently can be substituted by other herbicides. One study done by Mark Renz at the University of Wisconsin with various herbicides found that “all herbicides were effective at limiting resprouting of alfalfa at the appropriate rate and timing” (Renz, 2007). Canevari et al (2004) suggest a combination of 2,4-D and Banvel (dicamba) was particularly effective. Miller et al (2006) suggest various options while alerting to the restrictions of these herbicides for future crop rotation.

Based on the existing literature, we consider the following values (sometimes ranges) for the scenarios.

a) GT alfalfa seed costs

GT alfalfa seeds were sold at US\$6-7.50/lb during its deregulation period, according to various sources (<http://www.purdue.edu/UNS/x/2007a/070323NeesAlfalfa.html>; <http://ipcm.wisc.edu/WCMNews/tabid/53/EntryID/208/Default.aspx>; <http://www.roundupreadyalfalfa.com/home.aspx?page=valuecalculator>)<sup>40</sup>, including its technology fee (trait premium). The technology fee for areas “east of the Rocky Mountains”<sup>41</sup>, ([http://www.farmandranchguide.com/articles/2005/08/31/ag\\_news/regional\\_news/news11.tx](http://www.farmandranchguide.com/articles/2005/08/31/ag_news/regional_news/news11.tx); <http://www.soils.wisc.edu/extension/wfapmc/2006/pap/Undersander2.pdf>) is US\$125 per 50/lb bag, that for those areas west of the Rocky Mountains US\$150 per 50/lb bag.

Seeding rates are those of the conventional alfalfa farming cost studies used as comparison.

b) Glyphosate costs

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<sup>40</sup>One commenter to APHIS EIS NOI gives the value of US\$6.50 (comment tracking # 803a981a).

Glyphosate prices used in the scenarios area based on those reported by USDA NASS for the same year of the non-GT study being used:

**Table K-9. Glyphosate Prices, 1998-2008, \$ / gallon**

| 1998  | 1999  | 2000  | 2001  | 2002  | 2003  | 2004  | 2005  | 2006  | 2007  | 2008  |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 56.30 | 45.50 | 43.30 | 44.50 | 43.50 | 43.30 | 39.70 | 33.80 | 29.30 | 28.90 | 40.50 |

USDA, NASS, Agricultural Prices, various years.

In 2008, prices of glyphosate seem to have rebounded from a few years of reduced prices.

The number of glyphosate applications used in the scenarios is one or two per year at 22 ounces/acre. One application a year would then require 0.172 gallons and two applications would require 0.344 gallons. These volumes correspond to those used by several of the trials previously reviewed.

c) Weed content

In this exercise, we assume no glyphosate resistance and only glyphosate is used as a herbicide. We leave considerations regarding the potential need for additional herbicides for section 4, where we consider the impact of herbicide resistance to glyphosate. With one or two applications of glyphosate at 22 ounces/acre there is a range of possible results in terms of weed content in the final product, as reviewed above. Improvements in weed content are built into the scenarios as increases in the quality of hay (for example, from good to premium or to supreme) with reflections on prices, according to USDA available alfalfa hay prices for the relevant locality and year. We consider a range of scenarios, from no improvement at all in quality to improvements to supreme alfalfa hay quality.

Table K-10 is intended as an illustrative exercise regarding the possible impact of using GT alfalfa and is not applicable to all situations. It is based on the same circumstances assumed by the UC Cooperative Extension study, while altering seed prices, herbicide use and hay prices.

**Table K-10. Scenarios for GT Alfalfa**

|                                             | Conventional | 1 glyphosate application |          | 2 glyphosate applications |          |
|---------------------------------------------|--------------|--------------------------|----------|---------------------------|----------|
|                                             |              | GT (l)                   | GT (h)   | GT (l)                    | GT (h)   |
| Sales (8 tons/acre)                         | 1480         | 1560                     | 1480     | 1560                      | 1480     |
| Total operating costs/ acre                 | 685.00       | 619.16                   | 620.88   | 624.32                    | 627.76   |
| Return over operating costs                 | 795.00       | 940.84                   | 859.12   | 935.68                    | 852.24   |
| Cash overhead costs                         | 165.00       | 165.00                   | 165.00   | 165.00                    | 165.00   |
| Annual cost recovery: alfalfa establishment | 147.00       | 164.48                   | 177.41   | 165.91                    | 179.32   |
| Annual cost recovery: other                 | 549.00       | 549.00                   | 549.00   | 549.00                    | 549.00   |
| Total costs/acre                            | 1,546.00     | 1,497.64                 | 1,512.29 | 1,504.23                  | 1,521.08 |
| Return over total costs                     | -66.00       | 62.36                    | -32.29   | 55.77                     | -41.08   |

Source: column two from Frate et al., 2008; other columns added.

Columns three and four assume one glyphosate application during the establishment year, columns five and six assume two. Low cost scenarios (l) assume seeds cost US\$6/lb and glyphosate US\$30/ gallon, while the high cost scenarios (h) assume seeds cost US\$7.50/lb and glyphosate US\$40/ gallon. Seed prices already incorporate the technology fee (trait premium) of US\$ 150 per 50 lb bag. Each glyphosate application is assumed to use 22 ounces/acre. The high cost scenario also assumes GT alfalfa generated no benefits in terms of alfalfa quality. The low cost scenario assumes GT alfalfa improved alfalfa quality. Alfalfa that in the UC Cooperative Extension study was assumed to be sold as premium quality will be sold, under the low cost scenario, as supreme quality. Prices are based on those of the USDA AMS, 2007 California Market Summary, where prices for alfalfa hay in the San Joaquin Valley averaged around US\$185/ ton for premium and US\$195/ ton for supreme qualities.

This result depends on the assumptions made regarding the use of herbicides. One way of relaxing these assumptions is by increasing the use of glyphosate applications. Six applications

of glyphosate through the crop year at the high price scenario (or the equivalent addition in cost of other herbicides) would be required for GT alfalfa production costs to surpass those of conventional production, under these specific conditions.

Table K-11 shows the GT alfalfa results suggested by the Wisconsin study reviewed above, as well as extends the exercise to various additional scenarios regarding GT alfalfa. Again, it is intended only as an illustrative exercise regarding the possible impact of using GT alfalfa and is not applicable to all situations. It is based on the same circumstances assumed by Dan Undersander in his study, while altering seed prices, herbicide use and prices, and alfalfa hay prices in the indicated columns. Numbers are rounded to allow for space in table.

**Table K-11. Scenarios for GT Alfalfa**

|                                                  |             |             |             | a           |             | b           |             | C           |             |
|--------------------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
|                                                  | Conv.       | GT          | GT*         | Conv.       | GT          | Conv.       | GT          | Conv.       | GT          |
| Seed cost/ 50 lb bag (\$)                        | \$200       | \$250       | \$250       | \$200       | \$250       | \$200       | \$250       | \$200       | \$250       |
| Pounds of seed per acre                          | 12          | 12          | 12          | 12          | 12          | 12          | 12          | 12          | 12          |
| Technology fee/bag (\$/bag)                      | \$0         | \$125       | \$125       | \$0         | \$125       | \$0         | \$125       | \$0         | \$125       |
| Yield in seeding year (t/a DM)                   | 3.5         | 3.5         | 3.5         | 3.5         | 3.5         | 3.5         | 3.5         | 3.5         | 3.5         |
| Herbicide cost (\$/acre/application)             | \$20        | \$6         | \$6         | \$20        | \$6         | \$20        | \$7         | \$20        | \$7         |
| Herbicide application cost (\$/acre)             | \$10        | \$10        | \$10        | \$10        | \$10        | \$10        | \$10        | \$10        | \$10        |
| Number of herbicide applications                 | 1           | 1           | 1           | 2           | 2           | 2           | 2           | 1           | 1           |
| Value of ease of roundup use (\$/acre)           | \$0         | \$0         | \$0.0       | \$0.0       | \$0.0       | \$0.0       | \$0.0       | \$0.00      | \$0         |
| Yield depression from pursuit/raptor (t/a DM)    | 0.3         | 0.0         | 0.0         | 0.3         | 0.0         | 0.3         | 0.0         | 0.3         | 0.0         |
| Expected stand life (yrs including seeding year) | 3           | 3           | 3           | 3           | 3           | 3           | 3           | 3           | 3           |
| Value of hay (per ton DM)                        | \$100       | \$100       | \$100       | \$100       | \$100       | \$100       | \$100       | \$100       | \$110       |
| Fixed costs per acre per year                    | \$180       | \$180       | \$180       | \$180       | \$180       | \$180       | \$180       | \$180       | \$180       |
| Harvesting costs per acre per harvest            | \$35        | \$35        | \$35        | \$35        | \$35        | \$35        | \$35        | \$35        | \$35        |
| Number of harvests                               | 2           | 2           | 2           | 2           | 2           | 2           | 2           | 2           | 2           |
| <b>Seeding Year Production Costs/Results</b>     |             |             |             |             |             |             |             |             |             |
| Seed cost (prorated + tech fee) per acre         | \$16        | \$50        | \$30        | \$16        | \$50        | \$16        | \$50        | \$16        | \$50        |
| Total seed and herbicide cost per ton of hay     | \$14        | \$19        | \$13        | \$23        | \$23        | \$23        | \$24        | \$14        | \$19        |
| TOTAL COST PER TON OF HAY SEEDING YEAR           | \$86        | \$90        | \$85        | \$95        | \$95        | \$95        | \$95        | \$86        | \$91        |
| <b>PROFIT PER ACRE - SEEDING YEAR</b>            | <b>\$50</b> | <b>\$34</b> | <b>\$54</b> | <b>\$17</b> | <b>\$18</b> | <b>\$17</b> | <b>\$16</b> | <b>\$50</b> | <b>\$68</b> |

Source: first two data columns from Integrated Pest Crop Management, University of Wisconsin; remaining columns elaborated from the base numbers.

\* Original numbers - shown in the first two columns - prorate seed cost over life of stand but leave full technology fee in seeding year. We maintain this assumption, except for in the third column where we prorate the technology fee as well.

a. Two herbicide applications.

b. Two herbicide applications and glyphosate at \$40/ gallon

c. One application, glyphosate at \$40/ gallon and improved hay quality: \$110/ ton, a 10% increase in price. Data from various Midwestern markets<sup>42</sup> suggest \$100/ ton was the price paid for good quality hay within the last year, while premium quality hay would go for 15-35% more, so the quality improvement assumed is quite modest.

In table K-10 we see an improvement in returns over total costs in all scenarios with the use of GT alfalfa. Depending on the specific scenario, the improvement is the result from lower herbicide costs, improved hay quality, or both. In table K-11 Dan Undersander's scenario or reduced GT profit per acre in the seeding year is dependent on not distributing the cost of the technology fee throughout the life of the stand. If this is done, GT alfalfa shows improved profit per acre, suggesting that even in Undersander's scenario, profit per acre would be higher for GT

<sup>42</sup> Pipetone, Minnesota, Hay and Straw Auction; Midwest Hay and Straw Auction, Maurice, Iowa.

alfalfa in years following that of the seeding year. In the remaining scenarios, in two of the three cases, GT alfalfa increased profits in the seeding year, even if the cost of the technology fee were not distributed through the life of the stand.

## 2.3 Summary of Findings

Farming conditions for alfalfa forage vary considerably throughout the United States and we have not identified major cost elements that dominate farming costs under most circumstances. Percentage changes in yields or forage prices have a much greater impact on returns to alfalfa farming for forage than equivalent percent changes in any cost factors. Economies of scale in land preparation mean that technologies (seed varieties) that require more land preparation would be more attractive (and of larger benefit) to larger farms.

GT alfalfa production for forage will have impacts on the cost of seed and the cost of herbicide use. There is also enough evidence to suggest possible benefits on the quality of hay that would presumably lead to higher sales prices. Alfalfa forage farmers aiming at maximizing returns during the time horizon of an alfalfa life stand would likely benefit financially from the adoption of GT alfalfa.

## **3.0 Changes in Alfalfa Seed Farming**

### **3.1 Conventional Alfalfa Seed Farming**

Unlike alfalfa hay production, alfalfa seed production is largely concentrated both geographically and in number of producers. The latest complete information on alfalfa seed production comes from the 2007 Census of Agriculture, when 121,467 acres of alfalfa seed were harvested producing approximately 62 million tons of seeds at an average productivity of approximately 510 lbs/ acre. California was responsible for 31% of this production, Washington 17%, and Idaho 15%, with over 60% of production concentrated in those three states and the remaining also highly concentrated in Western states (Nevada, Oregon, Wyoming, Montana, and Utah). Mueller (Undated a) suggests California's share of production has fallen in recent years and a larger share is coming from the Northwestern states. In 2007, production came from 806 farms. This means that farming conditions for alfalfa seed production are likely more homogeneous than alfalfa hay farming.

However, there still is some variation. Non-dormant varieties of seed tend to be grown in California while dormant varieties are mostly grown in the Pacific Northwest (Mueller, 2005a). Varieties can be proprietary (grown under contract) or public, although almost all varieties today are developed and marketed by private breeding companies (Bouton, 1998). Seeds can also be certified or not.

Alfalfa seed acreage and production increased between 2007 and 2002, reversing the trend of decreases in alfalfa seed production over the last few years. Mueller (2008) attributes reduction in alfalfa seed acreage in California to "changes in economics, environmental constraints, and regulatory issues." Mueller (Undated a) lists among difficulties of alfalfa seed farming in California scarcity of water for crop irrigation and lack of development of new chemicals for insect control due to high registration costs. However, between 2007 and 2002, California gained almost 10,000 acres of alfalfa seed production.

Some farmers grow alfalfa seed as an option to an already existing alfalfa hay stand, allowing the stand to go to seed at the end of the stand life or when there is little water. According to Mueller (2005b) this is the case of most of the seed produced in the Imperial Valley (California), about half of the non-certified seed produced in Utah and much of the dryland seed produced in Montana. This seed would typically not receive certification.

Despite this mixed purpose of many alfalfa fields that generate seeds, there are clear differences in best practices for managing alfalfa for forage and for seed. Dense stands produce higher forage yields but lesser seed yields than thinner stands – as when alfalfa is planted in rows as opposed to solid planting – and certain chemicals used in seed production limit the use of the field for forage (Mueller, 2008). Alfalfa seed farmers also have some costs that are not present in alfalfa hay farming: some insects are only of concern for alfalfa seed production (Mueller, Undated a) and costs with pollination (bees) are considerable since alfalfa is dependent on bees for pollination. Honey bees are cheaper than leafcutter bees or alkali bees but require a long



season for pollination and are therefore only used in California. Leafcutter bees and alkali bees are also more efficient pollinators, although more expensive (Mueller, 2008). Leafcutter bees also have “higher labor requirements, significant annual fluctuations in bee prices, the need for incubation, housing, and net material, as well as a greater sensitivity to pesticides” (Mueller, 2008).

With respect to weeds, the separation of weed seeds from alfalfa seeds after harvesting is costly and control of weeds in the fields is given preference over post-harvest screening and separation (Mueller, Undated b). No primary or secondary noxious weeds are allowed for certified seed and dodder is of particular importance since it may be difficult to control (Mueller, 2008).

Another important difference between alfalfa hay and alfalfa seed production is that the quality of seed (germination, yield, dormancy and other varietal properties) are not readily observable at the moment of purchase and mechanisms come into place to offer clients (and breeding companies) assurance that seeds sold as pertaining to one variety or another will perform as expected. State Crop Improvement Associations – or sometimes Seed Grower Associations – provide certifications that seed production followed minimum standards such as isolation between different alfalfa varieties, absence of prohibited noxious weeds in the field, inspection of conditioning (separation) facilities, maintaining traceability of seed lots and seed testing.

Finally, an important cost in seed production is the seed itself. The development of crop varieties became a predominantly private activity in the past 30 years (Fernandez-Cornejo and Schimmelpenninck, 2004) and the Plant Protection Variety Act of the early 1970s simulated cultivar development in alfalfa (Bouton, 1998). Today almost all new alfalfa cultivars are proprietary.

We have not been able to identify the share of final seed prices represented by such contracts. This is an important aspect to be analyzed and will be dealt with to some extent in future Technical Reports where the possible consequences of supply and demand shifts in the seed market will be discussed. The cost studies reviewed below do seem to address the contracts between seed producers and seed breeding companies.

### *3.1.1 Cost studies*

One 1985 cost study for Fresno, California (Sheesley, 1985) found land rental to be the highest cost component (16.8%) of total annual production cost per acre, followed by irrigation (15.7%), harvesting costs (13.5% - including processing and certification), recovery of capital costs (10.9% - including stand establishment), insect control (9.6%) and pollination (6.7%).

Two cost studies for seed production are available from the University of Nevada Cooperative Extension (Kettle, Myer and Breazeale, 1999a and Kettle, Myer and Breazeale 1999b). Both were done at the end of 1998, one assuming a 250 acre alfalfa seed farm in Pershing County, the other a 750 acre farm in Humboldt County. These studies show pollinators (bees) accounting for roughly 30% of annual production costs and insect control accounting for another 10%, with weed control costs below 10% of the total.

A more recent study is available for Imperial County, California, from the University of California Cooperative Extension (Meister 2004). This study assumes that seeds will be produced for one year from an existing stand of alfalfa hay, noting that “most alfalfa seed is produced from hay fields that will be rotated to another crop in the fall.” Establishment costs are, therefore, absent in the study. Seeds are likely of a non-dormant variety and honey bees are used for pollination. Costs included are considered “typical” for the region, but an excel sheet is provided for farmers to not only fill in with their own costs by complement with additional line items that may have not been included in the study.

Table K-12 below shows the main cost items reported, with the last column showing the percentage total that each line item represents of the total costs.

**Table K-12. Alfalfa Seed Production Costs**

|                              | <b>\$/ acre</b> | <b>% of total costs</b> |
|------------------------------|-----------------|-------------------------|
| Irrigation                   | 35.81           | 7.88%                   |
| Insect Control               | 77.00           | 16.95%                  |
| Pollination                  | 84.00           | 18.49%                  |
| TOTAL GROWING PERIOD COSTS   | 196.81          | 43.32%                  |
| TOTAL HARVEST COSTS          | 108.18          | 23.81%                  |
| Land rent                    | 115.00          | 25.31%                  |
| Cash Overhead                | 34.30           | 7.55%                   |
| TOTAL CASH OVERHEAD COSTS    | 149.30          | 32.86%                  |
| <b>TOTAL CASH COSTS/ACRE</b> | <b>454.29</b>   | <b>100.00%</b>          |

Source: Meister, 2004

Pollination appears as the main operational cost followed by insect control. Overhead cash costs are a third of total and capital recovery costs are not included. Harvest costs are calculated at a 600 lb yield per acre. At a \$1 market value per lb, returns over total cash costs would be \$145.71/ acre. As in the case of alfalfa hay, returns are mostly affected by yield and sales price variations, as shown in table K-13.

**Table K-13. Sensitivity of Returns in Alfalfa Seed Production**

|     | <b>Insect control</b> | <b>Pollination</b> | <b>Irrigation</b> | <b>Yield*price</b> |
|-----|-----------------------|--------------------|-------------------|--------------------|
| 0*  | 145.71                | 145.71             | 145.71            | 145.71             |
| 10% | 138.01                | 137.31             | 142.13            | 205.71             |
| 20% | 130.31                | 128.91             | 138.55            | 265.71             |
| 30% | 122.61                | 120.51             | 134.97            | 325.71             |
| 40% | 114.91                | 112.11             | 131.39            | 385.71             |

Source: elaborated from the data in Meister 2004

\*Initial scenario assumes a yield of 600 lb/ acre at \$1/ lb.

A 2005 cost study is also available from the University of Idaho and the costs reported are considered typical for the southwestern part of the state (Rimbey et al, 2005). The study assumes a farm with 150 acres of alfalfa seed over a three year period (life of stand). Table K-14 summarizes the results. Pollination accounts for 25.1% of the operating costs, followed by insecticides at 16.5%. Irrigation and herbicides are just below 10% of total operating costs each.

**Table K-14. Returns to Alfalfa Seed Production, \$/ acre**

|                                          |               |
|------------------------------------------|---------------|
| Gross returns                            | 875           |
| Pollination                              | 160           |
| Insecticides and application             | 105.65        |
| Herbicides and application               | 59.36         |
| Irrigation                               | 61.08         |
| Operating costs                          | 637.36        |
| Land rent                                | 44            |
| Cash ownership costs (overhead)          | 210.98        |
| Amortized establishment                  | 39.79         |
| Non-cash ownership costs (cost-recovery) | 68.01         |
| Total costs                              | 916.35        |
| <b>Returns over operating costs</b>      | <b>237.64</b> |
| <b>Returns over total costs</b>          | <b>-41.35</b> |

Source: Rimbey et al, 2005

Table K-15 below shows how, again, yield and sales price of seeds have a much greater influence on returns than individual cost components.

**Table K-15. Sensitivity of Returns in Alfalfa Seed Production**

|     | <b>Insect control</b> | <b>Pollination</b> | <b>Irrigation</b> | <b>Weed control</b> | <b>Yield*price</b> |
|-----|-----------------------|--------------------|-------------------|---------------------|--------------------|
| 0   | -41.35                | -41.35             | -41.35            | -41.35              | -41.35             |
| 10% | -51.92                | -57.35             | -47.46            | -47.29              | 46.15              |
| 20% | -62.48                | -73.35             | -53.57            | -53.22              | 133.65             |
| 30% | -73.05                | -89.35             | -59.67            | -59.16              | 221.15             |
| 40% | -83.61                | -105.35            | -65.78            | -65.09              | 308.65             |

Source: elaborated from data in Rimbey et al, 2005

### 3.2 GT Alfalfa Seed Farming

The main possible advantage of GT alfalfa for seed production is in weed control. Canevari (2007) notes that the possibility of controlling post emergence dodder before seeding and without injury to alfalfa “would be a significant breakthrough.” However, as noted in the cost studies above, weed control, although fundamental for seed acceptance in the market, is a lesser cost in seed production than other operational costs such as pollination and insect control.

Putnam (2007) notes that the seed industry met in 2007 to discuss more stringent isolation distances for GT alfalfa seed production, given the current concerns with gene flow. Current isolation standards for certified seeds is 165 feet, with tolerance of 10% of the field within the isolation zone (Mueller, 2008). An increase in the isolation distance would have a cost impact on alfalfa seed production, since land rental is often a major cost component.

Our analysis of the impact of GT alfalfa on seed production is limited by lack of more information on breeder company – producer contracts. Benefits or costs to farmers in seed production will likely ultimately be determined by the contracts obtained with breeder companies. These contracts must provide sufficient financial returns to seed farmers so they will engage in the activity. However, bargaining conditions depend on market conditions of

supply and demand and competition between varieties (and breeder companies) may be highly affected by GT deregulation. To the extent possible, we will revisit this issue when we analyze potential supply and demand impacts of GT deregulation in future reports, in case any insights may be drawn from that analysis.

### 3.3 Summary of Findings

Alfalfa seed production is relatively concentrated geographically in the Northwestern part of the country and benefits from specific climatic conditions. Land costs, pollination and insect control tend to be major cost factors with irrigation and herbicide also important depending on location.

The impacts of GT alfalfa adoption for seed production depend on conditions established by the breeder company – producer contracts, that in turn will likely be more or less favorable to producers depending on market (supply and demand) conditions.

## 4.0 Proliferation Over Time of Glyphosate-Resistant Weeds

The analysis done in sections 2 and 3 look at short-term costs and returns of alfalfa farming and are limited to the life of stands. The choice a farmer faces of planting one or another crop must often consider costs and benefits beyond this time horizon. Farmers must, for example, take into consideration the long term value of their lands (soil fertility) as well as how crop rotation choices affect their expected long-term returns and exposure to risk, since some crops may not be substituted by others or even not be planted repeatedly on the same plot (alfalfa is an example due to autotoxicity). It is therefore important to include longer term considerations regarding the potential impact of GT alfalfa on the economics of alfalfa farming.

One long-term consideration is the limitation on crop-rotation. Since GT alfalfa cannot be removed with glyphosate, other methods must be used, whether mechanical, chemical or a combination of these. Orloff and Putnam (1997) suggest plowing is actually the most common method for alfalfa stand removal. However, when herbicides are used for removal, glyphosate seems to be the most commonly used (Canevari 2004). In our Technical Report *Effects of Glyphosate-Tolerant Weeds in Agricultural Systems* (appendix G), we note that potential substitutes for glyphosate in stand removal may limit the following crop of choice. This limitation may have a greater or lesser impact on long term farm profits depending on market circumstances (basically, what would be the crop of choice at a given point in time given expected returns).

Based on the comments to APHIS' Notice of Intent to prepare an Environmental Impact Statement, the long-term issue of greater concern, however, seems to be the impact of a potential increased presence of glyphosate resistant weeds over time, mostly through weed shift. Glyphosate is used to control weeds in GT alfalfa as well as in crops with which alfalfa is rotated (such as GT corn and GT soybeans). If the use of GT alfalfa leads to an increased presence of glyphosate resistant weeds, then glyphosate will have to be substituted or complemented in farming, not only for control of weeds in GT alfalfa fields, but may also for the control of weeds in those crops with which it is rotated.

Based on the cost studies presented in section 2, an increase in the presence of glyphosate resistant weeds in alfalfa fields, requiring the use of other herbicides for control of such weeds, would have the impact of an increase in production costs. In a worst case scenario, GT alfalfa would be treated as in a conventional system and result in alfalfa hay of quality similar to that of a conventional system. The price of the alfalfa seed would then likely also have to be reduced for the survival of the variety in the market.

There is some literature on the costs of herbicide use in GT crops that have been adopted earlier. An increase in herbicide costs over time in these crops would likely reflect cost effects of increased presence of GT resistant weeds. However, we have found no indication of such an increased cost to date. Brooks and Barfoot (2005) report that after 9 years of use of GT soybeans estimates of cost savings actually increased with savings mostly attributed to reduced herbicide costs. They also report continued cost savings with herbicides in the US after eight years of use of herbicide-tolerant cotton (mostly GT) and after six years of use of GT canola.

The continued savings in herbicide costs in GT crops to date does not mean absence of an increase in herbicide resistance, since costs depend not only on the volume of herbicide used but also on prices. It also does not mean increased costs would not still occur in the future. It only means that, to date, we found no evidence of a reversal in the herbicide cost reductions generally identified in GT crops in the United States.

It must also be noted that reduced costs with herbicides do not necessarily mean increased economic returns. Fernandez-Cornejo and McBride (2002) noted that the literature on the economic impact of GT soybeans in the United States is mixed and some farmer surveys show reduced herbicide costs being offset by higher technology fees. The long-term impact of supply and demand and changes in technology fees will impact returns obtained by farmers with GT alfalfa adoption. In future Technical Reports we will revisit this issue to the extent that analysis of supply and demand considerations allow additional inferences to be made.

#### 4.1 Summary of Findings

The increased returns expected for GT alfalfa farming in the short run may or may not continue with time. This depends on market considerations (including technological fees), limitations to crop rotation and cost impacts of any possible increased weed resistance over time. We have found no evidence of increased herbicide costs in GT crops of earlier adoption such as soybeans, cotton, canola and corn.

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## **Appendix K-2. Literature Search**

### **1.0 Literature Search Strategy**

For cost studies on alfalfa hay and seeds, as well as for the evidence on traits of GT alfalfa as compared to conventional alfalfa varieties we searched:

a) Various university (and cooperative extension) linked alfalfa portals and alfalfa symposium proceedings including:

- The California Alfalfa Workgroup: <http://alfalfa.ucdavis.edu/>
- The University of California Alfalfa Seed Production Homepage: <http://alfalfaseed.ucdavis.edu>
- University of Wisconsin Forage Research and Extension: <http://www.uwex.edu/ces/forage/>
- Oklahoma Alfalfa Page (Oklahoma State University): <http://alfalfa.okstate.edu/>
- University of Nevada Cooperative Extension: <http://www.unce.unr.edu/>
- North American Alfalfa Improvement Conference: <http://www.naaic.org>
- 2007 37th California Alfalfa and Forage Symposium: <http://alfalfa.ucdavis.edu/2007AlfalfaConference>
- 2006 Western Alfalfa and Forage Conference: <http://alfalfa.ucdavis.edu/2006AlfalfaConference>
- San Joaquin University of California Cooperative Extension: [http://cesanjoaquin.ucdavis.edu/Agriculture/Publications,\\_Research\\_Reports.htm](http://cesanjoaquin.ucdavis.edu/Agriculture/Publications,_Research_Reports.htm)

b) Producer related association websites:

- National Alfalfa and Forage Alliance: <http://www.alfalfa.org/>
- Nebraska Alfalfa Marketing Association: <http://www.nebraska-alfalfa.com/>
- Washington State Hay Growers Association: <http://www.wa-hay.org>

c) Specialized magazines:

- Western Farm Press: <http://westernfarmpress.com/>
- Hay and Forage Grower: <http://hayandforage.com/>

d) Search engines:

- [www.scirus.com](http://www.scirus.com)
- [www.scholar.google.com](http://www.scholar.google.com)

e) Academic journals including, but not limited to:

- The American Journal of Agricultural Economics
- Journal of Agricultural Economics
- Agronomy Journal
- Journal of Agronomy and Crop Science
- Journal of Agronomy

For information on the weed content of alfalfa hay, we took advantage of a search of specialized journals and databases previously done for other Technical Reports<sup>43</sup>.

For data on alfalfa hay prices we used USDA's Agricultural Marketing Service and its Livestock and Grain Hay Reports.

The North American Alfalfa Improvement Conference has a page with links to alfalfa variety test websites in over 20 state: <http://www.naaic.org/Resources/yields.htm>.

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<sup>43</sup> Search done for Technical Reports: Effects of Glyphosate Tolerant Weeds in Agricultural Systems (Appendix G) and Effects of Glyphosate Tolerant Weeds in non-Agricultural Ecosystems (Appendix H).

## **Appendix K-3.       Likelihood of Benefits of GT Alfalfa Forage by County**

The analysis presented in section 2 suggests GT alfalfa may offer benefits to alfalfa forage farmers in the form of increased quality of forage with decreased herbicide costs. In this appendix we attempt to identify those counties that would most likely benefit from GT alfalfa deregulation, based solely on these cost-return considerations. Any other costs and benefits of GT deregulation are not included in the exercise because they are not part of the scope of this report.

As this Technical Report has not addressed market (demand) restrictions to GT alfalfa (exports, for example), the exercise also abstracts of any demand considerations that may change the potential benefits to farmers of GT alfalfa adoption.

Within these constraints, we offer this exercise as an attempt to rank counties according to the short-term economic benefits accrued to farmers from GT adoption. To the extent possible, we will attempt to refine this analysis when addressing demand (international, GT sensitive, organic) in future Technical Reports.

This exercise assumes the greater the acreage of farms producing alfalfa for forage and the greater the amount of herbicide used on those farms, the more likely farmers of that county will benefit from GT alfalfa deregulation. Herbicide use is seen as an indicator of benefits of GT alfalfa adoption for any of the following reasons: a) greater use of herbicides indicates weeds are a problem in need of management and GT alfalfa weed control is cheaper; or b) greater use of herbicides indicates markets demand cleaner alfalfa and GT alfalfa favors alfalfa hay with a lesser weed content; or c) both. As we cannot claim the same relevance of herbicide use as an indicator of benefit to alfalfa seed farms, this exercise does not include alfalfa seed acreage<sup>44</sup>.

County level data on alfalfa acreage and on herbicide use is available from the 2007 Agricultural Census. The indicator used was built as follows:

1. We identified the share of farming acreage used for alfalfa forage (hay or haylage) in a county: likelihood that a randomly picked acre in the county is planted with alfalfa for forage (a);
2. We identified the share of farming acreage treated with herbicide in a county: likelihood that a randomly picked acre in the county was treated with herbicides in 2007 (b);
3. We excluded those counties with 0 alfalfa forage acreage<sup>45</sup>;
4. We excluded those counties with non-disclosed data for alfalfa hay or herbicide use<sup>46</sup>;

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<sup>44</sup> Herbicides are more homogeneously used in seed production so this is less of a distinction between alfalfa farms than in forage. Additionally, we were not able to identify as clearly the benefits of GT alfalfa adoption by alfalfa seed farmers.

<sup>45</sup> This was done to differentiate from alfalfa farms with 0 herbicide use in (c)

5. We multiplied (a) and (b), after the exclusions were made: likelihood that a randomly picked acre in the county will both be used for forage alfalfa and treated with herbicides (c);
6. We ranked counties according to (c).

The indicator is highly imperfect and counties highly ranked could presumably reflect herbicide use for other crops co-existing with alfalfa fields with little herbicide use (although, to the extent that weed presence is determined by local environmental conditions, there is likely a correlation between weed issues among crops planted next to each other).

The results are presented in the following pages. Blank cells represent undisclosed data (data withheld to protect identity of individual farms).

Among the top 100 counties, a considerable share is also found in Wisconsin, including the number one ranking county (Brown County, Wisconsin) where alfalfa acreage is high and the use of herbicide may be explained by the importance of dairy farms as consumers of high quality (lesser weed content) alfalfa. The relative scarcity of counties from California among the top ranked counties (with the notable exception of Imperial County) may be explained by the lesser acreage devoted to alfalfa in that state compared to states in the North Central region. If the rankings were done by value of production rather than by acreage, the results would presumably show a greater presence of counties in western states among the top ranked, since yields in that region tend to be higher.

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<sup>46</sup> We did not do the same for lack of alfalfa haylage data since this would have excluded most counties. For the great majority of counties, alfalfa haylage acreage is a small fraction of hay acreage.

**Table K-16. Alfalfa Forage Using Herbicide**

| County                   | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|--------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Wisconsin\Brown          | 81102                       | 31942                                | 35056                                    | 187167           | 35.80%                                         | 43.33%                                          | 15.5108%           |
| California\Imperial      | 213794                      | 127406                               |                                          | 427349           | 29.81%                                         | 50.03%                                          | 14.9149%           |
| Idaho\Jerome             | 86594                       | 42265                                | 10812                                    | 188753           | 28.12%                                         | 45.88%                                          | 12.9005%           |
| Wisconsin\Calumet        | 72759                       | 17330                                | 23125                                    | 151659           | 26.67%                                         | 47.98%                                          | 12.7974%           |
| Wisconsin\Kewaunee       | 70795                       | 21439                                | 33933                                    | 175449           | 31.56%                                         | 40.35%                                          | 12.7348%           |
| Wisconsin\Manitowoc      | 104866                      | 33608                                | 38579                                    | 248238           | 29.08%                                         | 42.24%                                          | 12.2845%           |
| Nevada\Esmeralda         | 5799                        | 12114                                |                                          | 24943            | 48.57%                                         | 23.25%                                          | 11.2913%           |
| Wisconsin\Fond du Lac    | 161464                      | 32834                                | 40740                                    | 335745           | 21.91%                                         | 48.09%                                          | 10.5386%           |
| Wisconsin\Outagamie      | 123605                      | 24407                                | 27812                                    | 247482           | 21.10%                                         | 49.95%                                          | 10.5385%           |
| Wisconsin\Sheboygan      | 81956                       | 21457                                | 25732                                    | 191719           | 24.61%                                         | 42.75%                                          | 10.5218%           |
| Wisconsin\Green          | 125391                      | 40730                                | 31904                                    | 306859           | 23.67%                                         | 40.86%                                          | 9.6723%            |
| Wisconsin\Washington     | 54743                       | 15263                                | 12978                                    | 129790           | 21.76%                                         | 42.18%                                          | 9.1775%            |
| New York\Genesee         | 82787                       | 14764                                | 20592                                    | 183539           | 19.26%                                         | 45.11%                                          | 8.6890%            |
| Wisconsin\Shawano        | 88160                       | 39061                                | 33614                                    | 271718           | 26.75%                                         | 32.45%                                          | 8.6780%            |
| Michigan\Missaukee       | 24973                       | 12690                                | 13119                                    | 88364            | 29.21%                                         | 28.26%                                          | 8.2545%            |
| Wisconsin\Dodge          | 214064                      | 33870                                | 30828                                    | 412949           | 15.67%                                         | 51.84%                                          | 8.1216%            |
| Idaho\Minidoka           | 138690                      | 29381                                |                                          | 226161           | 12.99%                                         | 61.32%                                          | 7.9667%            |
| Ohio\Wayne               | 106635                      | 26699                                | 19122                                    | 248409           | 18.45%                                         | 42.93%                                          | 7.9183%            |
| Wisconsin\Ozaukee        | 27035                       | 7177                                 | 7408                                     | 70689            | 20.63%                                         | 38.24%                                          | 7.8909%            |
| Pennsylvania\Lancaster   | 199696                      | 40155                                | 31107                                    | 425336           | 16.75%                                         | 46.95%                                          | 7.8662%            |
| Wisconsin\Portage        | 119750                      | 32179                                | 18999                                    | 281575           | 18.18%                                         | 42.53%                                          | 7.7298%            |
| Arizona\Yuma             | 131844                      | 25789                                |                                          | 210480           | 12.25%                                         | 62.64%                                          | 7.6749%            |
| Wisconsin\Dane           | 259883                      | 38492                                | 44366                                    | 535756           | 15.47%                                         | 48.51%                                          | 7.5020%            |
| Wisconsin\Clark          | 128881                      | 48558                                | 61774                                    | 440376           | 25.05%                                         | 29.27%                                          | 7.3323%            |
| New York\Ontario         | 82320                       | 16214                                | 18892                                    | 198937           | 17.65%                                         | 41.38%                                          | 7.3022%            |
| Idaho\Gooding            | 75078                       | 33174                                | 15138                                    | 223068           | 21.66%                                         | 33.66%                                          | 7.2894%            |
| Wisconsin\Oconto         | 69041                       | 23644                                | 20866                                    | 205924           | 21.61%                                         | 33.53%                                          | 7.2469%            |
| Wisconsin\Lafayette      | 141382                      | 37054                                | 23051                                    | 342617           | 17.54%                                         | 41.27%                                          | 7.2391%            |
| Wisconsin\Marathon       | 136630                      | 59852                                | 63572                                    | 490628           | 25.16%                                         | 27.85%                                          | 7.0055%            |
| New York\Wyoming         | 65995                       | 15007                                | 35401                                    | 218028           | 23.12%                                         | 30.27%                                          | 6.9982%            |
| Wisconsin\Winnebago      | 75823                       | 13902                                | 10891                                    | 164014           | 15.12%                                         | 46.23%                                          | 6.9882%            |
| Pennsylvania\Lebanon     | 55609                       | 6328                                 | 9593                                     | 113486           | 14.03%                                         | 49.00%                                          | 6.8743%            |
| Wisconsin\Waupaca        | 74421                       | 26250                                | 24448                                    | 234392           | 21.63%                                         | 31.75%                                          | 6.8675%            |
| Idaho\Canyon             | 107028                      | 40654                                | 2118                                     | 260247           | 16.44%                                         | 41.13%                                          | 6.7590%            |
| Wisconsin\Waukesha       | 48159                       | 7980                                 | 2322                                     | 86602            | 11.90%                                         | 55.61%                                          | 6.6152%            |
| Pennsylvania\Northampton | 37668                       | 6393                                 | 1781                                     | 68252            | 11.98%                                         | 55.19%                                          | 6.6096%            |
| Pennsylvania\Union       | 21702                       | 5508                                 | 6864                                     | 63795            | 19.39%                                         | 34.02%                                          | 6.5973%            |
| New York\Cayuga          | 86483                       | 22629                                | 24824                                    | 249476           | 19.02%                                         | 34.67%                                          | 6.5938%            |
| Wisconsin\St. Croix      | 117622                      | 31539                                | 21110                                    | 308275           | 17.08%                                         | 38.15%                                          | 6.5163%            |
| Pennsylvania\Franklin    | 101405                      | 15823                                | 21785                                    | 242634           | 15.50%                                         | 41.79%                                          | 6.4779%            |
| Wisconsin\Door           | 42894                       | 16355                                | 10635                                    | 134472           | 20.07%                                         | 31.90%                                          | 6.4023%            |
| Wisconsin\Chippewa       | 106936                      | 40677                                | 33859                                    | 353491           | 21.09%                                         | 30.25%                                          | 6.3787%            |
| Wisconsin\Pepin          | 35662                       | 10380                                | 10312                                    | 108426           | 19.08%                                         | 32.89%                                          | 6.2768%            |

| County                  | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| New York\Wayne          | 67145                       | 6853                                 | 19596                                    | 168471           | 15.70%                                         | 39.86%                                          | 6.2571%            |
| Wisconsin\Marquette     | 47234                       | 16345                                | 7939                                     | 135914           | 17.87%                                         | 34.75%                                          | 6.2094%            |
| Idaho\Jefferson         | 77758                       | 80999                                | 3418                                     | 325380           | 25.94%                                         | 23.90%                                          | 6.2000%            |
| Wisconsin\Barron        | 108425                      | 33529                                | 26147                                    | 324196           | 18.41%                                         | 33.44%                                          | 6.1562%            |
| Indiana\Elkhart         | 106408                      | 10888                                | 4532                                     | 163295           | 9.44%                                          | 65.16%                                          | 6.1534%            |
| Michigan\Clinton        | 177511                      | 12090                                | 13390                                    | 271558           | 9.38%                                          | 65.37%                                          | 6.1334%            |
| Michigan\Isabella       | 92493                       | 20493                                | 4893                                     | 196071           | 12.95%                                         | 47.17%                                          | 6.1077%            |
| Wisconsin\Jefferson     | 129117                      | 17594                                | 10494                                    | 244238           | 11.50%                                         | 52.87%                                          | 6.0796%            |
| Michigan\Muskegon       | 32174                       | 6693                                 | 5030                                     | 79663            | 14.72%                                         | 40.39%                                          | 5.9433%            |
| Wisconsin\Columbia      | 159434                      | 24494                                | 12539                                    | 316193           | 11.71%                                         | 50.42%                                          | 5.9056%            |
| New York\Livingston     | 83142                       | 14895                                | 20200                                    | 222415           | 15.78%                                         | 37.38%                                          | 5.8984%            |
| Michigan\Ogemaw         | 11172                       | 11608                                | 7740                                     | 60941            | 31.75%                                         | 18.33%                                          | 5.8203%            |
| Idaho\Twin Falls        | 144224                      | 68924                                | 8963                                     | 439537           | 17.72%                                         | 32.81%                                          | 5.8145%            |
| Pennsylvania\Blair      | 25363                       | 7171                                 | 10268                                    | 87434            | 19.95%                                         | 29.01%                                          | 5.7858%            |
| Iowa\Dubuque            | 140484                      | 27849                                | 11544                                    | 310817           | 12.67%                                         | 45.20%                                          | 5.7284%            |
| Michigan\Newaygo        | 39410                       | 17641                                | 8090                                     | 133403           | 19.29%                                         | 29.54%                                          | 5.6981%            |
| Michigan\Ionia          | 127429                      | 14552                                | 10854                                    | 238435           | 10.66%                                         | 53.44%                                          | 5.6946%            |
| Michigan\Ottawa         | 73175                       | 14306                                | 8267                                     | 170539           | 13.24%                                         | 42.91%                                          | 5.6794%            |
| Michigan\Sanilac        | 275435                      | 23688                                | 12177                                    | 417083           | 8.60%                                          | 66.04%                                          | 5.6786%            |
| Pennsylvania\Berks      | 95817                       | 16081                                | 13078                                    | 222119           | 13.13%                                         | 43.14%                                          | 5.6630%            |
| Ohio\Stark              | 62076                       | 11775                                | 5558                                     | 138061           | 12.55%                                         | 44.96%                                          | 5.6449%            |
| Michigan\Kent           | 82802                       | 12438                                | 7266                                     | 170117           | 11.58%                                         | 48.67%                                          | 5.6377%            |
| Wisconsin\Marinette     | 38673                       | 16164                                | 14087                                    | 144303           | 20.96%                                         | 26.80%                                          | 5.6182%            |
| Michigan\Livingston     | 43441                       | 9109                                 | 2897                                     | 96419            | 12.45%                                         | 45.05%                                          | 5.6101%            |
| New York\Onondaga       | 42110                       | 13934                                | 16228                                    | 150499           | 20.04%                                         | 27.98%                                          | 5.6076%            |
| Wisconsin\Pierce        | 93048                       | 27961                                | 16094                                    | 271178           | 16.25%                                         | 34.31%                                          | 5.5743%            |
| Minnesota\Stearns       | 283035                      | 65934                                | 32666                                    | 708284           | 13.92%                                         | 39.96%                                          | 5.5629%            |
| Wisconsin\Green Lake    | 69122                       | 8710                                 | 7001                                     | 142757           | 11.01%                                         | 48.42%                                          | 5.3287%            |
| Michigan\Lapeer         | 76439                       | 18243                                | 3294                                     | 176373           | 12.21%                                         | 43.34%                                          | 5.2922%            |
| Wisconsin\Walworth      | 120436                      | 13093                                | 7547                                     | 217593           | 9.49%                                          | 55.35%                                          | 5.2502%            |
| Wisconsin\Sauk          | 109242                      | 36122                                | 25786                                    | 358919           | 17.25%                                         | 30.44%                                          | 5.2498%            |
| Michigan\Alpena         | 16649                       | 17858                                | 5320                                     | 85947            | 26.97%                                         | 19.37%                                          | 5.2240%            |
| Washington\Franklin     | 237495                      | 77441                                | 3598                                     | 609046           | 13.31%                                         | 38.99%                                          | 5.1886%            |
| Michigan\Montcalm       | 111577                      | 20265                                | 7100                                     | 242804           | 11.27%                                         | 45.95%                                          | 5.1791%            |
| Michigan\Jackson        | 93073                       | 15897                                | 2461                                     | 182345           | 10.07%                                         | 51.04%                                          | 5.1388%            |
| Michigan\Allegan        | 149055                      | 16697                                | 9299                                     | 275120           | 9.45%                                          | 54.18%                                          | 5.1193%            |
| Michigan\Mason          | 26033                       | 7128                                 | 4343                                     | 76446            | 15.01%                                         | 34.05%                                          | 5.1099%            |
| Arizona\Maricopa        | 118576                      | 75394                                | 26160                                    | 485469           | 20.92%                                         | 24.43%                                          | 5.1094%            |
| Wisconsin\Dunn          | 123655                      | 35367                                | 24921                                    | 382545           | 15.76%                                         | 32.32%                                          | 5.0942%            |
| Wisconsin\Grant         | 182586                      | 65051                                | 38644                                    | 610914           | 16.97%                                         | 29.89%                                          | 5.0730%            |
| Wisconsin\Rock          | 224276                      | 18102                                | 8636                                     | 344361           | 7.76%                                          | 65.13%                                          | 5.0569%            |
| South Dakota\Yankton    | 176499                      | 29048                                | 594                                      | 322242           | 9.20%                                          | 54.77%                                          | 5.0383%            |
| Pennsylvania\Cumberland | 61951                       | 11577                                | 8496                                     | 157388           | 12.75%                                         | 39.36%                                          | 5.0202%            |



| County                  | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Nevada\Lincoln          | 9734                        | 11039                                |                                          | 46271            | 23.86%                                         | 21.04%                                          | 5.0188%            |
| South Dakota\Clay       | 197236                      | 17946                                |                                          | 266697           | 6.73%                                          | 73.96%                                          | 4.9764%            |
| Wisconsin\Kenosha       | 46546                       | 5693                                 | 1906                                     | 84345            | 9.01%                                          | 55.19%                                          | 4.9719%            |
| Minnesota\Winona        | 96444                       | 27635                                | 20436                                    | 305560           | 15.73%                                         | 31.56%                                          | 4.9655%            |
| Indiana\LaGrange        | 76789                       | 14888                                | 1994                                     | 161709           | 10.44%                                         | 47.49%                                          | 4.9574%            |
| New York\Seneca         | 50689                       | 9509                                 | 6477                                     | 127972           | 12.49%                                         | 39.61%                                          | 4.9479%            |
| Wisconsin\Waushara      | 64217                       | 11379                                | 5635                                     | 148969           | 11.42%                                         | 43.11%                                          | 4.9234%            |
| Michigan\Mecosta        | 25239                       | 21283                                | 4008                                     | 114715           | 22.05%                                         | 22.00%                                          | 4.8506%            |
| Illinois\Jo Daviess     | 139365                      | 23172                                | 4071                                     | 281457           | 9.68%                                          | 49.52%                                          | 4.7927%            |
| Wisconsin\Wood          | 52742                       | 22619                                | 21713                                    | 221962           | 19.97%                                         | 23.76%                                          | 4.7459%            |
| South Dakota\Bon Homme  | 155638                      | 28997                                |                                          | 308583           | 9.40%                                          | 50.44%                                          | 4.7394%            |
| Minnesota\Carver        | 86329                       | 9765                                 | 5903                                     | 169397           | 9.25%                                          | 50.96%                                          | 4.7137%            |
| Wisconsin\Langlade      | 41638                       | 8672                                 | 8365                                     | 122895           | 13.86%                                         | 33.88%                                          | 4.6969%            |
| Ohio\Columbiana         | 41869                       | 13152                                | 6069                                     | 130952           | 14.68%                                         | 31.97%                                          | 4.6929%            |
| Iowa\Winneshiek         | 139022                      | 24548                                | 8630                                     | 313762           | 10.57%                                         | 44.31%                                          | 4.6853%            |
| Michigan\Iosco          | 10722                       | 7702                                 | 2069                                     | 47731            | 20.47%                                         | 22.46%                                          | 4.5985%            |
| California\Yolo         | 185024                      | 57001                                |                                          | 479858           | 11.88%                                         | 38.56%                                          | 4.5802%            |
| Idaho\Lincoln           | 27084                       | 23248                                |                                          | 117377           | 19.81%                                         | 23.07%                                          | 4.5702%            |
| Wisconsin\Racine        | 75744                       | 6668                                 | 2086                                     | 120459           | 7.27%                                          | 62.88%                                          | 4.5696%            |
| Wisconsin\Juneau        | 67862                       | 12986                                | 8978                                     | 181046           | 12.13%                                         | 37.48%                                          | 4.5474%            |
| Illinois\Lake           | 19650                       | 2757                                 |                                          | 34525            | 7.99%                                          | 56.92%                                          | 4.5450%            |
| Washington\Grant        | 447587                      | 117488                               | 2580                                     | 1087952          | 11.04%                                         | 41.14%                                          | 4.5403%            |
| Wisconsin\Polk          | 78749                       | 30303                                | 17775                                    | 288994           | 16.64%                                         | 27.25%                                          | 4.5333%            |
| Illinois\Stephenson     | 248353                      | 15042                                | 5733                                     | 337932           | 6.15%                                          | 73.49%                                          | 4.5181%            |
| California\Kings        | 278025                      | 63840                                | 10998                                    | 680662           | 10.99%                                         | 40.85%                                          | 4.4910%            |
| Michigan\Washtenaw      | 80469                       | 13970                                | 1517                                     | 166881           | 9.28%                                          | 48.22%                                          | 4.4749%            |
| Wisconsin\Eau Claire    | 57074                       | 21335                                | 11551                                    | 205375           | 16.01%                                         | 27.79%                                          | 4.4499%            |
| Minnesota\Wabasha       | 96181                       | 19127                                | 12674                                    | 262263           | 12.13%                                         | 36.67%                                          | 4.4469%            |
| Ohio\Ashland            | 68163                       | 11653                                | 3031                                     | 150534           | 9.75%                                          | 45.28%                                          | 4.4170%            |
| Michigan\Grand Traverse | 17572                       | 9160                                 | 664                                      | 62577            | 15.70%                                         | 28.08%                                          | 4.4084%            |
| Wisconsin\Buffalo       | 75769                       | 33103                                | 21623                                    | 307035           | 17.82%                                         | 24.68%                                          | 4.3985%            |
| New York\Yates          | 30060                       | 13473                                | 9784                                     | 126118           | 18.44%                                         | 23.83%                                          | 4.3953%            |
| Colorado\Rio Grande     | 47667                       | 29401                                | 103                                      | 178908           | 16.49%                                         | 26.64%                                          | 4.3938%            |
| Iowa\Delaware           | 224019                      | 15377                                | 6457                                     | 333920           | 6.54%                                          | 67.09%                                          | 4.3867%            |
| Michigan\Barry          | 66370                       | 13845                                | 4803                                     | 168172           | 11.09%                                         | 39.47%                                          | 4.3762%            |
| Nebraska\Cuming         | 228441                      | 23213                                | 1276                                     | 360052           | 6.80%                                          | 63.45%                                          | 4.3153%            |
| Ohio\Richland           | 69479                       | 8829                                 | 4489                                     | 146580           | 9.09%                                          | 47.40%                                          | 4.3067%            |
| Michigan\Shiawassee     | 143023                      | 10525                                | 4881                                     | 226509           | 6.80%                                          | 63.14%                                          | 4.2946%            |
| Nebraska\Colfax         | 141733                      | 12044                                | 1583                                     | 213220           | 6.39%                                          | 66.47%                                          | 4.2483%            |
| New York\Niagara        | 45449                       | 10819                                | 8025                                     | 142636           | 13.21%                                         | 31.86%                                          | 4.2096%            |
| Pennsylvania\Mifflin    | 25060                       | 8716                                 | 6166                                     | 94133            | 15.81%                                         | 26.62%                                          | 4.2088%            |
| Minnesota\Goodhue       | 215174                      | 20191                                | 10559                                    | 396743           | 7.75%                                          | 54.24%                                          | 4.2036%            |
| Nebraska\Washington     | 148229                      | 12530                                | 850                                      | 217306           | 6.16%                                          | 68.21%                                          | 4.2000%            |
| Ohio\Medina             | 42607                       | 6794                                 | 2148                                     | 95493            | 9.36%                                          | 44.62%                                          | 4.1780%            |
| Pennsylvania\Lehigh     | 52099                       | 4394                                 | 1287                                     | 84643            | 6.71%                                          | 61.55%                                          | 4.1312%            |

| County                 | Acres Using Herbicide | Harvested Acres of Alfalfa Hay | Harvested Acres Alfalfa Haylage | Acres in Farm | % of Farm Acres in Alfalfa Forage (a) | % of Farm Acres Using Herbicide (b) | (c) = (a) x (b) |
|------------------------|-----------------------|--------------------------------|---------------------------------|---------------|---------------------------------------|-------------------------------------|-----------------|
| Pennsylvania\Chester   | 56776                 | 13343                          | 6897                            | 166891        | 12.13%                                | 34.02%                              | 4.1258%         |
| Wisconsin\Jackson      | 59144                 | 23611                          | 16001                           | 238978        | 16.58%                                | 24.75%                              | 4.1022%         |
| Minnesota\Wright       | 126706                | 18464                          | 4208                            | 265376        | 8.54%                                 | 47.75%                              | 4.0791%         |
| Wisconsin\La Crosse    | 43590                 | 15981                          | 9606                            | 165368        | 15.47%                                | 26.36%                              | 4.0785%         |
| Michigan\Ingham        | 113362                | 9469                           | 2839                            | 186209        | 6.61%                                 | 60.88%                              | 4.0240%         |
| Utah\Cache             | 47455                 | 50741                          | 2833                            | 251550        | 21.30%                                | 18.87%                              | 4.0178%         |
| Wisconsin\Vernon       | 74946                 | 47496                          | 20461                           | 357090        | 19.03%                                | 20.99%                              | 3.9942%         |
| Idaho\Boundary         | 21468                 | 9988                           |                                 | 73500         | 13.59%                                | 29.21%                              | 3.9691%         |
| Minnesota\Fillmore     | 201452                | 31698                          | 7502                            | 446331        | 8.78%                                 | 45.14%                              | 3.9641%         |
| Wisconsin\Iowa         | 91206                 | 37648                          | 20151                           | 364970        | 15.84%                                | 24.99%                              | 3.9576%         |
| Michigan\Menominee     | 18847                 | 13859                          | 8566                            | 103636        | 21.64%                                | 18.19%                              | 3.9351%         |
| Pennsylvania\Lawrence  | 30309                 | 7119                           | 3921                            | 92391         | 11.95%                                | 32.81%                              | 3.9200%         |
| Indiana\Steuben        | 53518                 | 6990                           | 1230                            | 106393        | 7.73%                                 | 50.30%                              | 3.8864%         |
| South Dakota\Douglas   | 117559                | 16158                          | 553                             | 225166        | 7.42%                                 | 52.21%                              | 3.8748%         |
| California\Riverside   | 102574                | 47418                          |                                 | 354753        | 13.37%                                | 28.91%                              | 3.8648%         |
| Wisconsin\Adams        | 48641                 | 8475                           | 2048                            | 115343        | 9.12%                                 | 42.17%                              | 3.8473%         |
| Pennsylvania\Clinton   | 13546                 | 3615                           | 5209                            | 56626         | 15.58%                                | 23.92%                              | 3.7277%         |
| New York\Madison       | 32839                 | 20466                          | 19512                           | 188320        | 21.23%                                | 17.44%                              | 3.7018%         |
| Michigan\Genesee       | 70092                 | 8773                           |                                 | 129232        | 6.79%                                 | 54.24%                              | 3.6819%         |
| Minnesota\Washington   | 34640                 | 6135                           | 878                             | 81237         | 8.63%                                 | 42.64%                              | 3.6811%         |
| Minnesota\Scott        | 50092                 | 7348                           | 2776                            | 117551        | 8.61%                                 | 42.61%                              | 3.6700%         |
| Wisconsin\Trempealeau  | 83399                 | 29707                          | 21527                           | 341370        | 15.01%                                | 24.43%                              | 3.6666%         |
| Ohio\Holmes            | 46446                 | 19645                          | 7850                            | 187658        | 14.65%                                | 24.75%                              | 3.6263%         |
| Maryland\Washington    | 46071                 | 5682                           | 4404                            | 114065        | 8.84%                                 | 40.39%                              | 3.5714%         |
| Nebraska\Cedar         | 264685                | 29750                          | 614                             | 474744        | 6.40%                                 | 55.75%                              | 3.5659%         |
| Minnesota\Benton       | 86625                 | 11080                          | 3146                            | 185994        | 7.65%                                 | 46.57%                              | 3.5623%         |
| Pennsylvania\Juniata   | 26383                 | 7592                           | 5176                            | 97681         | 13.07%                                | 27.01%                              | 3.5304%         |
| Michigan\Midland       | 42483                 | 5502                           | 1322                            | 90619         | 7.53%                                 | 46.88%                              | 3.5303%         |
| Minnesota\Chisago      | 43580                 | 9491                           | 1273                            | 115280        | 9.34%                                 | 37.80%                              | 3.5298%         |
| Idaho\Madison          | 100975                | 15114                          | 326                             | 210630        | 7.33%                                 | 47.94%                              | 3.5142%         |
| Pennsylvania\Snyder    | 27733                 | 8687                           | 4024                            | 100179        | 12.69%                                | 27.68%                              | 3.5126%         |
| Ohio\Mercer            | 191240                | 11880                          | 3812                            | 293026        | 5.36%                                 | 65.26%                              | 3.4950%         |
| Iowa\Clayton           | 174731                | 25447                          | 7916                            | 408987        | 8.16%                                 | 42.72%                              | 3.4851%         |
| Wisconsin\Monroe       | 71291                 | 37024                          | 23202                           | 351306        | 17.14%                                | 20.29%                              | 3.4789%         |
| South Dakota\Davison   | 131716                | 19504                          | 978                             | 279524        | 7.33%                                 | 47.12%                              | 3.4528%         |
| Nebraska\Wayne         | 166662                | 15299                          | 541                             | 276578        | 5.73%                                 | 60.26%                              | 3.4511%         |
| Minnesota\Olmsted      | 148966                | 15622                          | 4532                            | 296039        | 6.81%                                 | 50.32%                              | 3.4257%         |
| Michigan\Eaton         | 134767                | 11077                          | 1440                            | 222215        | 5.63%                                 | 60.65%                              | 3.4162%         |
| Pennsylvania\Dauphin   | 36913                 | 4420                           | 2989                            | 89533         | 8.28%                                 | 41.23%                              | 3.4117%         |
| Idaho\Butte            | 15615                 | 31843                          |                                 | 121176        | 26.28%                                | 12.89%                              | 3.3863%         |
| Minnesota\Isanti       | 51580                 | 9720                           | 652                             | 126202        | 8.22%                                 | 40.87%                              | 3.3590%         |
| South Dakota\Minnehaha | 250625                | 21271                          | 2507                            | 421416        | 5.64%                                 | 59.47%                              | 3.3557%         |
| Michigan\Gratiot       | 192285                | 8442                           | 5926                            | 286937        | 5.01%                                 | 67.01%                              | 3.3556%         |

| County                   | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|--------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Indiana\Noble            | 94633                       | 7676                                 | 1339                                     | 159860           | 5.64%                                          | 59.20%                                          | 3.3383%            |
| Michigan\Arenac          | 40626                       | 4650                                 | 2688                                     | 94604            | 7.76%                                          | 42.94%                                          | 3.3309%            |
| Michigan\Oceana          | 41145                       | 10201                                | 2049                                     | 123284           | 9.94%                                          | 33.37%                                          | 3.3162%            |
| Pennsylvania\Centre      | 36057                       | 12606                                | 7527                                     | 148464           | 13.56%                                         | 24.29%                                          | 3.2935%            |
| Iowa\Jackson             | 99037                       | 25234                                | 3889                                     | 296433           | 9.82%                                          | 33.41%                                          | 3.2823%            |
| Michigan\Montmorency     | 3485                        | 4460                                 |                                          | 21801            | 20.46%                                         | 15.99%                                          | 3.2703%            |
| Iowa\Adair               | 157105                      | 19882                                |                                          | 311678           | 6.38%                                          | 50.41%                                          | 3.2154%            |
| Nebraska\Scotts Bluff    | 127534                      | 31590                                | 855                                      | 360286           | 9.01%                                          | 35.40%                                          | 3.1877%            |
| Illinois\McHenry         | 162310                      | 9117                                 |                                          | 215584           | 4.23%                                          | 75.29%                                          | 3.1839%            |
| Minnesota\Hennepin       | 28354                       | 4391                                 | 560                                      | 66558            | 7.44%                                          | 42.60%                                          | 3.1689%            |
| Indiana\Adams            | 133261                      | 7394                                 | 475                                      | 182490           | 4.31%                                          | 73.02%                                          | 3.1488%            |
| South Dakota\Hutchinson  | 321643                      | 23966                                | 1372                                     | 509775           | 4.97%                                          | 63.10%                                          | 3.1361%            |
| California\San Joaquin   | 271636                      | 56969                                | 5782                                     | 737503           | 8.51%                                          | 36.83%                                          | 3.1339%            |
| Illinois\Cook            | 4596                        | 458                                  |                                          | 8198             | 5.59%                                          | 56.06%                                          | 3.1321%            |
| Minnesota\Otter Tail     | 336883                      | 62666                                | 12294                                    | 898703           | 8.34%                                          | 37.49%                                          | 3.1266%            |
| New York\Montgomery      | 17836                       | 16998                                | 10032                                    | 124556           | 21.70%                                         | 14.32%                                          | 3.1075%            |
| Idaho\Teton              | 36360                       | 12617                                | 189                                      | 122478           | 10.46%                                         | 29.69%                                          | 3.1040%            |
| Ohio\Tuscarawas          | 34716                       | 11531                                | 6599                                     | 142642           | 12.71%                                         | 24.34%                                          | 3.0934%            |
| Idaho\Camas              | 13312                       | 44382                                |                                          | 138417           | 32.06%                                         | 9.62%                                           | 3.0837%            |
| South Dakota\Grant       | 184776                      | 18919                                | 3123                                     | 363689           | 6.06%                                          | 50.81%                                          | 3.0792%            |
| Nebraska\Thurston        | 116370                      | 9654                                 | 866                                      | 199689           | 5.27%                                          | 58.28%                                          | 3.0701%            |
| Nebraska\Douglas         | 56413                       | 3518                                 | 325                                      | 84374            | 4.55%                                          | 66.86%                                          | 3.0453%            |
| Iowa\Allamakee           | 73252                       | 22491                                | 8778                                     | 274844           | 11.38%                                         | 26.65%                                          | 3.0322%            |
| Michigan\Kalamazoo       | 80797                       | 6698                                 | 1125                                     | 144873           | 5.40%                                          | 55.77%                                          | 3.0116%            |
| Pennsylvania\Bedford     | 41038                       | 19168                                | 13455                                    | 210990           | 15.46%                                         | 19.45%                                          | 3.0074%            |
| Illinois\Winnebago       | 136235                      | 6225                                 | 1200                                     | 183615           | 4.04%                                          | 74.20%                                          | 3.0003%            |
| Michigan\Gladwin         | 13977                       | 8723                                 | 1009                                     | 67634            | 14.39%                                         | 20.67%                                          | 2.9736%            |
| Michigan\St. Clair       | 95597                       | 7065                                 | 904                                      | 160482           | 4.97%                                          | 59.57%                                          | 2.9580%            |
| Indiana\Marshall         | 127315                      | 6152                                 | 1248                                     | 179016           | 4.13%                                          | 71.12%                                          | 2.9399%            |
| Vermont\Addison          | 22103                       | 13460                                | 33226                                    | 187482           | 24.90%                                         | 11.79%                                          | 2.9357%            |
| South Dakota\Codington   | 174728                      | 22632                                |                                          | 367107           | 6.16%                                          | 47.60%                                          | 2.9343%            |
| Nebraska\Knox            | 169089                      | 48576                                | 1050                                     | 536457           | 9.25%                                          | 31.52%                                          | 2.9158%            |
| Nebraska\Stanton         | 114278                      | 13916                                | 232                                      | 235686           | 6.00%                                          | 48.49%                                          | 2.9107%            |
| Pennsylvania\Mercer      | 54428                       | 10579                                | 5196                                     | 171860           | 9.18%                                          | 31.67%                                          | 2.9070%            |
| Iowa\Warren              | 97391                       | 17018                                | 365                                      | 241647           | 7.19%                                          | 40.30%                                          | 2.8992%            |
| South Dakota\Turner      | 249366                      | 14119                                | 1905                                     | 371436           | 4.31%                                          | 67.14%                                          | 2.8963%            |
| South Dakota\Sanborn     | 119245                      | 24493                                |                                          | 318254           | 7.70%                                          | 37.47%                                          | 2.8836%            |
| Kansas\Barton            | 191137                      | 45599                                | 1466                                     | 558977           | 8.42%                                          | 34.19%                                          | 2.8791%            |
| Michigan\Tuscola         | 214129                      | 12118                                | 3672                                     | 342729           | 4.61%                                          | 62.48%                                          | 2.8784%            |
| Michigan\Wexford         | 6216                        | 6224                                 | 618                                      | 38486            | 17.78%                                         | 16.15%                                          | 2.8714%            |
| Iowa\Jones               | 210907                      | 13127                                | 1089                                     | 324003           | 4.39%                                          | 65.09%                                          | 2.8561%            |
| Minnesota\Dakota         | 146456                      | 8177                                 | 3592                                     | 246026           | 4.78%                                          | 59.53%                                          | 2.8476%            |
| Iowa\Monroe              | 53071                       | 19979                                | 1722                                     | 201204           | 10.79%                                         | 26.38%                                          | 2.8449%            |
| South Dakota\Charles Mix | 278900                      | 42202                                | 2165                                     | 660519           | 6.72%                                          | 42.22%                                          | 2.8362%            |
| Ohio\Portage             | 34799                       | 4669                                 | 898                                      | 82759            | 6.73%                                          | 42.05%                                          | 2.8285%            |

| County                      | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-----------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Iowa\Johnson                | 183906                      | 13927                                | 1924                                     | 321139           | 4.94%                                          | 57.27%                                          | 2.8266%            |
| Michigan\Calhoun            | 121273                      | 10519                                | 1550                                     | 227994           | 5.29%                                          | 53.19%                                          | 2.8157%            |
| Minnesota\Houston           | 56711                       | 21269                                | 8342                                     | 244404           | 12.12%                                         | 23.20%                                          | 2.8113%            |
| Wisconsin\Richland          | 38424                       | 29942                                | 17164                                    | 253776           | 18.56%                                         | 15.14%                                          | 2.8105%            |
| Minnesota\Todd              | 99766                       | 32561                                | 7582                                     | 378734           | 10.60%                                         | 26.34%                                          | 2.7921%            |
| Minnesota\Anoka             | 14575                       | 4012                                 |                                          | 45987            | 8.72%                                          | 31.69%                                          | 2.7650%            |
| Ohio\Lorain                 | 66972                       | 4650                                 | 1648                                     | 124100           | 5.07%                                          | 53.97%                                          | 2.7387%            |
| Wisconsin\Taylor            | 49059                       | 17181                                | 15761                                    | 242932           | 13.56%                                         | 20.19%                                          | 2.7384%            |
| Wisconsin\Burnett           | 17835                       | 10356                                | 3787                                     | 96168            | 14.71%                                         | 18.55%                                          | 2.7274%            |
| Michigan\St. Joseph         | 130230                      | 8147                                 | 1565                                     | 215425           | 4.51%                                          | 60.45%                                          | 2.7254%            |
| Michigan\Macomb             | 36255                       | 2887                                 |                                          | 61994            | 4.66%                                          | 58.48%                                          | 2.7234%            |
| Michigan\Emmet              | 3760                        | 10039                                | 1237                                     | 39582            | 28.49%                                         | 9.50%                                           | 2.7061%            |
| Pennsylvania\Northumberland | 68840                       | 4267                                 | 4284                                     | 147660           | 5.79%                                          | 46.62%                                          | 2.6998%            |
| Iowa\Fayette                | 253150                      | 14588                                | 3873                                     | 417219           | 4.42%                                          | 60.68%                                          | 2.6848%            |
| Pennsylvania\Perry          | 40968                       | 7256                                 | 6261                                     | 144375           | 9.36%                                          | 28.38%                                          | 2.6567%            |
| Ohio\Knox                   | 87257                       | 9991                                 | 1941                                     | 198244           | 6.02%                                          | 44.01%                                          | 2.6492%            |
| Wisconsin\Rusk              | 25106                       | 13867                                | 13269                                    | 160534           | 16.90%                                         | 15.64%                                          | 2.6436%            |
| Nebraska\Boone              | 217196                      | 19950                                |                                          | 405334           | 4.92%                                          | 53.58%                                          | 2.6374%            |
| Nebraska\Pierce             | 174533                      | 13760                                | 1368                                     | 316773           | 4.78%                                          | 55.10%                                          | 2.6313%            |
| Pennsylvania\Butler         | 27407                       | 13545                                | 2525                                     | 129850           | 12.38%                                         | 21.11%                                          | 2.6121%            |
| Ohio\Shelby                 | 141801                      | 7374                                 | 1371                                     | 217969           | 4.01%                                          | 65.06%                                          | 2.6101%            |
| Indiana\Wayne               | 104917                      | 5937                                 | 744                                      | 164117           | 4.07%                                          | 63.93%                                          | 2.6024%            |
| Nebraska\Dawson             | 243915                      | 43137                                |                                          | 640541           | 6.73%                                          | 38.08%                                          | 2.5645%            |
| Kansas\Republic             | 214805                      | 19734                                |                                          | 406745           | 4.85%                                          | 52.81%                                          | 2.5622%            |
| California\Tulare           | 368037                      | 76413                                | 18449                                    | 1168684          | 8.12%                                          | 31.49%                                          | 2.5562%            |
| Minnesota\Morrison          | 108135                      | 30929                                | 12954                                    | 431346           | 10.17%                                         | 25.07%                                          | 2.5504%            |
| Iowa\Wapello                | 70890                       | 9283                                 | 593                                      | 166199           | 5.94%                                          | 42.65%                                          | 2.5346%            |
| California\Merced           | 308598                      | 82731                                | 5578                                     | 1041115          | 8.48%                                          | 29.64%                                          | 2.5142%            |
| Minnesota\Sherburne         | 50780                       | 5560                                 |                                          | 106127           | 5.24%                                          | 47.85%                                          | 2.5068%            |
| Pennsylvania\Westmoreland   | 33892                       | 17134                                | 3563                                     | 167489           | 12.36%                                         | 20.24%                                          | 2.5005%            |
| New York\Orleans            | 51648                       | 6504                                 | 2864                                     | 139764           | 6.70%                                          | 36.95%                                          | 2.4769%            |
| Iowa\Madison                | 110380                      | 17935                                |                                          | 283393           | 6.33%                                          | 38.95%                                          | 2.4650%            |
| South Dakota\Hanson         | 125501                      | 9084                                 | 296                                      | 219023           | 4.28%                                          | 57.30%                                          | 2.4540%            |
| South Dakota\Kingsbury      | 226653                      | 22344                                | 2276                                     | 477481           | 5.16%                                          | 47.47%                                          | 2.4476%            |
| Idaho\Bonneville            | 119613                      | 41382                                | 190                                      | 453068           | 9.18%                                          | 26.40%                                          | 2.4224%            |
| Michigan\Lenawee            | 215186                      | 8872                                 | 4799                                     | 348611           | 3.92%                                          | 61.73%                                          | 2.4207%            |
| Indiana\Fayette             | 60856                       | 3209                                 | 189                                      | 92505            | 3.67%                                          | 65.79%                                          | 2.4166%            |
| Idaho\Franklin              | 34405                       | 33233                                | 2258                                     | 224902           | 15.78%                                         | 15.30%                                          | 2.4141%            |
| Kansas\Finney               | 322716                      | 38844                                | 4027                                     | 760110           | 5.64%                                          | 42.46%                                          | 2.3946%            |
| Minnesota\Rice              | 113366                      | 10362                                | 3154                                     | 253094           | 5.34%                                          | 44.79%                                          | 2.3920%            |
| North Dakota\Stark          | 264472                      | 63043                                | 330                                      | 837143           | 7.57%                                          | 31.59%                                          | 2.3916%            |
| New York\Oneida             | 32794                       | 16395                                | 10524                                    | 192232           | 14.00%                                         | 17.06%                                          | 2.3889%            |
| Ohio\Mahoning               | 23385                       | 2648                                 | 1547                                     | 64082            | 6.55%                                          | 36.49%                                          | 2.3889%            |

| County                  | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Michigan\Hillsdale      | 139346                      | 12489                                |                                          | 269916           | 4.63%                                          | 51.63%                                          | 2.3887%            |
| Michigan\Oakland        | 6110                        | 3946                                 | 155                                      | 32504            | 12.62%                                         | 18.80%                                          | 2.3717%            |
| South Dakota\Aurora     | 184119                      | 17065                                |                                          | 364612           | 4.68%                                          | 50.50%                                          | 2.3634%            |
| Pennsylvania\Cambria    | 16873                       | 8807                                 | 2009                                     | 87924            | 12.30%                                         | 19.19%                                          | 2.3607%            |
| Vermont\Grand Isle      | 2879                        | 1188                                 | 1220                                     | 17138            | 14.05%                                         | 16.80%                                          | 2.3604%            |
| Nebraska\Buffalo        | 284998                      | 30942                                |                                          | 612171           | 5.05%                                          | 46.56%                                          | 2.3531%            |
| New York\Monroe         | 71222                       | 5832                                 |                                          | 133041           | 4.38%                                          | 53.53%                                          | 2.3467%            |
| New Jersey\Salem        | 44138                       | 4756                                 | 166                                      | 96530            | 5.10%                                          | 45.72%                                          | 2.3315%            |
| Nebraska\Howard         | 102789                      | 17085                                | 550                                      | 278876           | 6.32%                                          | 36.86%                                          | 2.3308%            |
| Illinois\Carroll        | 192276                      | 6977                                 | 1528                                     | 265153           | 3.21%                                          | 72.52%                                          | 2.3260%            |
| Michigan\Alcona         | 4907                        | 9764                                 |                                          | 45395            | 21.51%                                         | 10.81%                                          | 2.3250%            |
| Illinois\Kane           | 140312                      | 6124                                 |                                          | 192372           | 3.18%                                          | 72.94%                                          | 2.3219%            |
| Iowa\Union              | 79457                       | 12963                                | 385                                      | 214618           | 6.22%                                          | 37.02%                                          | 2.3026%            |
| Michigan\Presque Isle   | 11180                       | 10364                                |                                          | 71079            | 14.58%                                         | 15.73%                                          | 2.2934%            |
| Maryland\Frederick      | 79213                       | 6606                                 | 5205                                     | 202087           | 5.84%                                          | 39.20%                                          | 2.2909%            |
| South Dakota\Beadle     | 338872                      | 38312                                | 1597                                     | 769855           | 5.18%                                          | 44.02%                                          | 2.2819%            |
| Wisconsin\Lincoln       | 12358                       | 8641                                 | 5261                                     | 86770            | 16.02%                                         | 14.24%                                          | 2.2818%            |
| Michigan\Charlevoix     | 5607                        | 6973                                 |                                          | 41418            | 16.84%                                         | 13.54%                                          | 2.2791%            |
| Minnesota\Lincoln       | 164953                      | 10559                                | 700                                      | 286255           | 3.93%                                          | 57.62%                                          | 2.2665%            |
| South Dakota\Moody      | 189283                      | 10304                                |                                          | 293395           | 3.51%                                          | 64.51%                                          | 2.2658%            |
| Minnesota\Pennington    | 141091                      | 16944                                |                                          | 325292           | 5.21%                                          | 43.37%                                          | 2.2593%            |
| Ohio\Logan              | 126498                      | 6542                                 | 679                                      | 201306           | 3.59%                                          | 62.84%                                          | 2.2541%            |
| Ohio\Ottawa             | 81407                       | 3671                                 |                                          | 115145           | 3.19%                                          | 70.70%                                          | 2.2540%            |
| South Dakota\Faulk      | 252087                      | 33758                                |                                          | 614607           | 5.49%                                          | 41.02%                                          | 2.2528%            |
| South Dakota\Gregory    | 148475                      | 64016                                | 705                                      | 654445           | 9.89%                                          | 22.69%                                          | 2.2436%            |
| South Dakota\Deuel      | 131954                      | 15882                                | 1217                                     | 317164           | 5.39%                                          | 41.60%                                          | 2.2430%            |
| Minnesota\Mille Lacs    | 34712                       | 6817                                 | 3270                                     | 124956           | 8.07%                                          | 27.78%                                          | 2.2425%            |
| New York\Saratoga       | 11000                       | 6613                                 | 5055                                     | 75660            | 15.42%                                         | 14.54%                                          | 2.2421%            |
| South Dakota\Lake       | 202910                      | 10956                                |                                          | 314946           | 3.48%                                          | 64.43%                                          | 2.2412%            |
| Idaho\Cassia            | 174040                      | 53422                                |                                          | 644740           | 8.29%                                          | 26.99%                                          | 2.2367%            |
| Ohio\Summit             | 4021                        | 1138                                 | 141                                      | 15166            | 8.43%                                          | 26.51%                                          | 2.2360%            |
| Ohio\Auglaize           | 149433                      | 4708                                 | 2037                                     | 213296           | 3.16%                                          | 70.06%                                          | 2.2155%            |
| Michigan\Cass           | 110200                      | 7072                                 | 193                                      | 190330           | 3.82%                                          | 57.90%                                          | 2.2101%            |
| Michigan\Leelanau       | 16237                       | 4227                                 |                                          | 55751            | 7.58%                                          | 29.12%                                          | 2.2082%            |
| South Dakota\Brookings  | 226612                      | 19123                                | 1705                                     | 462579           | 4.50%                                          | 48.99%                                          | 2.2058%            |
| Illinois\Clinton        | 195048                      | 6503                                 | 1630                                     | 268441           | 3.03%                                          | 72.66%                                          | 2.2014%            |
| Minnesota\Dodge         | 170156                      | 4840                                 | 3088                                     | 248125           | 3.20%                                          | 68.58%                                          | 2.1911%            |
| Pennsylvania\York       | 142432                      | 9471                                 | 3646                                     | 292507           | 4.48%                                          | 48.69%                                          | 2.1836%            |
| New York\Erie           | 28104                       | 10310                                | 6904                                     | 149356           | 11.53%                                         | 18.82%                                          | 2.1687%            |
| Washington\Spokane      | 230886                      | 36386                                | 447                                      | 626329           | 5.88%                                          | 36.86%                                          | 2.1679%            |
| Kansas\Pawnee           | 181516                      | 25035                                | 3260                                     | 487373           | 5.81%                                          | 37.24%                                          | 2.1622%            |
| Indiana\Kosciusko       | 176724                      | 5835                                 | 1876                                     | 251340           | 3.07%                                          | 70.31%                                          | 2.1572%            |
| Colorado\Alamosa        | 26072                       | 25522                                | 283                                      | 176629           | 14.61%                                         | 14.76%                                          | 2.1565%            |
| Illinois\Rock Island    | 129027                      | 5118                                 | 207                                      | 178623           | 2.98%                                          | 72.23%                                          | 2.1534%            |
| Pennsylvania\Schuylkill | 42904                       | 4357                                 | 2683                                     | 118501           | 5.94%                                          | 36.21%                                          | 2.1509%            |

| County                | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-----------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| North Dakota\Rolette  | 222818                      | 30214                                | 884                                      | 567850           | 5.48%                                          | 39.24%                                          | 2.1489%            |
| South Dakota\McCook   | 232210                      | 11207                                | 1001                                     | 363408           | 3.36%                                          | 63.90%                                          | 2.1465%            |
| Indiana\Allen         | 184421                      | 5939                                 | 1544                                     | 254136           | 2.94%                                          | 72.57%                                          | 2.1368%            |
| Utah\Weber            | 14604                       | 16086                                | 415                                      | 106247           | 15.53%                                         | 13.75%                                          | 2.1348%            |
| Iowa\Poweshiek        | 187457                      | 11139                                |                                          | 312853           | 3.56%                                          | 59.92%                                          | 2.1334%            |
| Minnesota\Douglas     | 102687                      | 12598                                | 1719                                     | 262695           | 5.45%                                          | 39.09%                                          | 2.1304%            |
| South Dakota\Miner    | 129796                      | 14753                                |                                          | 300076           | 4.92%                                          | 43.25%                                          | 2.1266%            |
| Iowa\Cass             | 197024                      | 10626                                | 268                                      | 317913           | 3.43%                                          | 61.97%                                          | 2.1237%            |
| South Dakota\Hand     | 361092                      | 46311                                | 1188                                     | 898741           | 5.29%                                          | 40.18%                                          | 2.1234%            |
| Wisconsin\Sawyer      | 8024                        | 3062                                 | 2798                                     | 47093            | 12.44%                                         | 17.04%                                          | 2.1202%            |
| North Dakota\Adams    | 213275                      | 39030                                |                                          | 626663           | 6.23%                                          | 34.03%                                          | 2.1197%            |
| South Dakota\Hamlin   | 179952                      | 10296                                | 939                                      | 309740           | 3.63%                                          | 58.10%                                          | 2.1073%            |
| Iowa\Clinton          | 293639                      | 9694                                 | 1437                                     | 395585           | 2.81%                                          | 74.23%                                          | 2.0887%            |
| Ohio\Montgomery       | 79958                       | 2868                                 | 349                                      | 111000           | 2.90%                                          | 72.03%                                          | 2.0877%            |
| Iowa\Lee              | 123223                      | 8334                                 | 1208                                     | 238266           | 4.00%                                          | 51.72%                                          | 2.0711%            |
| South Dakota\Clark    | 220436                      | 23158                                | 1044                                     | 508768           | 4.76%                                          | 43.33%                                          | 2.0611%            |
| Iowa\Van Buren        | 69271                       | 13928                                | 640                                      | 221529           | 6.58%                                          | 31.27%                                          | 2.0563%            |
| Illinois\Boone        | 98587                       | 3920                                 |                                          | 137162           | 2.86%                                          | 71.88%                                          | 2.0542%            |
| Wisconsin\Crawford    | 33569                       | 24563                                | 10100                                    | 238225           | 14.55%                                         | 14.09%                                          | 2.0504%            |
| Kansas\Gray           | 241995                      | 23247                                | 2001                                     | 546118           | 4.62%                                          | 44.31%                                          | 2.0486%            |
| Ohio\Darke            | 240429                      | 8814                                 | 1643                                     | 350450           | 2.98%                                          | 68.61%                                          | 2.0471%            |
| Michigan\Wayne        | 8432                        | 738                                  |                                          | 17443            | 4.23%                                          | 48.34%                                          | 2.0452%            |
| Ohio\Morrow           | 97583                       | 4987                                 | 715                                      | 165023           | 3.46%                                          | 59.13%                                          | 2.0432%            |
| Michigan\Huron        | 294112                      | 13479                                |                                          | 440967           | 3.06%                                          | 66.70%                                          | 2.0387%            |
| Minnesota\Becker      | 131676                      | 21940                                | 2247                                     | 395858           | 6.11%                                          | 33.26%                                          | 2.0324%            |
| Nebraska\Valley       | 112832                      | 22676                                | 147                                      | 356296           | 6.41%                                          | 31.67%                                          | 2.0285%            |
| Ohio\Coshocton        | 42468                       | 11917                                | 2041                                     | 171084           | 8.16%                                          | 24.82%                                          | 2.0252%            |
| Ohio\Carroll          | 19402                       | 12111                                | 2134                                     | 116853           | 12.19%                                         | 16.60%                                          | 2.0241%            |
| Michigan\Osceola      | 9922                        | 24336                                | 6101                                     | 122166           | 24.91%                                         | 8.12%                                           | 2.0235%            |
| Maryland\Cecil        | 40543                       | 2908                                 | 695                                      | 85026            | 4.24%                                          | 47.68%                                          | 2.0206%            |
| South Dakota\Union    | 202715                      | 7753                                 |                                          | 278916           | 2.78%                                          | 72.68%                                          | 2.0203%            |
| North Dakota\Mercer   | 119095                      | 43828                                | 180                                      | 509552           | 8.64%                                          | 23.37%                                          | 2.0186%            |
| Indiana\Fulton        | 144504                      | 4155                                 | 610                                      | 184847           | 2.58%                                          | 78.17%                                          | 2.0152%            |
| Iowa\Iowa             | 175125                      | 13319                                | 371                                      | 345231           | 3.97%                                          | 50.73%                                          | 2.0116%            |
| North Dakota\Oliver   | 99633                       | 28744                                |                                          | 377904           | 7.61%                                          | 26.36%                                          | 2.0053%            |
| Iowa\Marion           | 104677                      | 11328                                | 248                                      | 246191           | 4.70%                                          | 42.52%                                          | 1.9992%            |
| Pennsylvania\Somerset | 30018                       | 15642                                | 12641                                    | 206651           | 13.69%                                         | 14.53%                                          | 1.9881%            |
| Ohio\Preble           | 164137                      | 5909                                 | 528                                      | 230616           | 2.79%                                          | 71.17%                                          | 1.9866%            |
| Iowa\Davis            | 52283                       | 16737                                | 1401                                     | 218698           | 8.29%                                          | 23.91%                                          | 1.9827%            |
| Iowa\Linn             | 208855                      | 9693                                 | 932                                      | 335378           | 3.17%                                          | 62.27%                                          | 1.9729%            |
| Nebraska\Butler       | 242151                      | 10147                                | 184                                      | 356151           | 2.90%                                          | 67.99%                                          | 1.9722%            |
| Indiana\LaPorte       | 196854                      | 4567                                 | 1987                                     | 256159           | 2.56%                                          | 76.85%                                          | 1.9662%            |
| Nebraska\Sherman      | 77545                       | 18329                                | 134                                      | 270072           | 6.84%                                          | 28.71%                                          | 1.9629%            |

| County                 | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Michigan\Bay           | 131729                      | 3698                                 | 1458                                     | 186256           | 2.77%                                          | 70.72%                                          | 1.9578%            |
| South Dakota\Edmunds   | 292389                      | 27401                                | 1436                                     | 656678           | 4.39%                                          | 44.53%                                          | 1.9553%            |
| North Dakota\Kidder    | 131031                      | 83788                                |                                          | 753284           | 11.12%                                         | 17.39%                                          | 1.9348%            |
| New York\Tompkins      | 18024                       | 4726                                 | 7953                                     | 108739           | 11.66%                                         | 16.58%                                          | 1.9327%            |
| Indiana\Whitley        | 98794                       | 3665                                 |                                          | 137082           | 2.67%                                          | 72.07%                                          | 1.9268%            |
| Pennsylvania\Columbia  | 43874                       | 4415                                 | 2180                                     | 122621           | 5.38%                                          | 35.78%                                          | 1.9244%            |
| New York\Lewis         | 19495                       | 9835                                 | 17761                                    | 167249           | 16.50%                                         | 11.66%                                          | 1.9233%            |
| Ohio\Butler            | 52819                       | 5577                                 | 290                                      | 127194           | 4.61%                                          | 41.53%                                          | 1.9155%            |
| Minnesota\Roseau       | 210697                      | 30811                                | 923                                      | 591316           | 5.37%                                          | 35.63%                                          | 1.9122%            |
| South Dakota\Tripp     | 248877                      | 76438                                | 2467                                     | 1014336          | 7.78%                                          | 24.54%                                          | 1.9086%            |
| Indiana\Franklin       | 62526                       | 4601                                 | 267                                      | 126322           | 3.85%                                          | 49.50%                                          | 1.9075%            |
| Pennsylvania\Lycoming  | 35525                       | 9077                                 | 4706                                     | 160456           | 8.59%                                          | 22.14%                                          | 1.9018%            |
| Indiana\Porter         | 88151                       | 2851                                 |                                          | 115047           | 2.48%                                          | 76.62%                                          | 1.8988%            |
| North Dakota\McHenry   | 378760                      | 57849                                | 925                                      | 1082911          | 5.43%                                          | 34.98%                                          | 1.8983%            |
| California\Fresno      | 643140                      | 69290                                | 9687                                     | 1636224          | 4.83%                                          | 39.31%                                          | 1.8972%            |
| Illinois\Ogle          | 281258                      | 8227                                 | 829                                      | 366470           | 2.47%                                          | 76.75%                                          | 1.8966%            |
| North Dakota\McIntosh  | 169849                      | 33648                                |                                          | 549685           | 6.12%                                          | 30.90%                                          | 1.8914%            |
| Iowa\Page              | 163947                      | 8479                                 |                                          | 271128           | 3.13%                                          | 60.47%                                          | 1.8910%            |
| Idaho\Payette          | 29537                       | 15850                                | 1818                                     | 166179           | 10.63%                                         | 17.77%                                          | 1.8897%            |
| Minnesota\Kandiyohi    | 216791                      | 11840                                | 3323                                     | 417138           | 3.64%                                          | 51.97%                                          | 1.8892%            |
| Michigan\Branch        | 149443                      | 6431                                 | 1468                                     | 250134           | 3.16%                                          | 59.75%                                          | 1.8867%            |
| Iowa\Adams             | 97825                       | 9655                                 | 82                                       | 224882           | 4.33%                                          | 43.50%                                          | 1.8835%            |
| Missouri\Nodaway       | 237677                      | 22794                                | 577                                      | 543224           | 4.30%                                          | 43.75%                                          | 1.8824%            |
| Iowa\Jasper            | 283021                      | 11690                                | 483                                      | 427822           | 2.85%                                          | 66.15%                                          | 1.8823%            |
| Indiana\DeKalb         | 98790                       | 4438                                 | 478                                      | 160665           | 3.06%                                          | 61.49%                                          | 1.8814%            |
| Indiana\Putnam         | 104043                      | 5112                                 |                                          | 168446           | 3.03%                                          | 61.77%                                          | 1.8745%            |
| Iowa\Appanoose         | 39253                       | 18287                                | 326                                      | 197904           | 9.41%                                          | 19.83%                                          | 1.8654%            |
| Nebraska\Nance         | 105962                      | 9015                                 |                                          | 226299           | 3.98%                                          | 46.82%                                          | 1.8653%            |
| North Dakota\Emmons    | 273025                      | 50672                                | 1136                                     | 871766           | 5.94%                                          | 31.32%                                          | 1.8612%            |
| Michigan\Van Buren     | 70106                       | 7994                                 | 1089                                     | 185343           | 4.90%                                          | 37.83%                                          | 1.8537%            |
| South Dakota\McPherson | 107515                      | 46056                                |                                          | 518187           | 8.89%                                          | 20.75%                                          | 1.8441%            |
| New Jersey\Warren      | 24363                       | 2818                                 | 1425                                     | 74975            | 5.66%                                          | 32.49%                                          | 1.8390%            |
| Pennsylvania\Indiana   | 30971                       | 15129                                | 5790                                     | 187711           | 11.14%                                         | 16.50%                                          | 1.8387%            |
| Iowa\Bremer            | 181706                      | 4952                                 | 1025                                     | 243057           | 2.46%                                          | 74.76%                                          | 1.8384%            |
| New York\Herkimer      | 14016                       | 14945                                | 10674                                    | 140017           | 18.30%                                         | 10.01%                                          | 1.8316%            |
| South Dakota\Roberts   | 286187                      | 21618                                | 848                                      | 592889           | 3.79%                                          | 48.27%                                          | 1.8291%            |
| South Dakota\Brule     | 178344                      | 23814                                | 3683                                     | 518462           | 5.30%                                          | 34.40%                                          | 1.8244%            |
| Minnesota\Clearwater   | 22576                       | 29369                                | 922                                      | 194190           | 15.60%                                         | 11.63%                                          | 1.8135%            |
| Illinois\Henderson     | 122494                      | 4100                                 | 182                                      | 170443           | 2.51%                                          | 71.87%                                          | 1.8055%            |
| Ohio\Trumbull          | 51368                       | 3205                                 | 2286                                     | 125136           | 4.39%                                          | 41.05%                                          | 1.8013%            |
| Iowa\Montgomery        | 139653                      | 6098                                 | 149                                      | 220463           | 2.83%                                          | 63.35%                                          | 1.7949%            |
| Indiana\Marion         | 10983                       | 485                                  |                                          | 17233            | 2.81%                                          | 63.73%                                          | 1.7937%            |
| Pennsylvania\Crawford  | 56194                       | 10246                                | 6931                                     | 232093           | 7.40%                                          | 24.21%                                          | 1.7919%            |
| North Dakota\Burleigh  | 216997                      | 62447                                | 1383                                     | 879542           | 7.26%                                          | 24.67%                                          | 1.7905%            |
| Ohio\Geauga            | 9914                        | 5165                                 | 600                                      | 56558            | 10.19%                                         | 17.53%                                          | 1.7867%            |

| County                 | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Pennsylvania\Adams     | 68853                       | 4281                                 | 3601                                     | 174595           | 4.51%                                          | 39.44%                                          | 1.7803%            |
| Iowa\Ia                | 199379                      | 6342                                 | 289                                      | 272578           | 2.43%                                          | 73.15%                                          | 1.7794%            |
| Michigan\Delta         | 8054                        | 10472                                | 2797                                     | 77762            | 17.06%                                         | 10.36%                                          | 1.7673%            |
| Idaho\Ada              | 28454                       | 20972                                | 1778                                     | 191477           | 11.88%                                         | 14.86%                                          | 1.7656%            |
| Iowa\Guthrie           | 195093                      | 11015                                | 338                                      | 354851           | 3.20%                                          | 54.98%                                          | 1.7590%            |
| Nebraska\Dodge         | 242294                      | 7748                                 | 553                                      | 338475           | 2.45%                                          | 71.58%                                          | 1.7556%            |
| New York\Columbia      | 19634                       | 6355                                 | 3798                                     | 106574           | 9.53%                                          | 18.42%                                          | 1.7551%            |
| Nebraska\Platte        | 259385                      | 11045                                | 1188                                     | 425730           | 2.87%                                          | 60.93%                                          | 1.7507%            |
| Iowa\Chickasaw         | 203409                      | 5621                                 | 1545                                     | 289146           | 2.48%                                          | 70.35%                                          | 1.7435%            |
| Illinois\Adams         | 210109                      | 10806                                | 788                                      | 374133           | 3.10%                                          | 56.16%                                          | 1.7403%            |
| Minnesota\Meeker       | 203775                      | 6564                                 | 2251                                     | 321781           | 2.74%                                          | 63.33%                                          | 1.7348%            |
| Ohio\Sandusky          | 134031                      | 4248                                 |                                          | 181337           | 2.34%                                          | 73.91%                                          | 1.7315%            |
| Illinois\Knox          | 267973                      | 8345                                 | 117                                      | 362951           | 2.33%                                          | 73.83%                                          | 1.7213%            |
| Indiana\Wabash         | 147729                      | 3631                                 | 1061                                     | 200689           | 2.34%                                          | 73.61%                                          | 1.7210%            |
| Maryland\Harford       | 28141                       | 2687                                 | 761                                      | 75166            | 4.59%                                          | 37.44%                                          | 1.7174%            |
| Wisconsin\Florence     | 1849                        | 3021                                 | 790                                      | 20264            | 18.81%                                         | 9.12%                                           | 1.7160%            |
| Minnesota\Rock         | 193526                      | 5940                                 | 958                                      | 279088           | 2.47%                                          | 69.34%                                          | 1.7139%            |
| Kansas\Stafford        | 190826                      | 21945                                | 685                                      | 502229           | 4.51%                                          | 38.00%                                          | 1.7121%            |
| Ohio\Champaign         | 141068                      | 5089                                 |                                          | 204901           | 2.48%                                          | 68.85%                                          | 1.7099%            |
| Michigan\Antrim        | 7863                        | 8969                                 | 863                                      | 67351            | 14.60%                                         | 11.67%                                          | 1.7043%            |
| Pennsylvania\Armstrong | 16901                       | 11806                                | 3259                                     | 122275           | 12.32%                                         | 13.82%                                          | 1.7030%            |
| North Dakota\Grant     | 237386                      | 79198                                | 1094                                     | 1058178          | 7.59%                                          | 22.43%                                          | 1.7022%            |
| South Dakota\Walworth  | 159356                      | 20749                                | 302                                      | 444128           | 4.74%                                          | 35.88%                                          | 1.7007%            |
| South Dakota\Jerauld   | 91246                       | 20034                                |                                          | 328624           | 6.10%                                          | 27.77%                                          | 1.6927%            |
| Michigan\Otsego        | 3018                        | 6143                                 | 175                                      | 33598            | 18.80%                                         | 8.98%                                           | 1.6892%            |
| Illinois\Mercer        | 231346                      | 6749                                 | 99                                       | 306306           | 2.24%                                          | 75.53%                                          | 1.6886%            |
| Ohio\Miami             | 133522                      | 4265                                 | 628                                      | 196943           | 2.48%                                          | 67.80%                                          | 1.6844%            |
| Michigan\Oscoda        | 1215                        | 2934                                 | 1346                                     | 17579            | 24.35%                                         | 6.91%                                           | 1.6828%            |
| Michigan\Dickinson     | 2479                        | 3490                                 | 709                                      | 24889            | 16.87%                                         | 9.96%                                           | 1.6804%            |
| Indiana\Miami          | 128023                      | 2988                                 | 1157                                     | 178030           | 2.33%                                          | 71.91%                                          | 1.6743%            |
| Idaho\Fremont          | 76852                       | 17469                                | 544                                      | 288114           | 6.25%                                          | 26.67%                                          | 1.6677%            |
| Idaho\Elmore           | 46543                       | 38569                                | 4452                                     | 346550           | 12.41%                                         | 13.43%                                          | 1.6673%            |
| South Dakota\Marshall  | 181197                      | 23530                                | 2649                                     | 534178           | 4.90%                                          | 33.92%                                          | 1.6624%            |
| North Dakota\Eddy      | 149437                      | 15343                                | 426                                      | 376620           | 4.19%                                          | 39.68%                                          | 1.6613%            |
| Iowa\Howard            | 174057                      | 6289                                 | 1115                                     | 278635           | 2.66%                                          | 62.47%                                          | 1.6599%            |
| Nebraska\Dakota        | 95513                       | 4818                                 |                                          | 166555           | 2.89%                                          | 57.35%                                          | 1.6589%            |
| Ohio\Licking           | 108667                      | 7169                                 | 612                                      | 225792           | 3.45%                                          | 48.13%                                          | 1.6585%            |
| Ohio\Fairfield         | 98322                       | 4761                                 | 556                                      | 177772           | 2.99%                                          | 55.31%                                          | 1.6542%            |
| Nevada\Lyon            | 25863                       | 43451                                |                                          | 260660           | 16.67%                                         | 9.92%                                           | 1.6540%            |
| Iowa\Buchanan          | 270265                      | 7030                                 | 911                                      | 360316           | 2.20%                                          | 75.01%                                          | 1.6531%            |
| Minnesota\Le Sueur     | 150404                      | 5282                                 | 1625                                     | 250696           | 2.76%                                          | 59.99%                                          | 1.6529%            |
| North Dakota\Dickey    | 329868                      | 24315                                |                                          | 697526           | 3.49%                                          | 47.29%                                          | 1.6485%            |
| Minnesota\Pipestone    | 129424                      | 7620                                 |                                          | 244670           | 3.11%                                          | 52.90%                                          | 1.6474%            |



| County                | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-----------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Michigan\Clare        | 5160                        | 12022                                | 2890                                     | 68356            | 21.82%                                         | 7.55%                                           | 1.6468%            |
| Iowa\Ringgold         | 56619                       | 19752                                | 560                                      | 264886           | 7.67%                                          | 21.37%                                          | 1.6391%            |
| Nebraska\Merrick      | 154676                      | 6499                                 |                                          | 247927           | 2.62%                                          | 62.39%                                          | 1.6354%            |
| South Dakota\Brown    | 569116                      | 32865                                | 882                                      | 1085020          | 3.11%                                          | 52.45%                                          | 1.6314%            |
| Indiana\Hendricks     | 133458                      | 3599                                 |                                          | 171741           | 2.10%                                          | 77.71%                                          | 1.6285%            |
| Pennsylvania\Beaver   | 7664                        | 7116                                 | 2430                                     | 67075            | 14.23%                                         | 11.43%                                          | 1.6261%            |
| Nebraska\Lancaster    | 238172                      | 11960                                | 160                                      | 421409           | 2.88%                                          | 56.52%                                          | 1.6255%            |
| South Dakota\Campbell | 100870                      | 24821                                | 999                                      | 400871           | 6.44%                                          | 25.16%                                          | 1.6207%            |
| Ohio\Ashtabula        | 53805                       | 5695                                 | 2153                                     | 161698           | 4.85%                                          | 33.27%                                          | 1.6150%            |
| Kansas\Rice           | 197934                      | 13873                                | 1097                                     | 428422           | 3.49%                                          | 46.20%                                          | 1.6144%            |
| Iowa\Washington       | 173106                      | 8818                                 | 1079                                     | 325836           | 3.04%                                          | 53.13%                                          | 1.6137%            |
| Nebraska\Boyd         | 43299                       | 23480                                |                                          | 251747           | 9.33%                                          | 17.20%                                          | 1.6042%            |
| South Dakota\Spink    | 442420                      | 28985                                | 743                                      | 907643           | 3.28%                                          | 48.74%                                          | 1.5965%            |
| Iowa\Keokuk           | 151285                      | 10526                                | 133                                      | 318160           | 3.35%                                          | 47.55%                                          | 1.5930%            |
| California\Solano     | 72462                       | 28129                                |                                          | 358225           | 7.85%                                          | 20.23%                                          | 1.5884%            |
| Michigan\Alger        | 1463                        | 2757                                 | 901                                      | 18357            | 19.93%                                         | 7.97%                                           | 1.5881%            |
| Michigan\Berrien      | 92607                       | 4894                                 |                                          | 169016           | 2.90%                                          | 54.79%                                          | 1.5865%            |
| New York\Jefferson    | 33400                       | 15005                                | 17654                                    | 262331           | 12.45%                                         | 12.73%                                          | 1.5851%            |
| North Dakota\Stutsman | 507108                      | 43353                                | 996                                      | 1193231          | 3.72%                                          | 42.50%                                          | 1.5796%            |
| Iowa\Muscatine        | 146202                      | 5318                                 |                                          | 221904           | 2.40%                                          | 65.89%                                          | 1.5790%            |
| Minnesota\Steele      | 165918                      | 5043                                 | 1685                                     | 266199           | 2.53%                                          | 62.33%                                          | 1.5753%            |
| Kansas\Dickinson      | 199738                      | 21700                                | 1012                                     | 536885           | 4.23%                                          | 37.20%                                          | 1.5738%            |
| Ohio\Huron            | 137748                      | 3658                                 | 1840                                     | 219369           | 2.51%                                          | 62.79%                                          | 1.5738%            |
| Kansas\Sedgwick       | 227813                      | 17347                                | 592                                      | 510308           | 3.52%                                          | 44.64%                                          | 1.5693%            |
| Nebraska\Seward       | 222228                      | 7677                                 | 127                                      | 332597           | 2.35%                                          | 66.82%                                          | 1.5678%            |
| North Dakota\Logan    | 135140                      | 38629                                |                                          | 577086           | 6.69%                                          | 23.42%                                          | 1.5675%            |
| Missouri\Andrew       | 101176                      | 8339                                 | 470                                      | 238559           | 3.69%                                          | 42.41%                                          | 1.5661%            |
| Indiana\Fountain      | 137729                      | 3580                                 | 465                                      | 188727           | 2.14%                                          | 72.98%                                          | 1.5641%            |
| Indiana\St. Joseph    | 141677                      | 2947                                 | 562                                      | 178674           | 1.96%                                          | 79.29%                                          | 1.5573%            |
| Iowa\Jefferson        | 71727                       | 8448                                 |                                          | 197301           | 4.28%                                          | 36.35%                                          | 1.5566%            |
| New York\Clinton      | 19896                       | 5828                                 | 11578                                    | 149219           | 11.66%                                         | 13.33%                                          | 1.5553%            |
| Ohio\Fayette          | 163981                      | 4117                                 | 365                                      | 218250           | 2.05%                                          | 75.13%                                          | 1.5430%            |
| Minnesota\Kanabec     | 29219                       | 9184                                 | 1438                                     | 141896           | 7.49%                                          | 20.59%                                          | 1.5415%            |
| Nevada\Churchill      | 9600                        | 25955                                | 1786                                     | 131448           | 21.10%                                         | 7.30%                                           | 1.5413%            |
| New York\Orange       | 12709                       | 4425                                 | 3472                                     | 80990            | 9.75%                                          | 15.69%                                          | 1.5301%            |
| Kansas\Kearny         | 164246                      | 24239                                | 873                                      | 519424           | 4.83%                                          | 31.62%                                          | 1.5287%            |
| Kansas\Haskell        | 162987                      | 14915                                |                                          | 398805           | 3.74%                                          | 40.87%                                          | 1.5285%            |
| Nebraska\Polk         | 186647                      | 5924                                 |                                          | 269195           | 2.20%                                          | 69.34%                                          | 1.5258%            |
| Illinois\Washington   | 267654                      | 5585                                 | 1551                                     | 353903           | 2.02%                                          | 75.63%                                          | 1.5250%            |
| Minnesota\Polk        | 683882                      | 24050                                | 2916                                     | 1099761          | 2.45%                                          | 62.18%                                          | 1.5248%            |
| Ohio\Clark            | 106994                      | 4477                                 |                                          | 177335           | 2.52%                                          | 60.33%                                          | 1.5232%            |
| Iowa\Henry            | 133087                      | 6288                                 | 278                                      | 239628           | 2.74%                                          | 55.54%                                          | 1.5218%            |
| Indiana\Vermillion    | 92994                       | 2866                                 |                                          | 132353           | 2.17%                                          | 70.26%                                          | 1.5215%            |
| Minnesota\Red Lake    | 108362                      | 6988                                 |                                          | 223469           | 3.13%                                          | 48.49%                                          | 1.5163%            |
| Iowa\Audubon          | 186641                      | 5927                                 | 381                                      | 279079           | 2.26%                                          | 66.88%                                          | 1.5116%            |

| County                 | Acres Using Herbicide | Harvested Acres of Alfalfa Hay | Harvested Acres Alfalfa Haylage | Acres in Farm | % of Farm Acres in Alfalfa Forage (a) | % of Farm Acres Using Herbicide (b) | (c) = (a) x (b) |
|------------------------|-----------------------|--------------------------------|---------------------------------|---------------|---------------------------------------|-------------------------------------|-----------------|
| Iowa\Benton            | 258623                | 8925                           | 448                             | 400934        | 2.34%                                 | 64.51%                              | 1.5080%         |
| Iowa\Crawford          | 308585                | 9019                           | 98                              | 432351        | 2.11%                                 | 71.37%                              | 1.5051%         |
| North Dakota\Bowman    | 145053                | 53845                          |                                 | 720756        | 7.47%                                 | 20.13%                              | 1.5035%         |
| Wisconsin\Washburn     | 16414                 | 6452                           | 3014                            | 101862        | 9.29%                                 | 16.11%                              | 1.4975%         |
| Nebraska\Cass          | 184134                | 5906                           | 505                             | 280920        | 2.28%                                 | 65.55%                              | 1.4959%         |
| Ohio\Putnam            | 215274                | 4650                           | 1733                            | 303751        | 2.10%                                 | 70.87%                              | 1.4893%         |
| North Dakota\Ward      | 613972                | 26813                          | 734                             | 1066242       | 2.58%                                 | 57.58%                              | 1.4877%         |
| Indiana\Union          | 54438                 | 1463                           |                                 | 73249         | 2.00%                                 | 74.32%                              | 1.4844%         |
| Washington\Island      | 1763                  | 1612                           | 1024                            | 17699         | 14.89%                                | 9.96%                               | 1.4835%         |
| North Dakota\Sheridan  | 182405                | 19743                          | 500                             | 500070        | 4.05%                                 | 36.48%                              | 1.4766%         |
| Illinois\Will          | 176183                | 4086                           |                                 | 220851        | 1.85%                                 | 79.77%                              | 1.4759%         |
| Wyoming\Teton          | 8963                  | 4610                           |                                 | 52930         | 8.71%                                 | 16.93%                              | 1.4749%         |
| Iowa\Clarke            | 30891                 | 17129                          | 203                             | 190727        | 9.09%                                 | 16.20%                              | 1.4718%         |
| Pennsylvania\Montour   | 11964                 | 2386                           | 718                             | 50252         | 6.18%                                 | 23.81%                              | 1.4706%         |
| Iowa\Tama              | 264709                | 10294                          |                                 | 430855        | 2.39%                                 | 61.44%                              | 1.4679%         |
| Pennsylvania\Jefferson | 9749                  | 9196                           | 2210                            | 87043         | 13.10%                                | 11.20%                              | 1.4677%         |
| Nebraska\Antelope      | 271299                | 14428                          |                                 | 516521        | 2.79%                                 | 52.52%                              | 1.4672%         |
| New York\Rensselaer    | 9314                  | 6511                           | 4862                            | 85034         | 13.37%                                | 10.95%                              | 1.4650%         |
| Maryland\Kent          | 75587                 | 2617                           | 567                             | 128220        | 2.48%                                 | 58.95%                              | 1.4639%         |
| Ohio\Union             | 151684                | 4170                           | 441                             | 218657        | 2.11%                                 | 69.37%                              | 1.4629%         |
| Michigan\Saginaw       | 212366                | 5488                           | 1756                            | 324407        | 2.23%                                 | 65.46%                              | 1.4618%         |
| North Dakota\Foster    | 219722                | 10633                          |                                 | 399912        | 2.66%                                 | 54.94%                              | 1.4608%         |
| North Dakota\Pierce    | 276588                | 17752                          | 52                              | 581146        | 3.06%                                 | 47.59%                              | 1.4581%         |
| Indiana\Henry          | 129400                | 3427                           |                                 | 174400        | 1.97%                                 | 74.20%                              | 1.4580%         |
| South Dakota\Lincoln   | 220417                | 6988                           | 322                             | 332762        | 2.20%                                 | 66.24%                              | 1.4551%         |
| Minnesota\Murray       | 265486                | 7880                           | 2183                            | 428869        | 2.35%                                 | 61.90%                              | 1.4525%         |
| Pennsylvania\Bucks     | 31959                 | 1341                           | 1275                            | 75883         | 3.45%                                 | 42.12%                              | 1.4519%         |
| Idaho\Bingham          | 206645                | 56101                          | 2279                            | 912607        | 6.40%                                 | 22.64%                              | 1.4485%         |
| Iowa\Cedar             | 239828                | 6851                           |                                 | 336885        | 2.03%                                 | 71.19%                              | 1.4477%         |
| Nevada\Pershing        | 28131                 | 30625                          |                                 | 244249        | 12.54%                                | 11.52%                              | 1.4441%         |
| New Jersey\Gloucester  | 19205                 | 1635                           |                                 | 46662         | 3.50%                                 | 41.16%                              | 1.4421%         |
| New York\Steuben       | 52302                 | 19575                          | 18466                           | 371932        | 10.23%                                | 14.06%                              | 1.4383%         |
| Nebraska\Dixon         | 133917                | 6180                           | 440                             | 248506        | 2.66%                                 | 53.89%                              | 1.4356%         |
| Maryland\Carroll       | 62087                 | 3469                           | 1174                            | 141934        | 3.27%                                 | 43.74%                              | 1.4310%         |
| Iowa\Lyon              | 234637                | 5246                           | 1112                            | 323054        | 1.97%                                 | 72.63%                              | 1.4294%         |
| Utah\Millard           | 61008                 | 72244                          | 2818                            | 566692        | 13.25%                                | 10.77%                              | 1.4260%         |
| Indiana\Hamilton       | 99217                 | 2071                           | 124                             | 123600        | 1.78%                                 | 80.27%                              | 1.4256%         |
| Illinois\McDonough     | 220147                | 5776                           | 340                             | 307725        | 1.99%                                 | 71.54%                              | 1.4219%         |
| Minnesota\Sibley       | 217535                | 5780                           | 1995                            | 345738        | 2.25%                                 | 62.92%                              | 1.4149%         |
| Michigan\Monroe        | 148492                | 4105                           |                                 | 207812        | 1.98%                                 | 71.45%                              | 1.4115%         |
| Ohio\Greene            | 111737                | 3130                           | 190                             | 162533        | 2.04%                                 | 68.75%                              | 1.4043%         |
| Minnesota\Wadena       | 26233                 | 11036                          | 1183                            | 151212        | 8.08%                                 | 17.35%                              | 1.4019%         |
| Minnesota\Pope         | 174270                | 8487                           | 1918                            | 360095        | 2.89%                                 | 48.40%                              | 1.3984%         |

| County                  | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Michigan\Benzie         | 4194                        | 1345                                 | 131                                      | 21069            | 7.01%                                          | 19.91%                                          | 1.3945%            |
| Pennsylvania\Huntingdon | 19214                       | 8204                                 | 7746                                     | 148289           | 10.76%                                         | 12.96%                                          | 1.3937%            |
| Michigan\Manistee       | 5559                        | 5300                                 |                                          | 46034            | 11.51%                                         | 12.08%                                          | 1.3903%            |
| Iowa\Shelby             | 259458                      | 6572                                 | 232                                      | 358376           | 1.90%                                          | 72.40%                                          | 1.3745%            |
| Iowa\Carroll            | 258139                      | 6676                                 | 145                                      | 358142           | 1.90%                                          | 72.08%                                          | 1.3727%            |
| Iowa\Polk               | 198228                      | 4305                                 |                                          | 249427           | 1.73%                                          | 79.47%                                          | 1.3717%            |
| Nebraska\Saunders       | 265223                      | 9032                                 | 405                                      | 427682           | 2.21%                                          | 62.01%                                          | 1.3684%            |
| Minnesota\Clay          | 384818                      | 13357                                |                                          | 613819           | 2.18%                                          | 62.69%                                          | 1.3642%            |
| North Dakota\Dunn       | 179409                      | 81712                                | 870                                      | 1043932          | 7.91%                                          | 17.19%                                          | 1.3595%            |
| Ohio\Delaware           | 94830                       | 2667                                 | 65                                       | 138140           | 1.98%                                          | 68.65%                                          | 1.3576%            |
| Illinois\Peoria         | 180307                      | 4785                                 | 272                                      | 259204           | 1.95%                                          | 69.56%                                          | 1.3571%            |
| Nebraska\Burt           | 206203                      | 4977                                 |                                          | 275041           | 1.81%                                          | 74.97%                                          | 1.3566%            |
| Illinois\Henry          | 382943                      | 7797                                 | 658                                      | 489903           | 1.73%                                          | 78.17%                                          | 1.3490%            |
| Kansas\Reno             | 287479                      | 27136                                | 1430                                     | 780893           | 3.66%                                          | 36.81%                                          | 1.3467%            |
| North Dakota\Morton     | 249881                      | 69330                                | 3819                                     | 1165098          | 6.28%                                          | 21.45%                                          | 1.3465%            |
| Iowa\Lucas              | 27689                       | 14216                                |                                          | 171150           | 8.31%                                          | 16.18%                                          | 1.3438%            |
| California\Mono         | 3548                        | 7525                                 |                                          | 44610            | 16.87%                                         | 7.95%                                           | 1.3416%            |
| North Dakota\Griggs     | 199410                      | 11085                                |                                          | 406115           | 2.73%                                          | 49.10%                                          | 1.3402%            |
| Indiana\Cass            | 177114                      | 3932                                 |                                          | 228199           | 1.72%                                          | 77.61%                                          | 1.3373%            |
| Nebraska\Jefferson      | 187013                      | 6775                                 | 801                                      | 325577           | 2.33%                                          | 57.44%                                          | 1.3366%            |
| Ohio\Henry              | 170191                      | 2983                                 | 1242                                     | 232238           | 1.82%                                          | 73.28%                                          | 1.3332%            |
| Minnesota\Beltrami      | 22855                       | 24381                                | 1407                                     | 210833           | 12.23%                                         | 10.84%                                          | 1.3259%            |
| Minnesota\Mower         | 264959                      | 5772                                 | 3043                                     | 419889           | 2.10%                                          | 63.10%                                          | 1.3247%            |
| Michigan\Schoolcraft    | 2913                        | 3228                                 |                                          | 26697            | 12.09%                                         | 10.91%                                          | 1.3193%            |
| Nebraska\Furnas         | 186103                      | 14082                                |                                          | 445844           | 3.16%                                          | 41.74%                                          | 1.3184%            |
| Iowa\Wayne              | 54819                       | 17561                                | 210                                      | 273212           | 6.50%                                          | 20.06%                                          | 1.3051%            |
| New York\Cortland       | 12435                       | 7453                                 | 8829                                     | 124824           | 13.04%                                         | 9.96%                                           | 1.2994%            |
| Iowa\Taylor             | 112007                      | 9013                                 | 219                                      | 282637           | 3.27%                                          | 39.63%                                          | 1.2944%            |
| South Dakota\Day        | 238192                      | 16978                                | 490                                      | 567218           | 3.08%                                          | 41.99%                                          | 1.2932%            |
| Nebraska\Otoe           | 179518                      | 7227                                 | 224                                      | 322146           | 2.31%                                          | 55.73%                                          | 1.2889%            |
| Illinois\Brown          | 72068                       | 3777                                 | 297                                      | 151058           | 2.70%                                          | 47.71%                                          | 1.2867%            |
| North Dakota\Mountrail  | 425412                      | 30757                                | 1629                                     | 1036572          | 3.12%                                          | 41.04%                                          | 1.2822%            |
| Ohio\Highland           | 119177                      | 7351                                 | 468                                      | 269803           | 2.90%                                          | 44.17%                                          | 1.2801%            |
| Kansas\Marion           | 183050                      | 21078                                | 1312                                     | 566309           | 3.95%                                          | 32.32%                                          | 1.2780%            |
| West Virginia\Jefferson | 22850                       | 2395                                 | 510                                      | 72091            | 4.03%                                          | 31.70%                                          | 1.2772%            |
| Ohio\Madison            | 173086                      | 3866                                 | 669                                      | 247913           | 1.83%                                          | 69.82%                                          | 1.2771%            |
| Nebraska\Adams          | 213969                      | 5602                                 |                                          | 306373           | 1.83%                                          | 69.84%                                          | 1.2770%            |
| Ohio\Crawford           | 160338                      | 2763                                 | 1068                                     | 219566           | 1.74%                                          | 73.02%                                          | 1.2741%            |
| Ohio\Williams           | 110060                      | 3914                                 | 1312                                     | 212509           | 2.46%                                          | 51.79%                                          | 1.2736%            |
| Iowa\Mahaska            | 144036                      | 7126                                 | 555                                      | 295128           | 2.60%                                          | 48.80%                                          | 1.2702%            |
| North Dakota\LaMoure    | 389626                      | 15083                                | 330                                      | 688012           | 2.24%                                          | 56.63%                                          | 1.2687%            |
| Pennsylvania\Sullivan   | 2944                        | 1857                                 | 1472                                     | 27821            | 11.97%                                         | 10.58%                                          | 1.2662%            |
| Nebraska\Sarpy          | 75987                       | 1519                                 | 165                                      | 100835           | 1.67%                                          | 75.36%                                          | 1.2585%            |
| North Dakota\Williams   | 466234                      | 35196                                |                                          | 1144868          | 3.07%                                          | 40.72%                                          | 1.2519%            |
| Minnesota\Lyon          | 254561                      | 8004                                 | 993                                      | 428693           | 2.10%                                          | 59.38%                                          | 1.2462%            |

| County                  | Acres Using Herbicide | Harvested Acres of Alfalfa Hay | Harvested Acres Alfalfa Haylage | Acres in Farm | % of Farm Acres in Alfalfa Forage (a) | % of Farm Acres Using Herbicide (b) | (c) = (a) x (b) |
|-------------------------|-----------------------|--------------------------------|---------------------------------|---------------|---------------------------------------|-------------------------------------|-----------------|
| Ohio\Erie               | 58100                 | 1514                           |                                 | 84085         | 1.80%                                 | 69.10%                              | 1.2441%         |
| Nebraska\Greeley        | 83351                 | 11504                          | 387                             | 282395        | 4.21%                                 | 29.52%                              | 1.2428%         |
| New York\Westchester    | 173                   | 711                            | 4502                            | 8521          | 61.18%                                | 2.03%                               | 1.2421%         |
| North Dakota\Bottineau  | 614263                | 21390                          |                                 | 1028699       | 2.08%                                 | 59.71%                              | 1.2416%         |
| Kansas\Jewell           | 182455                | 14793                          | 249                             | 471240        | 3.19%                                 | 38.72%                              | 1.2359%         |
| Indiana\Parke           | 112417                | 3131                           | 324                             | 177343        | 1.95%                                 | 63.39%                              | 1.2350%         |
| Iowa\Sioux              | 347107                | 6660                           | 1487                            | 478697        | 1.70%                                 | 72.51%                              | 1.2341%         |
| Pennsylvania\Luzerne    | 16258                 | 1827                           | 1536                            | 66577         | 5.05%                                 | 24.42%                              | 1.2335%         |
| Illinois\Madison        | 229189                | 4876                           | 377                             | 312936        | 1.68%                                 | 73.24%                              | 1.2294%         |
| Indiana\Hancock         | 137674                | 2619                           |                                 | 171673        | 1.53%                                 | 80.20%                              | 1.2234%         |
| Indiana\Clark           | 39660                 | 2161                           | 148                             | 86668         | 2.66%                                 | 45.76%                              | 1.2192%         |
| Illinois\Schuyler       | 107264                | 4886                           |                                 | 207457        | 2.36%                                 | 51.70%                              | 1.2177%         |
| Ohio\Warren             | 46876                 | 2305                           |                                 | 94348         | 2.44%                                 | 49.68%                              | 1.2138%         |
| Nebraska\Clay           | 259430                | 6212                           |                                 | 365099        | 1.70%                                 | 71.06%                              | 1.2090%         |
| Iowa\Dallas             | 215593                | 4943                           |                                 | 297090        | 1.66%                                 | 72.57%                              | 1.2074%         |
| Indiana\Morgan          | 77058                 | 2040                           |                                 | 114136        | 1.79%                                 | 67.51%                              | 1.2067%         |
| California\Stanislaus   | 220704                | 28836                          | 5045                            | 788954        | 4.29%                                 | 27.97%                              | 1.2013%         |
| Colorado\Conejos        | 12375                 | 50172                          | 294                             | 228700        | 22.07%                                | 5.41%                               | 1.1940%         |
| Illinois\Warren         | 226666                | 4402                           | 168                             | 294907        | 1.55%                                 | 76.86%                              | 1.1911%         |
| Illinois\Fulton         | 236119                | 7275                           | 187                             | 385302        | 1.94%                                 | 61.28%                              | 1.1868%         |
| Indiana\Huntington      | 153154                | 3065                           |                                 | 199070        | 1.54%                                 | 76.93%                              | 1.1845%         |
| Indiana\Harrison        | 62985                 | 4262                           | 244                             | 154998        | 2.91%                                 | 40.64%                              | 1.1813%         |
| Kansas\McPherson        | 234586                | 12983                          | 233                             | 514818        | 2.57%                                 | 45.57%                              | 1.1698%         |
| Nebraska\Hall           | 185830                | 6784                           |                                 | 328294        | 2.07%                                 | 56.60%                              | 1.1697%         |
| Pennsylvania\Venango    | 11616                 | 2812                           | 1413                            | 64796         | 6.52%                                 | 17.93%                              | 1.1689%         |
| North Dakota\Ransom     | 207676                | 15640                          |                                 | 527276        | 2.97%                                 | 39.39%                              | 1.1683%         |
| North Dakota\Burke      | 243396                | 15594                          |                                 | 570560        | 2.73%                                 | 42.66%                              | 1.1659%         |
| Virginia\Rockingham     | 55682                 | 7804                           | 3549                            | 233087        | 4.87%                                 | 23.89%                              | 1.1636%         |
| Iowa\Cherokee           | 216116                | 4807                           | 510                             | 314896        | 1.69%                                 | 68.63%                              | 1.1588%         |
| Oklahoma\Tillman        | 136497                | 18134                          |                                 | 463943        | 3.91%                                 | 29.42%                              | 1.1500%         |
| Indiana\Rush            | 169890                | 3182                           |                                 | 216890        | 1.47%                                 | 78.33%                              | 1.1492%         |
| Pennsylvania\Clearfield | 5322                  | 6292                           | 2196                            | 62721         | 13.53%                                | 8.49%                               | 1.1483%         |
| South Dakota\Hyde       | 106216                | 24976                          |                                 | 480989        | 5.19%                                 | 22.08%                              | 1.1467%         |
| Iowa\Woodbury           | 305556                | 7241                           | 181                             | 445554        | 1.67%                                 | 68.58%                              | 1.1424%         |
| Montana\Judith Basin    | 98503                 | 79911                          | 1475                            | 838477        | 9.71%                                 | 11.75%                              | 1.1403%         |
| Indiana\Jay             | 136959                | 3004                           | 223                             | 197225        | 1.64%                                 | 69.44%                              | 1.1362%         |
| Iowa\Pottawattamie      | 340167                | 7875                           |                                 | 485943        | 1.62%                                 | 70.00%                              | 1.1344%         |
| Iowa\Des Moines         | 113246                | 3427                           |                                 | 184975        | 1.85%                                 | 61.22%                              | 1.1343%         |
| Colorado\Prowers        | 198485                | 61489                          |                                 | 1037336       | 5.93%                                 | 19.13%                              | 1.1342%         |
| California\Colusa       | 170606                | 14900                          |                                 | 474092        | 3.14%                                 | 35.99%                              | 1.1310%         |
| Illinois\Hancock        | 261827                | 6230                           | 433                             | 392898        | 1.70%                                 | 66.64%                              | 1.1301%         |
| Iowa\Scott              | 196775                | 3549                           |                                 | 248646        | 1.43%                                 | 79.14%                              | 1.1296%         |
| Utah\Wayne              | 1858                  | 11732                          | 694                             | 45222         | 27.48%                                | 4.11%                               | 1.1290%         |

| County                  | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Illinois\Marshall       | 160511                      | 2853                                 | 88                                       | 204584           | 1.44%                                          | 78.46%                                          | 1.1279%            |
| Illinois\Whiteside      | 316817                      | 4990                                 | 856                                      | 405333           | 1.44%                                          | 78.16%                                          | 1.1273%            |
| Nebraska\Nemaha         | 127083                      | 3957                                 | 54                                       | 212686           | 1.89%                                          | 59.75%                                          | 1.1268%            |
| Nebraska\Nuckolls       | 172413                      | 6163                                 |                                          | 307096           | 2.01%                                          | 56.14%                                          | 1.1267%            |
| New Jersey\Monmouth     | 14220                       | 1498                                 | 38                                       | 44130            | 3.48%                                          | 32.22%                                          | 1.1216%            |
| Kansas\Harvey           | 198861                      | 5956                                 | 502                                      | 338598           | 1.91%                                          | 58.73%                                          | 1.1202%            |
| Iowa\Marshall           | 233574                      | 3930                                 | 1110                                     | 324270           | 1.55%                                          | 72.03%                                          | 1.1195%            |
| North Dakota\McLean     | 575838                      | 25997                                | 279                                      | 1162923          | 2.26%                                          | 49.52%                                          | 1.1188%            |
| North Dakota\Hettinger  | 279244                      | 20069                                |                                          | 707833           | 2.84%                                          | 39.45%                                          | 1.1185%            |
| Nebraska\Saline         | 176727                      | 5628                                 |                                          | 298304           | 1.89%                                          | 59.24%                                          | 1.1177%            |
| Iowa\Decatur            | 42752                       | 13543                                | 110                                      | 228528           | 5.97%                                          | 18.71%                                          | 1.1176%            |
| California\Madera       | 152691                      | 29759                                | 4040                                     | 679729           | 4.97%                                          | 22.46%                                          | 1.1170%            |
| North Dakota\Divide     | 326200                      | 17132                                |                                          | 708034           | 2.42%                                          | 46.07%                                          | 1.1148%            |
| Idaho\Kootenai          | 35499                       | 5362                                 |                                          | 130851           | 4.10%                                          | 27.13%                                          | 1.1117%            |
| California\Los Angeles  | 16992                       | 7693                                 |                                          | 108463           | 7.09%                                          | 15.67%                                          | 1.1112%            |
| New York\Chautauqua     | 42339                       | 6570                                 | 8007                                     | 235858           | 6.18%                                          | 17.95%                                          | 1.1094%            |
| Idaho\Lewis             | 149915                      | 4469                                 |                                          | 245944           | 1.82%                                          | 60.95%                                          | 1.1076%            |
| Colorado\Boulder        | 16530                       | 11913                                | 772                                      | 137668           | 9.21%                                          | 12.01%                                          | 1.1064%            |
| Ohio\Fulton             | 125112                      | 2396                                 | 594                                      | 183913           | 1.63%                                          | 68.03%                                          | 1.1060%            |
| Minnesota\Mahnomen      | 83152                       | 7884                                 |                                          | 243958           | 3.23%                                          | 34.08%                                          | 1.1015%            |
| North Dakota\Wells      | 417451                      | 15035                                |                                          | 757008           | 1.99%                                          | 55.14%                                          | 1.0952%            |
| Ohio\Muskingum          | 21325                       | 13437                                | 764                                      | 166448           | 8.53%                                          | 12.81%                                          | 1.0931%            |
| Iowa\Mitchell           | 210746                      | 3280                                 | 1189                                     | 294041           | 1.52%                                          | 71.67%                                          | 1.0893%            |
| New Jersey\Cumberland   | 33894                       | 1551                                 |                                          | 69489            | 2.23%                                          | 48.78%                                          | 1.0887%            |
| Indiana\Tippecanoe      | 170803                      | 2850                                 | 177                                      | 218301           | 1.39%                                          | 78.24%                                          | 1.0849%            |
| Minnesota\Pine          | 26491                       | 12248                                | 5390                                     | 207629           | 8.49%                                          | 12.76%                                          | 1.0839%            |
| Nebraska\Harlan         | 179333                      | 7390                                 |                                          | 350947           | 2.11%                                          | 51.10%                                          | 1.0760%            |
| Minnesota\Lac qui Parle | 261941                      | 6965                                 |                                          | 412051           | 1.69%                                          | 63.57%                                          | 1.0745%            |
| Utah\Piute              | 2170                        | 8870                                 |                                          | 42380            | 20.93%                                         | 5.12%                                           | 1.0717%            |
| Iowa\Plymouth           | 341216                      | 8017                                 | 371                                      | 517248           | 1.62%                                          | 65.97%                                          | 1.0698%            |
| Indiana\Decatur         | 155816                      | 2562                                 | 313                                      | 204702           | 1.40%                                          | 76.12%                                          | 1.0691%            |
| Montana\Gallatin        | 108197                      | 54242                                | 5327                                     | 776868           | 7.67%                                          | 13.93%                                          | 1.0679%            |
| Utah\Sevier             | 13629                       | 25878                                | 1099                                     | 185708           | 14.53%                                         | 7.34%                                           | 1.0661%            |
| New Jersey              | 243360                      | 20310                                | 3234                                     | 733450           | 3.21%                                          | 33.18%                                          | 1.0651%            |
| Minnesota\Swift         | 238827                      | 5908                                 | 817                                      | 388442           | 1.73%                                          | 61.48%                                          | 1.0644%            |
| New York\Otsego         | 13826                       | 14617                                | 9352                                     | 176481           | 13.58%                                         | 7.83%                                           | 1.0640%            |
| Iowa\Black Hawk         | 214031                      | 3447                                 | 493                                      | 282163           | 1.40%                                          | 75.85%                                          | 1.0592%            |
| Indiana\Johnson         | 112943                      | 1895                                 |                                          | 142181           | 1.33%                                          | 79.44%                                          | 1.0587%            |
| Iowa\Mills              | 127956                      | 3199                                 |                                          | 196840           | 1.63%                                          | 65.01%                                          | 1.0564%            |
| Kansas\Rush             | 147512                      | 11791                                |                                          | 405912           | 2.90%                                          | 36.34%                                          | 1.0556%            |
| Kansas\Edwards          | 161433                      | 12595                                |                                          | 439243           | 2.87%                                          | 36.75%                                          | 1.0539%            |
| Iowa\Boone              | 244868                      | 4694                                 | 39                                       | 332048           | 1.43%                                          | 73.74%                                          | 1.0512%            |
| Ohio\Ross               | 88757                       | 5057                                 | 866                                      | 223650           | 2.65%                                          | 39.69%                                          | 1.0510%            |
| New York\Dutchess       | 10828                       | 7738                                 | 2408                                     | 102360           | 9.91%                                          | 10.58%                                          | 1.0485%            |
| Indiana\Wells           | 155834                      | 2153                                 | 381                                      | 194602           | 1.30%                                          | 80.08%                                          | 1.0427%            |

| County                    | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|---------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Nebraska\Phelps           | 220500                      | 5476                                 |                                          | 340291           | 1.61%                                          | 64.80%                                          | 1.0427%            |
| Minnesota\Yellow Medicine | 275692                      | 6177                                 | 140                                      | 409223           | 1.54%                                          | 67.37%                                          | 1.0400%            |
| Missouri\Scotland         | 77384                       | 5123                                 | 2072                                     | 231697           | 3.11%                                          | 33.40%                                          | 1.0371%            |
| Utah\Utah                 | 40355                       | 30197                                | 403                                      | 345634           | 8.85%                                          | 11.68%                                          | 1.0337%            |
| Iowa\Floyd                | 213379                      | 3534                                 | 763                                      | 298459           | 1.44%                                          | 71.49%                                          | 1.0293%            |
| Indiana\Ripley            | 92944                       | 2427                                 | 352                                      | 159017           | 1.75%                                          | 58.45%                                          | 1.0215%            |
| Pennsylvania\Carbon       | 6118                        | 667                                  |                                          | 20035            | 3.33%                                          | 30.54%                                          | 1.0166%            |
| South Dakota\Potter       | 222912                      | 12155                                |                                          | 516683           | 2.35%                                          | 43.14%                                          | 1.0149%            |
| Ohio\Hancock              | 166106                      | 2878                                 | 875                                      | 247981           | 1.51%                                          | 66.98%                                          | 1.0137%            |
| Minnesota\Norman          | 308270                      | 8620                                 |                                          | 512922           | 1.68%                                          | 60.10%                                          | 1.0100%            |
| Illinois\Cumberland       | 97625                       | 1747                                 | 420                                      | 144981           | 1.49%                                          | 67.34%                                          | 1.0065%            |
| Nebraska\Custer           | 430466                      | 59242                                | 1659                                     | 1614280          | 3.77%                                          | 26.67%                                          | 1.0060%            |
| New York\Franklin         | 13579                       | 5839                                 | 6819                                     | 130852           | 9.67%                                          | 10.38%                                          | 1.0039%            |
| Illinois\Monroe           | 122423                      | 2598                                 |                                          | 178134           | 1.46%                                          | 68.73%                                          | 1.0023%            |
| Ohio\Wood                 | 196978                      | 3852                                 |                                          | 275552           | 1.40%                                          | 71.48%                                          | 0.9993%            |
| Kansas\Seward             | 152265                      | 10290                                |                                          | 395981           | 2.60%                                          | 38.45%                                          | 0.9992%            |
| Montana\Flathead          | 32308                       | 18783                                | 726                                      | 251597           | 7.75%                                          | 12.84%                                          | 0.9957%            |
| Iowa\Dickinson            | 174603                      | 2921                                 |                                          | 226331           | 1.29%                                          | 77.14%                                          | 0.9956%            |
| Washington\Kittitas       | 41643                       | 8721                                 |                                          | 191087           | 4.56%                                          | 21.79%                                          | 0.9946%            |
| South Dakota\Hughes       | 171203                      | 9816                                 |                                          | 411199           | 2.39%                                          | 41.64%                                          | 0.9939%            |
| Illinois\Douglas          | 217819                      | 2928                                 | 191                                      | 261513           | 1.19%                                          | 83.29%                                          | 0.9934%            |
| Iowa\Louisa               | 109393                      | 3057                                 | 81                                       | 186007           | 1.69%                                          | 58.81%                                          | 0.9922%            |
| Indiana\Delaware          | 126900                      | 1863                                 |                                          | 154470           | 1.21%                                          | 82.15%                                          | 0.9908%            |
| Oklahoma\Alfalfa          | 133542                      | 21702                                | 90                                       | 542813           | 4.01%                                          | 24.60%                                          | 0.9877%            |
| Colorado\Saguache         | 33474                       | 24327                                |                                          | 287272           | 8.47%                                          | 11.65%                                          | 0.9868%            |
| Nebraska\Gage             | 304607                      | 9091                                 | 297                                      | 540226           | 1.74%                                          | 56.39%                                          | 0.9799%            |
| Indiana\Randolph          | 178201                      | 2950                                 |                                          | 231784           | 1.27%                                          | 76.88%                                          | 0.9785%            |
| Nebraska\Johnson          | 68380                       | 4403                                 |                                          | 175500           | 2.51%                                          | 38.96%                                          | 0.9775%            |
| Illinois\Woodford         | 225230                      | 3442                                 | 167                                      | 288400           | 1.25%                                          | 78.10%                                          | 0.9773%            |
| North Dakota\McKenzie     | 242002                      | 45683                                | 920                                      | 1074656          | 4.34%                                          | 22.52%                                          | 0.9765%            |
| Illinois\Jersey           | 142907                      | 2450                                 |                                          | 189462           | 1.29%                                          | 75.43%                                          | 0.9754%            |
| Idaho\Custer              | 6376                        | 23590                                |                                          | 124191           | 18.99%                                         | 5.13%                                           | 0.9752%            |
| Pennsylvania\Fayette      | 16010                       | 9338                                 | 2707                                     | 140688           | 8.56%                                          | 11.38%                                          | 0.9743%            |
| Illinois\Jackson          | 140427                      | 3166                                 | 327                                      | 224414           | 1.56%                                          | 62.57%                                          | 0.9740%            |
| Iowa\Sac                  | 266145                      | 4209                                 | 585                                      | 363295           | 1.32%                                          | 73.26%                                          | 0.9667%            |
| Nebraska\Thayer           | 207309                      | 5743                                 |                                          | 351364           | 1.63%                                          | 59.00%                                          | 0.9644%            |
| Minnesota\Cottonwood      | 263380                      | 4794                                 | 523                                      | 381249           | 1.39%                                          | 69.08%                                          | 0.9635%            |
| Maryland\Baltimore        | 27525                       | 1922                                 | 223                                      | 78282            | 2.74%                                          | 35.16%                                          | 0.9635%            |
| Ohio\Franklin             | 34911                       | 974                                  |                                          | 59601            | 1.63%                                          | 58.57%                                          | 0.9572%            |
| Nebraska\Webster          | 116647                      | 7645                                 |                                          | 305507           | 2.50%                                          | 38.18%                                          | 0.9555%            |
| New York\Schoharie        | 6189                        | 9408                                 | 4660                                     | 95490            | 14.73%                                         | 6.48%                                           | 0.9549%            |
| California\Glenn          | 160151                      | 13851                                | 360                                      | 489186           | 2.91%                                          | 32.74%                                          | 0.9511%            |
| North Dakota\Benson       | 413321                      | 13259                                |                                          | 759341           | 1.75%                                          | 54.43%                                          | 0.9504%            |

| County                 | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Kansas\Cloud           | 152934                      | 9058                                 |                                          | 383981           | 2.36%                                          | 39.83%                                          | 0.9395%            |
| Missouri\Buchanan      | 95929                       | 3649                                 | 168                                      | 197533           | 1.93%                                          | 48.56%                                          | 0.9384%            |
| Minnesota\McLeod       | 151966                      | 7887                                 | 4554                                     | 449655           | 2.77%                                          | 33.80%                                          | 0.9351%            |
| Ohio\Pickaway          | 202548                      | 3715                                 | 125                                      | 288905           | 1.33%                                          | 70.11%                                          | 0.9319%            |
| Indiana\Jefferson      | 44878                       | 2017                                 | 164                                      | 102514           | 2.13%                                          | 43.78%                                          | 0.9314%            |
| South Dakota\Corson    | 170319                      | 89144                                | 507                                      | 1283038          | 6.99%                                          | 13.27%                                          | 0.9276%            |
| New York\Schuyler      | 6648                        | 2947                                 | 3196                                     | 66368            | 9.26%                                          | 10.02%                                          | 0.9272%            |
| Minnesota\Kittson      | 237862                      | 11453                                |                                          | 542062           | 2.11%                                          | 43.88%                                          | 0.9271%            |
| Washington\Walla Walla | 292200                      | 14772                                |                                          | 682350           | 2.16%                                          | 42.82%                                          | 0.9271%            |
| Idaho\Caribou          | 77970                       | 21060                                |                                          | 421373           | 5.00%                                          | 18.50%                                          | 0.9248%            |
| Illinois\Menard        | 132173                      | 1974                                 |                                          | 168594           | 1.17%                                          | 78.40%                                          | 0.9179%            |
| Nebraska\Fillmore      | 253421                      | 4737                                 |                                          | 362155           | 1.31%                                          | 69.98%                                          | 0.9153%            |
| Illinois\Pike          | 223021                      | 6064                                 | 163                                      | 389808           | 1.60%                                          | 57.21%                                          | 0.9140%            |
| Iowa\Story             | 256720                      | 4402                                 |                                          | 352240           | 1.25%                                          | 72.88%                                          | 0.9108%            |
| Minnesota\Brown        | 219559                      | 5209                                 |                                          | 354725           | 1.47%                                          | 61.90%                                          | 0.9089%            |
| Montana\Pondera        | 299660                      | 27044                                |                                          | 944486           | 2.86%                                          | 31.73%                                          | 0.9085%            |
| Iowa\Harrison          | 245613                      | 4650                                 | 273                                      | 365071           | 1.35%                                          | 67.28%                                          | 0.9072%            |
| Illinois\Lee           | 341304                      | 3750                                 | 400                                      | 395624           | 1.05%                                          | 86.27%                                          | 0.9049%            |
| New Jersey\Camden      | 2589                        | 268                                  |                                          | 8760             | 3.06%                                          | 29.55%                                          | 0.9042%            |
| Minnesota\Nobles       | 284116                      | 4104                                 | 1571                                     | 422300           | 1.34%                                          | 67.28%                                          | 0.9041%            |
| Michigan\Kalkaska      | 1345                        | 3695                                 |                                          | 23464            | 15.75%                                         | 5.73%                                           | 0.9027%            |
| Ohio\Perry             | 26280                       | 3291                                 |                                          | 97965            | 3.36%                                          | 26.83%                                          | 0.9012%            |
| Illinois\Moultrie      | 146527                      | 1631                                 | 100                                      | 167791           | 1.03%                                          | 87.33%                                          | 0.9009%            |
| Maryland\Howard        | 10027                       | 440                                  | 334                                      | 29371            | 2.64%                                          | 34.14%                                          | 0.8997%            |
| Indiana\Warren         | 155504                      | 2220                                 |                                          | 195930           | 1.13%                                          | 79.37%                                          | 0.8993%            |
| Ohio\Defiance          | 143455                      | 2856                                 | 553                                      | 233213           | 1.46%                                          | 61.51%                                          | 0.8992%            |
| Utah\Davis             | 5871                        | 3715                                 |                                          | 49279            | 7.54%                                          | 11.91%                                          | 0.8981%            |
| Illinois\Morgan        | 252133                      | 3308                                 | 350                                      | 320512           | 1.14%                                          | 78.67%                                          | 0.8978%            |
| North Dakota\Sargent   | 301061                      | 7605                                 |                                          | 505015           | 1.51%                                          | 59.61%                                          | 0.8977%            |
| Iowa\Hardin            | 229860                      | 4485                                 |                                          | 339001           | 1.32%                                          | 67.81%                                          | 0.8971%            |
| Kansas\Lincoln         | 125083                      | 11753                                | 1652                                     | 432479           | 3.10%                                          | 28.92%                                          | 0.8965%            |
| Nebraska\Pawnee        | 82310                       | 5159                                 |                                          | 217669           | 2.37%                                          | 37.81%                                          | 0.8962%            |
| Nebraska\Hamilton      | 245024                      | 3718                                 |                                          | 319115           | 1.17%                                          | 76.78%                                          | 0.8946%            |
| Oklahoma\Grady         | 141890                      | 22971                                | 307                                      | 608373           | 3.83%                                          | 23.32%                                          | 0.8924%            |
| Illinois\De Kalb       | 315166                      | 3880                                 |                                          | 370772           | 1.05%                                          | 85.00%                                          | 0.8895%            |
| Indiana\Monroe         | 12575                       | 1799                                 | 223                                      | 53538            | 3.78%                                          | 23.49%                                          | 0.8871%            |
| Kansas\Nemaha          | 165880                      | 10179                                | 664                                      | 450508           | 2.41%                                          | 36.82%                                          | 0.8862%            |
| Indiana\Washington     | 95363                       | 3156                                 | 550                                      | 199942           | 1.85%                                          | 47.70%                                          | 0.8841%            |
| Ohio\Marion            | 135923                      | 2458                                 | 320                                      | 206832           | 1.34%                                          | 65.72%                                          | 0.8827%            |
| Minnesota\Stevens      | 236416                      | 4324                                 |                                          | 340347           | 1.27%                                          | 69.46%                                          | 0.8825%            |
| California\Sacramento  | 88706                       | 9960                                 | 780                                      | 328593           | 3.27%                                          | 27.00%                                          | 0.8823%            |
| Colorado\Weld          | 321831                      | 109575                               | 9951                                     | 2088715          | 5.72%                                          | 15.41%                                          | 0.8817%            |
| Ohio\Seneca            | 168060                      | 3340                                 | 448                                      | 269371           | 1.41%                                          | 62.39%                                          | 0.8773%            |
| Colorado\Morgan        | 135939                      | 32332                                | 1829                                     | 728092           | 4.69%                                          | 18.67%                                          | 0.8760%            |
| New York\Fulton        | 2282                        | 2666                                 | 1718                                     | 33851            | 12.95%                                         | 6.74%                                           | 0.8731%            |

| County                  | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Indiana\Madison         | 173183                      | 2381                                 |                                          | 217355           | 1.10%                                          | 79.68%                                          | 0.8728%            |
| Kentucky\Shelby         | 39223                       | 8946                                 | 408                                      | 205286           | 4.56%                                          | 19.11%                                          | 0.8706%            |
| New York\Oswego         | 12166                       | 4860                                 | 2315                                     | 100195           | 7.16%                                          | 12.14%                                          | 0.8695%            |
| Indiana\Lake            | 105611                      | 1358                                 |                                          | 128439           | 1.06%                                          | 82.23%                                          | 0.8694%            |
| Nebraska\Kearney        | 228246                      | 3997                                 |                                          | 324218           | 1.23%                                          | 70.40%                                          | 0.8679%            |
| Pennsylvania\Montgomery | 9403                        | 1234                                 | 387                                      | 41908            | 3.87%                                          | 22.44%                                          | 0.8679%            |
| Indiana\Boone           | 191271                      | 1994                                 | 256                                      | 222706           | 1.01%                                          | 85.88%                                          | 0.8677%            |
| Pennsylvania\Potter     | 9191                        | 4091                                 | 3284                                     | 88457            | 8.34%                                          | 10.39%                                          | 0.8663%            |
| Idaho\Bannock           | 41557                       | 20926                                | 652                                      | 321870           | 6.70%                                          | 12.91%                                          | 0.8656%            |
| Michigan\Cheboygan      | 1972                        | 8651                                 | 1262                                     | 47562            | 20.84%                                         | 4.15%                                           | 0.8642%            |
| Utah\Sanpete            | 21072                       | 35994                                | 3705                                     | 311551           | 12.74%                                         | 6.76%                                           | 0.8618%            |
| North Dakota\Barnes     | 566785                      | 12374                                | 119                                      | 907184           | 1.38%                                          | 62.48%                                          | 0.8604%            |
| Utah\Beaver             | 10727                       | 19908                                |                                          | 158323           | 12.57%                                         | 6.78%                                           | 0.8520%            |
| Idaho\Oneida            | 28535                       | 28802                                | 505                                      | 313775           | 9.34%                                          | 9.09%                                           | 0.8494%            |
| Iowa\Monona             | 281554                      | 4666                                 |                                          | 393600           | 1.19%                                          | 71.53%                                          | 0.8480%            |
| Kansas\Saline           | 137639                      | 11438                                |                                          | 431209           | 2.65%                                          | 31.92%                                          | 0.8467%            |
| Illinois\Randolph       | 165579                      | 3044                                 | 227                                      | 252926           | 1.29%                                          | 65.47%                                          | 0.8466%            |
| New York\Washington     | 27529                       | 12640                                |                                          | 202877           | 6.23%                                          | 13.57%                                          | 0.8454%            |
| New York\Chenango       | 15044                       | 9325                                 | 8269                                     | 177267           | 9.93%                                          | 8.49%                                           | 0.8423%            |
| Missouri\Lewis          | 102772                      | 4206                                 | 1375                                     | 261299           | 2.14%                                          | 39.33%                                          | 0.8401%            |
| Montana\Teton           | 263268                      | 42172                                |                                          | 1152691          | 3.66%                                          | 22.84%                                          | 0.8356%            |
| Pennsylvania\Fulton     | 11696                       | 4363                                 | 3279                                     | 103516           | 7.38%                                          | 11.30%                                          | 0.8341%            |
| Wisconsin\Bayfield      | 5280                        | 9107                                 | 3415                                     | 89284            | 14.02%                                         | 5.91%                                           | 0.8294%            |
| Missouri\Clark          | 92775                       | 5423                                 | 752                                      | 262937           | 2.35%                                          | 35.28%                                          | 0.8286%            |
| Illinois\Macoupin       | 283640                      | 4110                                 | 425                                      | 394228           | 1.15%                                          | 71.95%                                          | 0.8277%            |
| Maryland\Garrett        | 6903                        | 7245                                 | 3681                                     | 95514            | 11.44%                                         | 7.23%                                           | 0.8267%            |
| Indiana\Starke          | 105993                      | 1841                                 |                                          | 153651           | 1.20%                                          | 68.98%                                          | 0.8265%            |
| Illinois\Effingham      | 161509                      | 2713                                 | 284                                      | 242009           | 1.24%                                          | 66.74%                                          | 0.8265%            |
| Pennsylvania\Bradford   | 23902                       | 12358                                | 12220                                    | 266635           | 9.22%                                          | 8.96%                                           | 0.8263%            |
| Illinois\Bond           | 177984                      | 1985                                 | 353                                      | 224760           | 1.04%                                          | 79.19%                                          | 0.8237%            |
| California\Kern         | 479518                      | 85756                                | 9768                                     | 2361765          | 4.04%                                          | 20.30%                                          | 0.8212%            |
| Montana\Roosevelt       | 331221                      | 52241                                |                                          | 1451828          | 3.60%                                          | 22.81%                                          | 0.8209%            |
| Ohio\Lucas              | 46177                       | 703                                  |                                          | 62906            | 1.12%                                          | 73.41%                                          | 0.8203%            |
| Minnesota\Waseca        | 166839                      | 2467                                 | 699                                      | 254531           | 1.24%                                          | 65.55%                                          | 0.8153%            |
| Oregon\Union            | 72767                       | 26633                                |                                          | 487584           | 5.46%                                          | 14.92%                                          | 0.8152%            |
| Illinois\Shelby         | 286268                      | 4033                                 | 212                                      | 387288           | 1.10%                                          | 73.92%                                          | 0.8102%            |
| California\Siskiyou     | 48829                       | 59216                                |                                          | 597534           | 9.91%                                          | 8.17%                                           | 0.8098%            |
| New York\Tioga          | 8048                        | 4829                                 | 6608                                     | 106834           | 10.71%                                         | 7.53%                                           | 0.8065%            |
| Nebraska\Madison        | 196825                      | 12022                                |                                          | 542363           | 2.22%                                          | 36.29%                                          | 0.8044%            |
| Illinois\Tazewell       | 257021                      | 3383                                 |                                          | 329268           | 1.03%                                          | 78.06%                                          | 0.8020%            |
| North Dakota\Richland   | 686941                      | 9127                                 | 432                                      | 905922           | 1.06%                                          | 75.83%                                          | 0.8001%            |
| New York\St. Lawrence   | 31038                       | 11305                                | 19632                                    | 347246           | 8.91%                                          | 8.94%                                           | 0.7963%            |
| New York\Cattaraugus    | 19436                       | 6416                                 | 7356                                     | 183439           | 7.51%                                          | 10.60%                                          | 0.7955%            |



| County                | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-----------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Kansas\Washington     | 205329                      | 11476                                | 145                                      | 548034           | 2.12%                                          | 37.47%                                          | 0.7945%            |
| Indiana\Daviess       | 145501                      | 1912                                 | 254                                      | 199367           | 1.09%                                          | 72.98%                                          | 0.7929%            |
| Illinois\Fayette      | 200702                      | 3455                                 | 149                                      | 303258           | 1.19%                                          | 66.18%                                          | 0.7865%            |
| Kansas\Mitchell       | 173040                      | 8674                                 | 270                                      | 444249           | 2.01%                                          | 38.95%                                          | 0.7842%            |
| Colorado\Broomfield   | 880                         | 348                                  |                                          | 6250             | 5.57%                                          | 14.08%                                          | 0.7840%            |
| Oklahoma\Canadian     | 136055                      | 14541                                | 369                                      | 508771           | 2.93%                                          | 26.74%                                          | 0.7837%            |
| Ohio\Hardin           | 170459                      | 2914                                 | 118                                      | 256822           | 1.18%                                          | 66.37%                                          | 0.7836%            |
| Indiana\Lawrence      | 29400                       | 4721                                 | 105                                      | 134637           | 3.58%                                          | 21.84%                                          | 0.7827%            |
| Illinois\Scott        | 85967                       | 1661                                 |                                          | 135731           | 1.22%                                          | 63.34%                                          | 0.7751%            |
| Minnesota\Freeborn    | 263180                      | 4423                                 |                                          | 388488           | 1.14%                                          | 67.74%                                          | 0.7713%            |
| Indiana\Switzerland   | 10899                       | 1437                                 | 157                                      | 47461            | 3.36%                                          | 22.96%                                          | 0.7713%            |
| Minnesota\Nicollet    | 182815                      | 3164                                 |                                          | 273981           | 1.15%                                          | 66.73%                                          | 0.7706%            |
| Nebraska\Richardson   | 153200                      | 3919                                 |                                          | 279148           | 1.40%                                          | 54.88%                                          | 0.7705%            |
| Kansas\Grant          | 152067                      | 5760                                 |                                          | 337320           | 1.71%                                          | 45.08%                                          | 0.7698%            |
| Minnesota\Redwood     | 406667                      | 5044                                 | 759                                      | 553855           | 1.05%                                          | 73.42%                                          | 0.7693%            |
| North Dakota\Renville | 350868                      | 6723                                 |                                          | 554345           | 1.21%                                          | 63.29%                                          | 0.7676%            |
| Iowa\O'Brien          | 266226                      | 3188                                 | 248                                      | 345774           | 0.99%                                          | 76.99%                                          | 0.7651%            |
| California\Sutter     | 155045                      | 6388                                 |                                          | 359802           | 1.78%                                          | 43.09%                                          | 0.7651%            |
| Missouri\Marion       | 115306                      | 3713                                 |                                          | 237016           | 1.57%                                          | 48.65%                                          | 0.7621%            |
| Iowa\Greene           | 258587                      | 3674                                 |                                          | 353516           | 1.04%                                          | 73.15%                                          | 0.7602%            |
| New Jersey\Somerset   | 8271                        | 954                                  | 25                                       | 32721            | 2.99%                                          | 25.28%                                          | 0.7563%            |
| Kentucky\Meade        | 22148                       | 4806                                 | 230                                      | 121448           | 4.15%                                          | 18.24%                                          | 0.7562%            |
| Pennsylvania\Clarion  | 13149                       | 7116                                 | 2918                                     | 132140           | 7.59%                                          | 9.95%                                           | 0.7556%            |
| New York\Chemung      | 5173                        | 2846                                 | 3348                                     | 65124            | 9.51%                                          | 7.94%                                           | 0.7555%            |
| Indiana\Jackson       | 133245                      | 2310                                 | 163                                      | 209293           | 1.18%                                          | 63.66%                                          | 0.7523%            |
| South Dakota\Jones    | 78961                       | 25627                                |                                          | 519314           | 4.93%                                          | 15.20%                                          | 0.7503%            |
| Iowa\Franklin         | 291369                      | 3267                                 | 193                                      | 366609           | 0.94%                                          | 79.48%                                          | 0.7501%            |
| Arizona\Pinal         | 150501                      | 54495                                |                                          | 1047112          | 5.20%                                          | 14.37%                                          | 0.7480%            |
| Wyoming\Big Horn      | 39229                       | 35845                                | 724                                      | 438033           | 8.35%                                          | 8.96%                                           | 0.7477%            |
| Iowa\Butler           | 232312                      | 4196                                 | 345                                      | 375781           | 1.21%                                          | 61.82%                                          | 0.7471%            |
| Iowa\Clay             | 239130                      | 3313                                 | 38                                       | 328216           | 1.02%                                          | 72.86%                                          | 0.7439%            |
| Indiana\Clay          | 110227                      | 1612                                 | 51                                       | 157563           | 1.06%                                          | 69.96%                                          | 0.7384%            |
| Delaware\Kent         | 114805                      | 1635                                 | 306                                      | 173808           | 1.12%                                          | 66.05%                                          | 0.7376%            |
| Kansas\Phillips       | 149228                      | 12089                                |                                          | 494990           | 2.44%                                          | 30.15%                                          | 0.7363%            |
| Minnesota\Hubbard     | 19995                       | 5348                                 | 510                                      | 126198           | 4.64%                                          | 15.84%                                          | 0.7355%            |
| Kansas\Ottawa         | 113893                      | 12259                                | 54                                       | 437265           | 2.82%                                          | 26.05%                                          | 0.7335%            |
| New York\Albany       | 3701                        | 5541                                 | 1801                                     | 61030            | 12.03%                                         | 6.06%                                           | 0.7295%            |
| Maryland\Montgomery   | 27907                       | 743                                  | 446                                      | 67613            | 1.76%                                          | 41.27%                                          | 0.7258%            |
| Idaho\Blaine          | 11873                       | 22083                                | 388                                      | 191949           | 11.71%                                         | 6.19%                                           | 0.7241%            |
| South Dakota\Lawrence | 7262                        | 17738                                |                                          | 133503           | 13.29%                                         | 5.44%                                           | 0.7227%            |
| New York\Broome       | 6242                        | 3462                                 | 5222                                     | 86613            | 10.03%                                         | 7.21%                                           | 0.7226%            |
| North Dakota\Slope    | 133136                      | 31965                                |                                          | 768938           | 4.16%                                          | 17.31%                                          | 0.7198%            |
| Ohio\Lake             | 4490                        | 413                                  |                                          | 16065            | 2.57%                                          | 27.95%                                          | 0.7185%            |
| Wisconsin\Ashland     | 2903                        | 4977                                 | 2605                                     | 55370            | 13.69%                                         | 5.24%                                           | 0.7179%            |
| Kentucky\Larue        | 28597                       | 3868                                 | 70                                       | 125432           | 3.14%                                          | 22.80%                                          | 0.7158%            |

| County                      | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-----------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Michigan\Lake               | 1042                        | 2575                                 | 560                                      | 21376            | 14.67%                                         | 4.87%                                           | 0.7149%            |
| Idaho\Owyhee                | 44907                       | 48409                                | 3165                                     | 569305           | 9.06%                                          | 7.89%                                           | 0.7146%            |
| Iowa\Worth                  | 164056                      | 2225                                 | 101                                      | 231605           | 1.00%                                          | 70.83%                                          | 0.7114%            |
| Kansas\Clay                 | 141545                      | 5606                                 | 583                                      | 350949           | 1.76%                                          | 40.33%                                          | 0.7113%            |
| Ohio\Allen                  | 126888                      | 1756                                 | 206                                      | 187238           | 1.05%                                          | 67.77%                                          | 0.7101%            |
| Montana\Daniels             | 256997                      | 19602                                | 825                                      | 860238           | 2.37%                                          | 29.88%                                          | 0.7094%            |
| Indiana\Blackford           | 71735                       | 706                                  |                                          | 84626            | 0.83%                                          | 84.77%                                          | 0.7072%            |
| Iowa\Fremont                | 166656                      | 2543                                 |                                          | 245299           | 1.04%                                          | 67.94%                                          | 0.7043%            |
| Illinois\Stark              | 147154                      | 1375                                 |                                          | 169775           | 0.81%                                          | 86.68%                                          | 0.7020%            |
| Indiana\Howard              | 130459                      | 1247                                 | 159                                      | 162281           | 0.87%                                          | 80.39%                                          | 0.6965%            |
| Utah\Iron                   | 36706                       | 45230                                | 459                                      | 492235           | 9.28%                                          | 7.46%                                           | 0.6922%            |
| Montana\Sheridan            | 394189                      | 19749                                |                                          | 1065503          | 1.85%                                          | 37.00%                                          | 0.6857%            |
| Missouri\Knox               | 80905                       | 3341                                 | 2100                                     | 253679           | 2.14%                                          | 31.89%                                          | 0.6840%            |
| South Dakota\Bennett        | 125228                      | 30980                                |                                          | 753263           | 4.11%                                          | 16.62%                                          | 0.6837%            |
| Montana\Cascade             | 196747                      | 65292                                | 456                                      | 1379645          | 4.77%                                          | 14.26%                                          | 0.6796%            |
| Vermont\Franklin            | 20397                       | 2268                                 | 8524                                     | 180006           | 6.00%                                          | 11.33%                                          | 0.6794%            |
| Kentucky\Hardin             | 53951                       | 5916                                 | 269                                      | 222267           | 2.78%                                          | 24.27%                                          | 0.6754%            |
| Indiana\Pulaski             | 180910                      | 1734                                 | 278                                      | 232240           | 0.87%                                          | 77.90%                                          | 0.6749%            |
| Indiana\Vigo                | 85931                       | 1141                                 | 17                                       | 121454           | 0.95%                                          | 70.75%                                          | 0.6746%            |
| Illinois\Kendall            | 142743                      | 1315                                 |                                          | 166872           | 0.79%                                          | 85.54%                                          | 0.6741%            |
| Minnesota\Lake of the Woods | 11047                       | 5721                                 |                                          | 96932            | 5.90%                                          | 11.40%                                          | 0.6726%            |
| Kansas\Riley                | 65491                       | 5094                                 | 432                                      | 231960           | 2.38%                                          | 28.23%                                          | 0.6726%            |
| Ohio\Washington             | 13323                       | 6563                                 | 1187                                     | 124069           | 6.25%                                          | 10.74%                                          | 0.6708%            |
| Washington\Benton           | 216247                      | 12412                                |                                          | 632636           | 1.96%                                          | 34.18%                                          | 0.6706%            |
| Nebraska\York               | 257068                      | 3121                                 |                                          | 346137           | 0.90%                                          | 74.27%                                          | 0.6696%            |
| Illinois\Calhoun            | 26102                       | 1975                                 |                                          | 87938            | 2.25%                                          | 29.68%                                          | 0.6666%            |
| Kansas\Geary                | 33172                       | 4428                                 |                                          | 148465           | 2.98%                                          | 22.34%                                          | 0.6664%            |
| Missouri\Harrison           | 90533                       | 10714                                | 317                                      | 388353           | 2.84%                                          | 23.31%                                          | 0.6622%            |
| Kansas\Ford                 | 229968                      | 11521                                |                                          | 634240           | 1.82%                                          | 36.26%                                          | 0.6586%            |
| Indiana\Grant               | 146233                      | 1839                                 |                                          | 202138           | 0.91%                                          | 72.34%                                          | 0.6582%            |
| Kansas\Sumner               | 294614                      | 10764                                | 394                                      | 709865           | 1.57%                                          | 41.50%                                          | 0.6524%            |
| Washington\Adams            | 374027                      | 20982                                |                                          | 1098487          | 1.91%                                          | 34.05%                                          | 0.6504%            |
| Kansas\Decatur              | 160063                      | 9457                                 |                                          | 483134           | 1.96%                                          | 33.13%                                          | 0.6485%            |
| Indiana\Dearborn            | 17461                       | 1574                                 | 35                                       | 65830            | 2.44%                                          | 26.52%                                          | 0.6483%            |
| Ohio\Clinton                | 145819                      | 2112                                 |                                          | 218493           | 0.97%                                          | 66.74%                                          | 0.6451%            |
| Indiana\Newton              | 159943                      | 1459                                 |                                          | 190432           | 0.77%                                          | 83.99%                                          | 0.6435%            |
| Missouri\Atchison           | 215979                      | 2747                                 |                                          | 304035           | 0.90%                                          | 71.04%                                          | 0.6418%            |
| Missouri\Pike               | 146548                      | 5633                                 | 407                                      | 373142           | 1.62%                                          | 39.27%                                          | 0.6357%            |
| Illinois\La Salle           | 524115                      | 4617                                 | 399                                      | 643291           | 0.78%                                          | 81.47%                                          | 0.6353%            |
| Oregon\Klamath              | 46634                       | 61859                                |                                          | 675127           | 9.16%                                          | 6.91%                                           | 0.6329%            |
| Montana\Fergus              | 239114                      | 158137                               |                                          | 2446047          | 6.47%                                          | 9.78%                                           | 0.6320%            |
| Ohio\Jefferson              | 3583                        | 7127                                 | 1381                                     | 69468            | 12.25%                                         | 5.16%                                           | 0.6317%            |
| Illinois\Coles              | 204821                      | 1795                                 | 207                                      | 254869           | 0.79%                                          | 80.36%                                          | 0.6313%            |

| County               | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|----------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Maryland\Caroline    | 75354                       | 1145                                 | 292                                      | 131277           | 1.09%                                          | 57.40%                                          | 0.6283%            |
| Illinois\Bureau      | 389175                      | 3693                                 |                                          | 478389           | 0.77%                                          | 81.35%                                          | 0.6280%            |
| South Dakota\Lyman   | 269826                      | 21977                                | 214                                      | 976457           | 2.27%                                          | 27.63%                                          | 0.6280%            |
| Kentucky\Oldham      | 9222                        | 2447                                 |                                          | 60024            | 4.08%                                          | 15.36%                                          | 0.6263%            |
| Missouri\DeKalb      | 68613                       | 6137                                 | 50                                       | 260472           | 2.38%                                          | 26.34%                                          | 0.6257%            |
| Colorado\Logan       | 218403                      | 36713                                |                                          | 1132299          | 3.24%                                          | 19.29%                                          | 0.6254%            |
| Minnesota\Traverse   | 223300                      | 2725                                 | 281                                      | 327627           | 0.92%                                          | 68.16%                                          | 0.6253%            |
| North Dakota\Cass    | 839187                      | 8017                                 |                                          | 1038930          | 0.77%                                          | 80.77%                                          | 0.6233%            |
| Iowa\Grundy          | 262795                      | 2363                                 |                                          | 315968           | 0.75%                                          | 83.17%                                          | 0.6220%            |
| North Dakota\Nelson  | 264602                      | 7113                                 |                                          | 550121           | 1.29%                                          | 48.10%                                          | 0.6219%            |
| Kansas\Stanton       | 160814                      | 4499                                 | 2126                                     | 414184           | 1.60%                                          | 38.83%                                          | 0.6210%            |
| Ohio\Van Wert        | 201535                      | 1482                                 | 390                                      | 246497           | 0.76%                                          | 81.76%                                          | 0.6209%            |
| Iowa\Hancock         | 290999                      | 2684                                 | 91                                       | 361006           | 0.77%                                          | 80.61%                                          | 0.6196%            |
| Illinois\Iroquois    | 572067                      | 4573                                 | 364                                      | 677803           | 0.73%                                          | 84.40%                                          | 0.6148%            |
| Oklahoma\Washita     | 168781                      | 12700                                |                                          | 591031           | 2.15%                                          | 28.56%                                          | 0.6136%            |
| Washington\Ciallam   | 1319                        | 1633                                 | 774                                      | 22822            | 10.55%                                         | 5.78%                                           | 0.6096%            |
| Illinois\Greene      | 184546                      | 2463                                 |                                          | 273088           | 0.90%                                          | 67.58%                                          | 0.6095%            |
| Oregon\Umatilla      | 371489                      | 34341                                |                                          | 1447321          | 2.37%                                          | 25.67%                                          | 0.6090%            |
| Minnesota\Renville   | 410652                      | 4395                                 | 1285                                     | 619734           | 0.92%                                          | 66.26%                                          | 0.6073%            |
| Vermont\Bennington   | 2272                        | 1931                                 | 1638                                     | 36580            | 9.76%                                          | 6.21%                                           | 0.6060%            |
| Indiana\Montgomery   | 233991                      | 2339                                 |                                          | 301279           | 0.78%                                          | 77.67%                                          | 0.6030%            |
| Delaware\New Castle  | 36305                       | 744                                  |                                          | 66981            | 1.11%                                          | 54.20%                                          | 0.6021%            |
| South Dakota\Buffalo | 50928                       | 10296                                | 1174                                     | 312068           | 3.68%                                          | 16.32%                                          | 0.5998%            |
| Montana\Lincoln      | 4831                        | 3341                                 |                                          | 51885            | 6.44%                                          | 9.31%                                           | 0.5996%            |
| Indiana\Bartholomew  | 128965                      | 1285                                 |                                          | 166356           | 0.77%                                          | 77.52%                                          | 0.5988%            |
| Illinois\Cass        | 112742                      | 1597                                 |                                          | 173543           | 0.92%                                          | 64.96%                                          | 0.5978%            |
| Pennsylvania\Tioga   | 13899                       | 8336                                 | 6228                                     | 184108           | 7.91%                                          | 7.55%                                           | 0.5972%            |
| Iowa\Buena Vista     | 273845                      | 2861                                 |                                          | 362553           | 0.79%                                          | 75.53%                                          | 0.5960%            |
| Pennsylvania\Erie    | 45451                       | 2201                                 | 1708                                     | 173125           | 2.26%                                          | 26.25%                                          | 0.5928%            |
| Minnesota\Wilkin     | 329471                      | 3249                                 |                                          | 424976           | 0.76%                                          | 77.53%                                          | 0.5927%            |
| Nebraska\Gosper      | 112811                      | 2669                                 |                                          | 225572           | 1.18%                                          | 50.01%                                          | 0.5917%            |
| Missouri\Daviess     | 99938                       | 6469                                 |                                          | 330911           | 1.95%                                          | 30.20%                                          | 0.5904%            |
| Ohio\Wyandot         | 156944                      | 1729                                 | 80                                       | 219631           | 0.82%                                          | 71.46%                                          | 0.5886%            |
| South Dakota\Sully   | 353978                      | 6121                                 |                                          | 608976           | 1.01%                                          | 58.13%                                          | 0.5842%            |
| Minnesota\Grant      | 196724                      | 2961                                 | 102                                      | 321501           | 0.95%                                          | 61.19%                                          | 0.5830%            |
| Idaho\Power          | 118937                      | 9961                                 |                                          | 451198           | 2.21%                                          | 26.36%                                          | 0.5819%            |
| Indiana\Orange       | 42449                       | 1300                                 |                                          | 97411            | 1.33%                                          | 43.58%                                          | 0.5816%            |
| Ohio\Brown           | 106519                      | 3133                                 |                                          | 240389           | 1.30%                                          | 44.31%                                          | 0.5775%            |
| Iowa\Palo Alto       | 269608                      | 2360                                 | 306                                      | 353332           | 0.75%                                          | 76.30%                                          | 0.5757%            |
| Oklahoma\Grant       | 169195                      | 13621                                |                                          | 633052           | 2.15%                                          | 26.73%                                          | 0.5751%            |
| Kansas\Smith         | 165786                      | 7253                                 |                                          | 457429           | 1.59%                                          | 36.24%                                          | 0.5747%            |
| Indiana\Greene       | 91516                       | 1642                                 | 165                                      | 169750           | 1.06%                                          | 53.91%                                          | 0.5739%            |
| Indiana\Floyd        | 7344                        | 450                                  |                                          | 23997            | 1.88%                                          | 30.60%                                          | 0.5739%            |
| Colorado\Montrose    | 25194                       | 22978                                | 500                                      | 321056           | 7.31%                                          | 7.85%                                           | 0.5738%            |
| Oklahoma\Kay         | 198327                      | 6991                                 |                                          | 492178           | 1.42%                                          | 40.30%                                          | 0.5724%            |

| County                | Acres Using Herbicide | Harvested Acres of Alfalfa Hay | Harvested Acres Alfalfa Haylage | Acres in Farm | % of Farm Acres in Alfalfa Forage (a) | % of Farm Acres Using Herbicide (b) | (c) = (a) x (b) |
|-----------------------|-----------------------|--------------------------------|---------------------------------|---------------|---------------------------------------|-------------------------------------|-----------------|
| Nebraska\Lincoln      | 362583                | 38790                          | 1577                            | 1601185       | 2.52%                                 | 22.64%                              | 0.5709%         |
| Colorado\Sedgwick     | 96982                 | 5170                           |                                 | 296695        | 1.74%                                 | 32.69%                              | 0.5696%         |
| Minnesota\Koochiching | 2142                  | 7315                           | 754                             | 55109         | 14.64%                                | 3.89%                               | 0.5691%         |
| Nebraska\Franklin     | 111088                | 4345                           |                                 | 291515        | 1.49%                                 | 38.11%                              | 0.5680%         |
| Idaho\Latah           | 157203                | 4156                           | 121                             | 344472        | 1.24%                                 | 45.64%                              | 0.5666%         |
| Vermont               | 86442                 | 31769                          | 67504                           | 1233313       | 8.05%                                 | 7.01%                               | 0.5642%         |
| Indiana\Owen          | 28288                 | 1536                           |                                 | 87813         | 1.75%                                 | 32.21%                              | 0.5635%         |
| Oklahoma\Kingfisher   | 147964                | 12149                          |                                 | 566212        | 2.15%                                 | 26.13%                              | 0.5607%         |
| South Dakota\Meade    | 179202                | 150760                         | 1761                            | 2208880       | 6.90%                                 | 8.11%                               | 0.5602%         |
| Colorado\Adams        | 273807                | 9723                           | 299                             | 701575        | 1.43%                                 | 39.03%                              | 0.5575%         |
| Missouri\St. Charles  | 86802                 | 1303                           | 260                             | 156136        | 1.00%                                 | 55.59%                              | 0.5565%         |
| Nebraska\Box Butte    | 220134                | 10254                          | 1122                            | 670815        | 1.70%                                 | 32.82%                              | 0.5565%         |
| Oklahoma\Oklahoma     | 25326                 | 5565                           | 45                              | 159823        | 3.51%                                 | 15.85%                              | 0.5562%         |
| Missouri\Worth        | 19348                 | 6561                           | 52                              | 151802        | 4.36%                                 | 12.75%                              | 0.5552%         |
| Kansas\Pottawatomie   | 96954                 | 10063                          | 426                             | 428601        | 2.45%                                 | 22.62%                              | 0.5536%         |
| Virginia\Augusta      | 43271                 | 9145                           | 1323                            | 286195        | 3.66%                                 | 15.12%                              | 0.5530%         |
| Montana\Mineral       | 2117                  | 1332                           |                                 | 22654         | 5.88%                                 | 9.34%                               | 0.5495%         |
| Ohio\Paulding         | 169486                | 2105                           |                                 | 255564        | 0.82%                                 | 66.32%                              | 0.5462%         |
| Illinois\Grundy       | 171545                | 1476                           |                                 | 215474        | 0.69%                                 | 79.61%                              | 0.5453%         |
| Kansas\Marshall       | 219101                | 8172                           | 740                             | 599022        | 1.49%                                 | 36.58%                              | 0.5442%         |
| Ohio\Hamilton         | 5323                  | 463                            |                                 | 21290         | 2.17%                                 | 25.00%                              | 0.5437%         |
| Indiana\Jennings      | 82580                 | 1176                           | 82                              | 138331        | 0.91%                                 | 59.70%                              | 0.5429%         |
| New Jersey\Sussex     | 5680                  | 3243                           | 809                             | 65242         | 6.21%                                 | 8.71%                               | 0.5407%         |
| Indiana\Shelby        | 178223                | 1188                           | 80                              | 205432        | 0.62%                                 | 86.76%                              | 0.5355%         |
| Pennsylvania\Forest   | 795                   | 624                            | 150                             | 10728         | 7.21%                                 | 7.41%                               | 0.5347%         |
| Kentucky\Christian    | 137562                | 4114                           | 543                             | 346450        | 1.34%                                 | 39.71%                              | 0.5337%         |
| Illinois\St. Clair    | 240932                | 2076                           |                                 | 306533        | 0.68%                                 | 78.60%                              | 0.5323%         |
| Oregon\Washington     | 63837                 | 1285                           | 74                              | 127984        | 1.06%                                 | 49.88%                              | 0.5296%         |
| Michigan\Luce         | 586                   | 702                            |                                 | 8819          | 7.96%                                 | 6.64%                               | 0.5289%         |
| Kansas\Kingman        | 107290                | 11529                          | 3158                            | 546231        | 2.69%                                 | 19.64%                              | 0.5281%         |
| New York\Ulster       | 9442                  | 2014                           | 1138                            | 75205         | 4.19%                                 | 12.56%                              | 0.5262%         |
| Maryland\St. Mary's   | 24598                 | 1007                           |                                 | 68648         | 1.47%                                 | 35.83%                              | 0.5256%         |
| Iowa\Osceola          | 195134                | 1696                           |                                 | 251161        | 0.68%                                 | 77.69%                              | 0.5246%         |
| Illinois\McLean       | 569087                | 4195                           |                                 | 675984        | 0.62%                                 | 84.19%                              | 0.5224%         |
| Oklahoma\Garvin       | 74455                 | 17535                          | 36                              | 500804        | 3.51%                                 | 14.87%                              | 0.5216%         |
| Wisconsin\Price       | 6747                  | 4371                           | 3734                            | 102407        | 7.91%                                 | 6.59%                               | 0.5214%         |
| Oregon\Yamhill        | 68881                 | 1781                           | 693                             | 180846        | 1.37%                                 | 38.09%                              | 0.5211%         |
| Montana\Richland      | 190142                | 44729                          |                                 | 1279300       | 3.50%                                 | 14.86%                              | 0.5197%         |
| Idaho\Bear Lake       | 11788                 | 22934                          | 820                             | 233112        | 10.19%                                | 5.06%                               | 0.5153%         |
| Minnesota\Blue Earth  | 293851                | 2651                           | 364                             | 415326        | 0.73%                                 | 70.75%                              | 0.5136%         |
| Kansas\Norton         | 157221                | 8639                           | 564                             | 531248        | 1.73%                                 | 29.59%                              | 0.5127%         |
| Virginia\Stafford     | 3849                  | 520                            |                                 | 19816         | 2.62%                                 | 19.42%                              | 0.5097%         |
| Illinois\Perry        | 142019                | 1436                           |                                 | 200354        | 0.72%                                 | 70.88%                              | 0.5080%         |

| County                     | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|----------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Indiana\Carroll            | 158239                      | 1187                                 |                                          | 192334           | 0.62%                                          | 82.27%                                          | 0.5078%            |
| Illinois\Sangamon          | 395593                      | 3228                                 | 206                                      | 518153           | 0.66%                                          | 76.35%                                          | 0.5060%            |
| Nebraska\Keith             | 161324                      | 10582                                |                                          | 581567           | 1.82%                                          | 27.74%                                          | 0.5047%            |
| Kentucky\Mason             | 7702                        | 12057                                | 720                                      | 139814           | 9.14%                                          | 5.51%                                           | 0.5034%            |
| Indiana\Clinton            | 214543                      | 1519                                 |                                          | 255314           | 0.59%                                          | 84.03%                                          | 0.4999%            |
| Missouri\Jackson           | 55354                       | 1749                                 |                                          | 139190           | 1.26%                                          | 39.77%                                          | 0.4997%            |
| Idaho\Idaho                | 120969                      | 14264                                | 152                                      | 590927           | 2.44%                                          | 20.47%                                          | 0.4994%            |
| Utah\Salt Lake             | 17343                       | 3324                                 |                                          | 107477           | 3.09%                                          | 16.14%                                          | 0.4991%            |
| Illinois\Livingston        | 518890                      | 3580                                 | 219                                      | 628502           | 0.60%                                          | 82.56%                                          | 0.4990%            |
| Kentucky\Nelson            | 29710                       | 5989                                 | 473                                      | 196225           | 3.29%                                          | 15.14%                                          | 0.4986%            |
| Washington\Lincoln         | 404343                      | 14545                                |                                          | 1090178          | 1.33%                                          | 37.09%                                          | 0.4948%            |
| Oregon\Lake                | 36956                       | 64174                                |                                          | 692778           | 9.26%                                          | 5.33%                                           | 0.4941%            |
| California\Modoc           | 38303                       | 45890                                |                                          | 597740           | 7.68%                                          | 6.41%                                           | 0.4920%            |
| Kentucky\Lincoln           | 13386                       | 9474                                 | 2192                                     | 178315           | 6.54%                                          | 7.51%                                           | 0.4911%            |
| Michigan\Mackinac          | 673                         | 2650                                 | 761                                      | 21698            | 15.72%                                         | 3.10%                                           | 0.4876%            |
| Illinois\Saline            | 73070                       | 917                                  |                                          | 117233           | 0.78%                                          | 62.33%                                          | 0.4875%            |
| Nebraska\Morrill           | 135558                      | 26228                                | 2970                                     | 902005           | 3.24%                                          | 15.03%                                          | 0.4865%            |
| Colorado\Pitkin            | 1536                        | 2574                                 |                                          | 28539            | 9.02%                                          | 5.38%                                           | 0.4854%            |
| South Dakota\Haakon        | 143765                      | 44691                                |                                          | 1151144          | 3.88%                                          | 12.49%                                          | 0.4849%            |
| Pennsylvania\Wyoming       | 5319                        | 4210                                 | 1318                                     | 77957            | 7.09%                                          | 6.82%                                           | 0.4838%            |
| North Dakota\Pembina       | 451355                      | 4515                                 |                                          | 649281           | 0.70%                                          | 69.52%                                          | 0.4834%            |
| Indiana\White              | 255481                      | 1906                                 |                                          | 318110           | 0.60%                                          | 80.31%                                          | 0.4812%            |
| Indiana\Warrick            | 71142                       | 815                                  |                                          | 109932           | 0.74%                                          | 64.71%                                          | 0.4798%            |
| Connecticut\Hartford       | 11367                       | 968                                  | 235                                      | 53504            | 2.25%                                          | 21.25%                                          | 0.4777%            |
| North Dakota\Golden Valley | 96884                       | 16022                                |                                          | 570210           | 2.81%                                          | 16.99%                                          | 0.4774%            |
| Illinois\Montgomery        | 258399                      | 2002                                 | 216                                      | 347765           | 0.64%                                          | 74.30%                                          | 0.4739%            |
| Iowa\Cerro Gordo           | 267319                      | 2010                                 |                                          | 336732           | 0.60%                                          | 79.39%                                          | 0.4739%            |
| Massachusetts\Hampshire    | 7450                        | 1094                                 | 673                                      | 52756            | 3.35%                                          | 14.12%                                          | 0.4730%            |
| Nebraska\Red Willow        | 146366                      | 6441                                 |                                          | 446479           | 1.44%                                          | 32.78%                                          | 0.4729%            |
| Texas\EI Paso              | 26849                       | 4858                                 | 145                                      | 168556           | 2.97%                                          | 15.93%                                          | 0.4728%            |
| Iowa\Humboldt              | 216204                      | 1596                                 |                                          | 270227           | 0.59%                                          | 80.01%                                          | 0.4725%            |
| Pennsylvania\Monroe        | 5420                        | 740                                  |                                          | 29165            | 2.54%                                          | 18.58%                                          | 0.4715%            |
| Kansas\Pratt               | 177008                      | 6123                                 |                                          | 480162           | 1.28%                                          | 36.86%                                          | 0.4701%            |
| Iowa\Winnebago             | 168922                      | 1749                                 |                                          | 251523           | 0.70%                                          | 67.16%                                          | 0.4670%            |
| New Jersey\Morris          | 2197                        | 615                                  |                                          | 17028            | 3.61%                                          | 12.90%                                          | 0.4660%            |
| Montana\McCone             | 252879                      | 20625                                |                                          | 1060883          | 1.94%                                          | 23.84%                                          | 0.4634%            |
| Indiana\Martin             | 32139                       | 542                                  |                                          | 61331            | 0.88%                                          | 52.40%                                          | 0.4631%            |
| Virginia\Clarke            | 9767                        | 1668                                 | 517                                      | 67919            | 3.22%                                          | 14.38%                                          | 0.4626%            |
| Indiana\Sullivan           | 132976                      | 1094                                 |                                          | 177368           | 0.62%                                          | 74.97%                                          | 0.4624%            |
| Kansas\Leavenworth         | 54832                       | 2969                                 | 232                                      | 194854           | 1.64%                                          | 28.14%                                          | 0.4623%            |
| Idaho\Washington           | 26893                       | 29866                                |                                          | 417092           | 7.16%                                          | 6.45%                                           | 0.4617%            |
| Wisconsin\Vilas            | 1160                        | 392                                  |                                          | 9942             | 3.94%                                          | 11.67%                                          | 0.4600%            |
| Colorado\Delta             | 13294                       | 21832                                | 214                                      | 252530           | 8.73%                                          | 5.26%                                           | 0.4596%            |
| Missouri\Holt              | 146331                      | 1725                                 | 33                                       | 236901           | 0.74%                                          | 61.77%                                          | 0.4584%            |
| Iowa\Calhoun               | 267288                      | 2197                                 |                                          | 359434           | 0.61%                                          | 74.36%                                          | 0.4545%            |

| County                   | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|--------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Kentucky\Todd            | 88411                       | 1766                                 | 245                                      | 197976           | 1.02%                                          | 44.66%                                          | 0.4536%            |
| Minnesota\Faribault      | 348232                      | 1952                                 | 717                                      | 453761           | 0.59%                                          | 76.74%                                          | 0.4514%            |
| Indiana\Posey            | 169827                      | 1016                                 | 80                                       | 204004           | 0.54%                                          | 83.25%                                          | 0.4472%            |
| Oregon\Multnomah         | 9362                        | 238                                  | 149                                      | 28506            | 1.36%                                          | 32.84%                                          | 0.4459%            |
| Montana\Wibaux           | 55929                       | 19272                                |                                          | 492554           | 3.91%                                          | 11.35%                                          | 0.4443%            |
| Oklahoma\McClain         | 50009                       | 10022                                |                                          | 336852           | 2.98%                                          | 14.85%                                          | 0.4417%            |
| Illinois\Mason           | 206968                      | 1586                                 |                                          | 273362           | 0.58%                                          | 75.71%                                          | 0.4393%            |
| Illinois\Putnam          | 44166                       | 390                                  |                                          | 62705            | 0.62%                                          | 70.43%                                          | 0.4381%            |
| Ohio\Adams               | 26100                       | 5547                                 | 128                                      | 183961           | 3.08%                                          | 14.19%                                          | 0.4377%            |
| Iowa\Pocahontas          | 294576                      | 1392                                 | 558                                      | 362404           | 0.54%                                          | 81.28%                                          | 0.4374%            |
| Kansas\Rooks             | 165489                      | 8316                                 |                                          | 561251           | 1.48%                                          | 29.49%                                          | 0.4369%            |
| Kentucky\Bourbon         | 13213                       | 10700                                | 529                                      | 184323           | 6.09%                                          | 7.17%                                           | 0.4367%            |
| Ohio\Clermont            | 41621                       | 1143                                 |                                          | 104691           | 1.09%                                          | 39.76%                                          | 0.4341%            |
| Virginia\Page            | 10756                       | 1445                                 | 225                                      | 64387            | 2.59%                                          | 16.71%                                          | 0.4333%            |
| Kansas\Rawlins           | 190652                      | 7613                                 | 286                                      | 590628           | 1.34%                                          | 32.28%                                          | 0.4317%            |
| Nebraska\Holt            | 319464                      | 29629                                | 2105                                     | 1532629          | 2.07%                                          | 20.84%                                          | 0.4316%            |
| Idaho\Gem                | 13486                       | 10747                                | 878                                      | 190757           | 6.09%                                          | 7.07%                                           | 0.4308%            |
| Virginia\Loudoun         | 17681                       | 4839                                 | 98                                       | 142452           | 3.47%                                          | 12.41%                                          | 0.4302%            |
| North Dakota\Towner      | 358833                      | 4399                                 |                                          | 607330           | 0.72%                                          | 59.08%                                          | 0.4280%            |
| North Dakota\Grand Forks | 513778                      | 5654                                 |                                          | 825552           | 0.68%                                          | 62.23%                                          | 0.4262%            |
| Missouri\Lafayette       | 179263                      | 2634                                 | 306                                      | 352916           | 0.83%                                          | 50.79%                                          | 0.4232%            |
| Maryland\Anne Arundel    | 9299                        | 388                                  |                                          | 29244            | 1.33%                                          | 31.80%                                          | 0.4219%            |
| Illinois\Edgar           | 294466                      | 1507                                 | 256                                      | 352535           | 0.50%                                          | 83.53%                                          | 0.4177%            |
| Missouri\Gentry          | 51561                       | 6007                                 | 158                                      | 275935           | 2.23%                                          | 18.69%                                          | 0.4175%            |
| Missouri\Shelby          | 126917                      | 2431                                 | 311                                      | 289182           | 0.95%                                          | 43.89%                                          | 0.4161%            |
| Connecticut\Litchfield   | 6522                        | 2661                                 | 2210                                     | 87412            | 5.57%                                          | 7.46%                                           | 0.4158%            |
| West Virginia\Berkeley   | 8672                        | 2423                                 | 278                                      | 75102            | 3.60%                                          | 11.55%                                          | 0.4153%            |
| Illinois\Macon           | 252605                      | 1386                                 |                                          | 290603           | 0.48%                                          | 86.92%                                          | 0.4146%            |
| Michigan\Marquette       | 1208                        | 3103                                 |                                          | 30092            | 10.31%                                         | 4.01%                                           | 0.4139%            |
| Montana\Broadwater       | 45277                       | 20608                                |                                          | 474892           | 4.34%                                          | 9.53%                                           | 0.4137%            |
| Montana\Ravalli          | 17438                       | 15037                                | 1223                                     | 262872           | 6.19%                                          | 6.63%                                           | 0.4103%            |
| New Jersey\Burlington    | 34401                       | 876                                  |                                          | 85790            | 1.02%                                          | 40.10%                                          | 0.4095%            |
| Illinois\Jefferson       | 132745                      | 1661                                 |                                          | 232531           | 0.71%                                          | 57.09%                                          | 0.4078%            |
| Delaware\Sussex          | 184089                      | 1308                                 | 298                                      | 269464           | 0.60%                                          | 68.32%                                          | 0.4072%            |
| Wyoming\Lincoln          | 11724                       | 39848                                | 892                                      | 342630           | 11.89%                                         | 3.42%                                           | 0.4069%            |
| Kansas\Douglas           | 89647                       | 1874                                 | 320                                      | 220636           | 0.99%                                          | 40.63%                                          | 0.4040%            |
| Pennsylvania\Washington  | 8961                        | 16278                                | 3767                                     | 211053           | 9.50%                                          | 4.25%                                           | 0.4033%            |
| Washington\Whatcom       | 25890                       | 791                                  | 847                                      | 102584           | 1.60%                                          | 25.24%                                          | 0.4030%            |
| Illinois\De Witt         | 166321                      | 955                                  |                                          | 198680           | 0.48%                                          | 83.71%                                          | 0.4024%            |
| Kansas\Sheridan          | 201802                      | 5393                                 |                                          | 522052           | 1.03%                                          | 38.66%                                          | 0.3993%            |
| New Jersey\Hunterdon     | 20390                       | 1546                                 | 412                                      | 100027           | 1.96%                                          | 20.38%                                          | 0.3990%            |
| Ohio\Pike                | 18012                       | 1337                                 | 99                                       | 80636            | 1.78%                                          | 22.34%                                          | 0.3978%            |
| South Dakota\Perkins     | 130815                      | 101477                               |                                          | 1829157          | 5.55%                                          | 7.15%                                           | 0.3968%            |

| County                  | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Missouri\Montgomery     | 104474                      | 2272                                 | 58                                       | 248070           | 0.94%                                          | 42.11%                                          | 0.3956%            |
| Kentucky\Woodford       | 13543                       | 3948                                 | 185                                      | 119087           | 3.47%                                          | 11.37%                                          | 0.3947%            |
| Nevada\Humboldt         | 44197                       | 51041                                |                                          | 756313           | 6.75%                                          | 5.84%                                           | 0.3944%            |
| Iowa\Emmet              | 195888                      | 1255                                 |                                          | 249779           | 0.50%                                          | 78.42%                                          | 0.3940%            |
| Texas\Lamb              | 226749                      | 4999                                 | 1995                                     | 634703           | 1.10%                                          | 35.73%                                          | 0.3937%            |
| Iowa\Hamilton           | 264625                      | 1781                                 |                                          | 346552           | 0.51%                                          | 76.36%                                          | 0.3924%            |
| Montana\Stillwater      | 66382                       | 43459                                |                                          | 857474           | 5.07%                                          | 7.74%                                           | 0.3924%            |
| Illinois\Kankakee       | 337001                      | 1701                                 | 29                                       | 385808           | 0.45%                                          | 87.35%                                          | 0.3917%            |
| Kansas\Hamilton         | 162930                      | 6510                                 | 2428                                     | 610864           | 1.46%                                          | 26.67%                                          | 0.3903%            |
| Michigan\Baraga         | 1249                        | 738                                  | 347                                      | 18644            | 5.82%                                          | 6.70%                                           | 0.3899%            |
| Ohio\Harrison           | 4495                        | 6173                                 | 1381                                     | 93342            | 8.09%                                          | 4.82%                                           | 0.3897%            |
| Missouri\Clinton        | 84746                       | 2508                                 | 80                                       | 237447           | 1.09%                                          | 35.69%                                          | 0.3890%            |
| Oregon\Morrow           | 258892                      | 18269                                |                                          | 1104250          | 1.65%                                          | 23.45%                                          | 0.3879%            |
| Kansas\Osborne          | 130776                      | 5233                                 |                                          | 420136           | 1.25%                                          | 31.13%                                          | 0.3877%            |
| Montana\Valley          | 312582                      | 51908                                | 732                                      | 2061260          | 2.55%                                          | 15.16%                                          | 0.3873%            |
| South Dakota\Pennington | 96557                       | 55621                                | 663                                      | 1185055          | 4.75%                                          | 8.15%                                           | 0.3870%            |
| Missouri\Audrain        | 250425                      | 2685                                 | 68                                       | 424880           | 0.65%                                          | 58.94%                                          | 0.3819%            |
| Indiana\Jasper          | 269019                      | 1644                                 |                                          | 340339           | 0.48%                                          | 79.04%                                          | 0.3818%            |
| Virginia\Goochland      | 13151                       | 1020                                 |                                          | 59292            | 1.72%                                          | 22.18%                                          | 0.3816%            |
| Indiana\Benton          | 235007                      | 837                                  | 347                                      | 270810           | 0.44%                                          | 86.78%                                          | 0.3794%            |
| Missouri\Perry          | 63714                       | 3163                                 | 233                                      | 238893           | 1.42%                                          | 26.67%                                          | 0.3791%            |
| Virginia\Hanover        | 34849                       | 914                                  |                                          | 91789            | 1.00%                                          | 37.97%                                          | 0.3781%            |
| Oklahoma\Custer         | 124205                      | 9835                                 |                                          | 568728           | 1.73%                                          | 21.84%                                          | 0.3777%            |
| Kansas\Ellsworth        | 68967                       | 7288                                 |                                          | 365046           | 2.00%                                          | 18.89%                                          | 0.3772%            |
| Kansas\Crawford         | 96162                       | 4295                                 | 300                                      | 342349           | 1.34%                                          | 28.09%                                          | 0.3770%            |
| Ohio\Scioto             | 22934                       | 1657                                 | 52                                       | 102025           | 1.68%                                          | 22.48%                                          | 0.3765%            |
| Missouri\Ralls          | 101546                      | 2230                                 |                                          | 245509           | 0.91%                                          | 41.36%                                          | 0.3757%            |
| South Dakota\Jackson    | 101726                      | 51461                                |                                          | 1184156          | 4.35%                                          | 8.59%                                           | 0.3733%            |
| Illinois\Vermilion      | 379936                      | 1807                                 | 235                                      | 457375           | 0.45%                                          | 83.07%                                          | 0.3709%            |
| Virginia\Shenandoah     | 20889                       | 3200                                 | 327                                      | 141286           | 2.50%                                          | 14.78%                                          | 0.3691%            |
| Indiana\Gibson          | 181769                      | 1041                                 | 43                                       | 231082           | 0.47%                                          | 78.66%                                          | 0.3690%            |
| Washington\Klickitat    | 49069                       | 26515                                | 477                                      | 601216           | 4.49%                                          | 8.16%                                           | 0.3664%            |
| Oregon\Clackamas        | 58998                       | 1371                                 | 682                                      | 182743           | 1.12%                                          | 32.28%                                          | 0.3627%            |
| Missouri\Boone          | 68699                       | 3175                                 | 355                                      | 258734           | 1.36%                                          | 26.55%                                          | 0.3623%            |
| Missouri\Livingston     | 117745                      | 2827                                 | 107                                      | 309024           | 0.95%                                          | 38.10%                                          | 0.3618%            |
| Kentucky\Fayette        | 17960                       | 3214                                 | 509                                      | 135969           | 2.74%                                          | 13.21%                                          | 0.3617%            |
| Minnesota\Crow Wing     | 7939                        | 6660                                 | 84                                       | 121716           | 5.54%                                          | 6.52%                                           | 0.3614%            |
| Oklahoma\Cleveland      | 25092                       | 3482                                 | 196                                      | 159816           | 2.30%                                          | 15.70%                                          | 0.3613%            |
| South Dakota\Todd       | 49035                       | 55694                                |                                          | 869445           | 6.41%                                          | 5.64%                                           | 0.3613%            |
| Oregon\Hood River       | 11080                       | 236                                  |                                          | 26952            | 0.88%                                          | 41.11%                                          | 0.3600%            |
| Kentucky\Spencer        | 7058                        | 2720                                 |                                          | 73289            | 3.71%                                          | 9.63%                                           | 0.3574%            |
| Washington\Whitman      | 682373                      | 8456                                 |                                          | 1271141          | 0.67%                                          | 53.68%                                          | 0.3571%            |
| Missouri\Cass           | 92031                       | 2075                                 | 2062                                     | 326609           | 1.27%                                          | 28.18%                                          | 0.3569%            |
| Nevada\Nye              | 3011                        | 9787                                 |                                          | 90868            | 10.77%                                         | 3.31%                                           | 0.3569%            |
| Colorado\Mesa           | 18649                       | 26158                                | 389                                      | 372511           | 7.13%                                          | 5.01%                                           | 0.3568%            |

| County                  | Acres Using Herbicide | Harvested Acres of Alfalfa Hay | Harvested Acres Alfalfa Haylage | Acres in Farm | % of Farm Acres in Alfalfa Forage (a) | % of Farm Acres Using Herbicide (b) | (c) = (a) x (b) |
|-------------------------|-----------------------|--------------------------------|---------------------------------|---------------|---------------------------------------|-------------------------------------|-----------------|
| Kansas\Atchison         | 104365                | 2108                           | 92                              | 254101        | 0.87%                                 | 41.07%                              | 0.3556%         |
| Kentucky\Ballard        | 58864                 | 733                            |                                 | 110199        | 0.67%                                 | 53.42%                              | 0.3553%         |
| Oregon\Marion           | 163706                | 1740                           | 305                             | 307647        | 0.66%                                 | 53.21%                              | 0.3537%         |
| Massachusetts\Berkshire | 4423                  | 1245                           | 2268                            | 66352         | 5.29%                                 | 6.67%                               | 0.3529%         |
| Kansas\Brown            | 203864                | 1971                           | 110                             | 346758        | 0.60%                                 | 58.79%                              | 0.3528%         |
| Illinois\Massac         | 42297                 | 670                            |                                 | 89693         | 0.75%                                 | 47.16%                              | 0.3523%         |
| Kansas\Morris           | 87031                 | 6901                           |                                 | 413558        | 1.67%                                 | 21.04%                              | 0.3512%         |
| South Dakota\Ziebach    | 113107                | 34754                          |                                 | 1058403       | 3.28%                                 | 10.69%                              | 0.3509%         |
| Illinois\Logan          | 268789                | 1338                           |                                 | 320356        | 0.42%                                 | 83.90%                              | 0.3504%         |
| Oregon\Malheur          | 82551                 | 58166                          |                                 | 1170664       | 4.97%                                 | 7.05%                               | 0.3504%         |
| Utah\Juab               | 15381                 | 15445                          |                                 | 260444        | 5.93%                                 | 5.91%                               | 0.3502%         |
| Minnesota\Watsonwan     | 194661                | 1095                           | 205                             | 269094        | 0.48%                                 | 72.34%                              | 0.3495%         |
| New York\Essex          | 1616                  | 3333                           | 2115                            | 50226         | 10.85%                                | 3.22%                               | 0.3490%         |
| Nebraska\Dawes          | 56876                 | 44100                          |                                 | 848753        | 5.20%                                 | 6.70%                               | 0.3482%         |
| Missouri\Platte         | 75964                 | 1462                           |                                 | 178656        | 0.82%                                 | 42.52%                              | 0.3480%         |
| Nebraska\Hitchcock      | 134867                | 3113                           |                                 | 347924        | 0.89%                                 | 38.76%                              | 0.3468%         |
| Iowa\Webster            | 321006                | 2222                           |                                 | 453930        | 0.49%                                 | 70.72%                              | 0.3462%         |
| Maryland\Queen Anne's   | 81331                 | 804                            | 110                             | 146927        | 0.62%                                 | 55.35%                              | 0.3443%         |
| Indiana\Ohio            | 3110                  | 511                            |                                 | 21500         | 2.38%                                 | 14.47%                              | 0.3438%         |
| Minnesota\Jackson       | 291443                | 1883                           |                                 | 400531        | 0.47%                                 | 72.76%                              | 0.3421%         |
| Oklahoma\Jackson        | 173669                | 4420                           |                                 | 474502        | 0.93%                                 | 36.60%                              | 0.3409%         |
| Missouri\Lincoln        | 97131                 | 1775                           | 396                             | 248858        | 0.87%                                 | 39.03%                              | 0.3405%         |
| Oklahoma\Garfield       | 190667                | 7838                           |                                 | 663431        | 1.18%                                 | 28.74%                              | 0.3395%         |
| Minnesota\Aitkin        | 9412                  | 4688                           | 1648                            | 132672        | 4.78%                                 | 7.09%                               | 0.3388%         |
| Kansas\Jefferson        | 90632                 | 2278                           | 767                             | 285803        | 1.07%                                 | 31.71%                              | 0.3379%         |
| Connecticut\New London  | 6545                  | 1708                           | 363                             | 63380         | 3.27%                                 | 10.33%                              | 0.3374%         |
| Massachusetts\Bristol   | 2601                  | 1464                           | 517                             | 39252         | 5.05%                                 | 6.63%                               | 0.3344%         |
| New York\Delaware       | 7128                  | 7211                           | 5639                            | 165572        | 7.76%                                 | 4.31%                               | 0.3341%         |
| Montana\Fallon          | 42672                 | 73050                          | 1635                            | 978818        | 7.63%                                 | 4.36%                               | 0.3326%         |
| Kansas\Hodgeman         | 173945                | 5280                           |                                 | 525754        | 1.00%                                 | 33.08%                              | 0.3323%         |
| Missouri\Macon          | 84670                 | 5852                           | 247                             | 394372        | 1.55%                                 | 21.47%                              | 0.3320%         |
| South Dakota\Mellette   | 40256                 | 43478                          | 415                             | 729778        | 6.01%                                 | 5.52%                               | 0.3318%         |
| Kansas\Gove             | 209645                | 4870                           | 701                             | 593622        | 0.94%                                 | 35.32%                              | 0.3314%         |
| New Jersey\Cape May     | 2216                  | 95                             |                                 | 7976          | 1.19%                                 | 27.78%                              | 0.3309%         |
| Kentucky\Fleming        | 9240                  | 11323                          | 445                             | 181608        | 6.48%                                 | 5.09%                               | 0.3297%         |
| Kansas\Doniphan         | 135323                | 1464                           | 32                              | 247815        | 0.60%                                 | 54.61%                              | 0.3296%         |
| Kentucky\Henry          | 9972                  | 7022                           | 29                              | 146399        | 4.82%                                 | 6.81%                               | 0.3281%         |
| Colorado\Yuma           | 341307                | 17062                          |                                 | 1334453       | 1.28%                                 | 25.58%                              | 0.3270%         |
| Kentucky\Mercer         | 6339                  | 9722                           | 595                             | 141437        | 7.29%                                 | 4.48%                               | 0.3269%         |
| Montana\Chouteau        | 664137                | 25519                          |                                 | 2277842       | 1.12%                                 | 29.16%                              | 0.3266%         |
| Colorado\Larimer        | 36595                 | 20052                          | 1348                            | 489819        | 4.37%                                 | 7.47%                               | 0.3264%         |
| Vermont\Rutland         | 5987                  | 4746                           | 4538                            | 130580        | 7.11%                                 | 4.58%                               | 0.3260%         |
| New York\Allegany       | 8274                  | 5081                           | 3873                            | 150832        | 5.94%                                 | 5.49%                               | 0.3256%         |



| County                  | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Washington\Skagit       | 34793                       | 254                                  | 847                                      | 108541           | 1.01%                                          | 32.06%                                          | 0.3252%            |
| Illinois\Franklin       | 147884                      | 852                                  | 98                                       | 207877           | 0.46%                                          | 71.14%                                          | 0.3251%            |
| Kentucky\Barren         | 33323                       | 6316                                 | 495                                      | 264717           | 2.57%                                          | 12.59%                                          | 0.3239%            |
| Oregon\Deschutes        | 6440                        | 8165                                 | 141                                      | 129369           | 6.42%                                          | 4.98%                                           | 0.3196%            |
| Missouri\Grundy         | 67502                       | 2535                                 |                                          | 231995           | 1.09%                                          | 29.10%                                          | 0.3179%            |
| Kentucky\Simpson        | 32708                       | 1379                                 |                                          | 119122           | 1.16%                                          | 27.46%                                          | 0.3179%            |
| Missouri\Barton         | 137682                      | 2810                                 |                                          | 349319           | 0.80%                                          | 39.41%                                          | 0.3171%            |
| Nebraska\Kimball        | 133274                      | 6617                                 |                                          | 527611           | 1.25%                                          | 25.26%                                          | 0.3168%            |
| Oklahoma\Comanche       | 141703                      | 5384                                 | 140                                      | 497502           | 1.11%                                          | 28.48%                                          | 0.3163%            |
| Texas\Wilbarger         | 102570                      | 10509                                | 1071                                     | 613873           | 1.89%                                          | 16.71%                                          | 0.3152%            |
| Illinois\Ford           | 230103                      | 1001                                 |                                          | 270720           | 0.37%                                          | 85.00%                                          | 0.3143%            |
| Colorado\Douglas        | 17116                       | 6466                                 | 106                                      | 189210           | 3.47%                                          | 9.05%                                           | 0.3142%            |
| Kansas\Lyon             | 110028                      | 6196                                 | 205                                      | 473679           | 1.35%                                          | 23.23%                                          | 0.3139%            |
| Kansas\Ellis            | 134595                      | 6314                                 | 128                                      | 526202           | 1.22%                                          | 25.58%                                          | 0.3131%            |
| Pennsylvania\Cameron    | 298                         | 228                                  | 44                                       | 5092             | 5.34%                                          | 5.85%                                           | 0.3126%            |
| North Dakota\Steele     | 294175                      | 1716                                 |                                          | 401959           | 0.43%                                          | 73.19%                                          | 0.3124%            |
| Pennsylvania\Elk        | 1223                        | 2033                                 | 785                                      | 33258            | 8.47%                                          | 3.68%                                           | 0.3116%            |
| Kentucky\Trigg          | 43485                       | 1313                                 |                                          | 135685           | 0.97%                                          | 32.05%                                          | 0.3101%            |
| Vermont\Orleans         | 10128                       | 1395                                 | 3778                                     | 130308           | 3.97%                                          | 7.77%                                           | 0.3085%            |
| North Dakota\Walsh      | 484281                      | 4016                                 |                                          | 795415           | 0.50%                                          | 60.88%                                          | 0.3074%            |
| Nebraska\Perkins        | 290402                      | 3294                                 |                                          | 558405           | 0.59%                                          | 52.01%                                          | 0.3068%            |
| Missouri\Caldwell       | 55492                       | 3458                                 |                                          | 250108           | 1.38%                                          | 22.19%                                          | 0.3068%            |
| Maryland\Charles        | 16935                       | 492                                  |                                          | 52147            | 0.94%                                          | 32.48%                                          | 0.3064%            |
| Ohio\Vinton             | 2315                        | 1792                                 |                                          | 36811            | 4.87%                                          | 6.29%                                           | 0.3061%            |
| Idaho\Clearwater        | 9596                        | 1544                                 |                                          | 69568            | 2.22%                                          | 13.79%                                          | 0.3061%            |
| Idaho\Lemhi             | 4917                        | 21478                                | 818                                      | 189644           | 11.76%                                         | 2.59%                                           | 0.3048%            |
| Kansas\Trego            | 121434                      | 4623                                 |                                          | 429588           | 1.08%                                          | 28.27%                                          | 0.3042%            |
| Ohio\Guernsey           | 7338                        | 7081                                 | 748                                      | 137584           | 5.69%                                          | 5.33%                                           | 0.3035%            |
| Michigan\Houghton       | 899                         | 1543                                 | 340                                      | 23643            | 7.96%                                          | 3.80%                                           | 0.3028%            |
| South Dakota\Dewey      | 96913                       | 65514                                |                                          | 1449585          | 4.52%                                          | 6.69%                                           | 0.3022%            |
| Montana\Lake            | 35661                       | 33618                                | 766                                      | 637306           | 5.40%                                          | 5.60%                                           | 0.3019%            |
| Illinois\Christian      | 373555                      | 1616                                 | 12                                       | 449512           | 0.36%                                          | 83.10%                                          | 0.3010%            |
| Vermont\Chittenden      | 4786                        | 1904                                 | 2450                                     | 83382            | 5.22%                                          | 5.74%                                           | 0.2997%            |
| Missouri\Monroe         | 97851                       | 2035                                 | 510                                      | 288293           | 0.88%                                          | 33.94%                                          | 0.2996%            |
| Washington\Chelan       | 16789                       | 1561                                 |                                          | 93883            | 1.66%                                          | 17.88%                                          | 0.2973%            |
| Colorado\Dolores        | 10518                       | 8545                                 |                                          | 173872           | 4.91%                                          | 6.05%                                           | 0.2973%            |
| North Dakota\Traill     | 441501                      | 1990                                 |                                          | 543650           | 0.37%                                          | 81.21%                                          | 0.2973%            |
| Montana\Liberty         | 347346                      | 6982                                 |                                          | 904327           | 0.77%                                          | 38.41%                                          | 0.2965%            |
| Iowa\Wright             | 259669                      | 1222                                 |                                          | 327728           | 0.37%                                          | 79.23%                                          | 0.2954%            |
| Kentucky\Hart           | 13204                       | 8027                                 | 127                                      | 191047           | 4.27%                                          | 6.91%                                           | 0.2950%            |
| Colorado\Phillips       | 205251                      | 2661                                 |                                          | 431154           | 0.62%                                          | 47.61%                                          | 0.2938%            |
| Kentucky\Bullitt        | 6684                        | 1147                                 |                                          | 51148            | 2.24%                                          | 13.07%                                          | 0.2931%            |
| Missouri\Cape Girardeau | 111377                      | 1784                                 | 625                                      | 302631           | 0.80%                                          | 36.80%                                          | 0.2930%            |
| North Dakota\Ramsey     | 463004                      | 3104                                 | 125                                      | 714525           | 0.45%                                          | 64.80%                                          | 0.2928%            |
| Kansas\Anderson         | 117675                      | 3227                                 | 126                                      | 367192           | 0.91%                                          | 32.05%                                          | 0.2926%            |

| County                  | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Idaho\Bonner            | 5816                        | 4298                                 | 180                                      | 94380            | 4.74%                                          | 6.16%                                           | 0.2924%            |
| New Mexico\Dona Ana     | 55104                       | 18295                                | 125                                      | 589373           | 3.13%                                          | 9.35%                                           | 0.2922%            |
| Oklahoma\Noble          | 118997                      | 5315                                 |                                          | 466947           | 1.14%                                          | 25.48%                                          | 0.2901%            |
| Montana\Glacier         | 294683                      | 28397                                |                                          | 1700179          | 1.67%                                          | 17.33%                                          | 0.2895%            |
| Montana\Dawson          | 184445                      | 29735                                |                                          | 1378564          | 2.16%                                          | 13.38%                                          | 0.2886%            |
| Iowa\Kossuth            | 460251                      | 2196                                 | 69                                       | 601517           | 0.38%                                          | 76.52%                                          | 0.2881%            |
| Virginia\Wythe          | 9322                        | 6141                                 | 1638                                     | 159126           | 4.89%                                          | 5.86%                                           | 0.2864%            |
| Kansas\Woodson          | 56523                       | 3437                                 |                                          | 261607           | 1.31%                                          | 21.61%                                          | 0.2839%            |
| Missouri\Greene         | 18858                       | 7702                                 | 176                                      | 231988           | 3.40%                                          | 8.13%                                           | 0.2760%            |
| Kansas\Cowley           | 124068                      | 7338                                 |                                          | 575584           | 1.27%                                          | 21.56%                                          | 0.2748%            |
| Kansas\Allen            | 74057                       | 2630                                 |                                          | 267409           | 0.98%                                          | 27.69%                                          | 0.2724%            |
| Nebraska\Dundy          | 169834                      | 5662                                 |                                          | 594834           | 0.95%                                          | 28.55%                                          | 0.2718%            |
| Indiana\Knox            | 278180                      | 1041                                 |                                          | 327267           | 0.32%                                          | 85.00%                                          | 0.2704%            |
| Kansas\Harper           | 86579                       | 5955                                 | 1276                                     | 481291           | 1.50%                                          | 17.99%                                          | 0.2703%            |
| Wyoming\Park            | 55248                       | 37844                                |                                          | 881736           | 4.29%                                          | 6.27%                                           | 0.2689%            |
| New Jersey\Ocean        | 1925                        | 135                                  |                                          | 9833             | 1.37%                                          | 19.58%                                          | 0.2688%            |
| Minnesota\Itasca        | 3346                        | 6278                                 | 669                                      | 93274            | 7.45%                                          | 3.59%                                           | 0.2672%            |
| Oklahoma\Major          | 83813                       | 8079                                 | 400                                      | 517334           | 1.64%                                          | 16.20%                                          | 0.2655%            |
| Montana\Hill            | 551870                      | 13796                                |                                          | 1697232          | 0.81%                                          | 32.52%                                          | 0.2643%            |
| Nebraska\Deuel          | 91657                       | 2243                                 |                                          | 278915           | 0.80%                                          | 32.86%                                          | 0.2643%            |
| Idaho\Adams             | 8428                        | 6953                                 |                                          | 148996           | 4.67%                                          | 5.66%                                           | 0.2640%            |
| Nebraska\Hayes          | 121726                      | 4178                                 | 280                                      | 453818           | 0.98%                                          | 26.82%                                          | 0.2635%            |
| Kentucky\Nicholas       | 3976                        | 8008                                 |                                          | 110198           | 7.27%                                          | 3.61%                                           | 0.2622%            |
| Missouri\Warren         | 50358                       | 1121                                 |                                          | 146798           | 0.76%                                          | 34.30%                                          | 0.2620%            |
| Indiana\Vanderburgh     | 54612                       | 248                                  |                                          | 71927            | 0.34%                                          | 75.93%                                          | 0.2618%            |
| Illinois\Jasper         | 185820                      | 832                                  |                                          | 243451           | 0.34%                                          | 76.33%                                          | 0.2609%            |
| Maine\Androscoggin      | 3966                        | 500                                  | 1198                                     | 50844            | 3.34%                                          | 7.80%                                           | 0.2605%            |
| Illinois\Union          | 45394                       | 742                                  | 117                                      | 122362           | 0.70%                                          | 37.10%                                          | 0.2604%            |
| Kansas\Sherman          | 305463                      | 3679                                 |                                          | 657942           | 0.56%                                          | 46.43%                                          | 0.2596%            |
| Kansas\Jackson          | 84049                       | 3141                                 | 370                                      | 339291           | 1.03%                                          | 24.77%                                          | 0.2563%            |
| Missouri\Jefferson      | 11621                       | 1432                                 | 436                                      | 92225            | 2.03%                                          | 12.60%                                          | 0.2552%            |
| Connecticut\Windham     | 6839                        | 631                                  | 717                                      | 60136            | 2.24%                                          | 11.37%                                          | 0.2549%            |
| Missouri\Ray            | 86588                       | 2504                                 |                                          | 291798           | 0.86%                                          | 29.67%                                          | 0.2546%            |
| Washington\Stevens      | 21364                       | 32477                                | 1121                                     | 531082           | 6.33%                                          | 4.02%                                           | 0.2545%            |
| Missouri\Linn           | 67965                       | 3955                                 | 109                                      | 330072           | 1.23%                                          | 20.59%                                          | 0.2535%            |
| Pennsylvania\Lackawanna | 1976                        | 1233                                 | 788                                      | 39756            | 5.08%                                          | 4.97%                                           | 0.2527%            |
| Missouri\Schuyler       | 13324                       | 4145                                 | 250                                      | 152378           | 2.88%                                          | 8.74%                                           | 0.2522%            |
| Missouri\Howard         | 92309                       | 2087                                 |                                          | 276590           | 0.75%                                          | 33.37%                                          | 0.2518%            |
| Kentucky\Caldwell       | 39628                       | 1293                                 |                                          | 142770           | 0.91%                                          | 27.76%                                          | 0.2514%            |
| Oklahoma\Blaine         | 132180                      | 6525                                 |                                          | 585908           | 1.11%                                          | 22.56%                                          | 0.2512%            |
| Kansas\Graham           | 145659                      | 4425                                 | 133                                      | 514815           | 0.89%                                          | 28.29%                                          | 0.2505%            |
| Oklahoma\Kiowa          | 127804                      | 6226                                 |                                          | 564592           | 1.10%                                          | 22.64%                                          | 0.2496%            |
| Kansas\Miami            | 81796                       | 2873                                 |                                          | 307083           | 0.94%                                          | 26.64%                                          | 0.2492%            |

| County                   | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|--------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Nebraska\Cheyenne        | 227062                      | 6248                                 |                                          | 754598           | 0.83%                                          | 30.09%                                          | 0.2491%            |
| Indiana\Scott            | 38248                       | 250                                  |                                          | 62041            | 0.40%                                          | 61.65%                                          | 0.2484%            |
| Missouri\Jasper          | 63986                       | 2431                                 | 160                                      | 258815           | 1.00%                                          | 24.72%                                          | 0.2475%            |
| Kentucky\Logan           | 109473                      | 1762                                 | 129                                      | 289931           | 0.65%                                          | 37.76%                                          | 0.2463%            |
| Virginia\Madison         | 16309                       | 1031                                 | 560                                      | 102757           | 1.55%                                          | 15.87%                                          | 0.2457%            |
| Wyoming\Goshen           | 75118                       | 58944                                | 1788                                     | 1368342          | 4.44%                                          | 5.49%                                           | 0.2437%            |
| Kansas\Russell           | 104882                      | 4560                                 |                                          | 443550           | 1.03%                                          | 23.65%                                          | 0.2431%            |
| Montana\Blaine           | 234414                      | 53439                                | 2672                                     | 2330605          | 2.41%                                          | 10.06%                                          | 0.2422%            |
| Montana\Park             | 36382                       | 38637                                |                                          | 762753           | 5.07%                                          | 4.77%                                           | 0.2416%            |
| Illinois\Crawford        | 157618                      | 643                                  |                                          | 205356           | 0.31%                                          | 76.75%                                          | 0.2403%            |
| Missouri\Callaway        | 72845                       | 3253                                 | 183                                      | 322929           | 1.06%                                          | 22.56%                                          | 0.2400%            |
| Idaho\Benewah            | 51723                       | 1093                                 |                                          | 153591           | 0.71%                                          | 33.68%                                          | 0.2396%            |
| Washington\Yakima        | 156824                      | 37363                                | 4069                                     | 1649281          | 2.51%                                          | 9.51%                                           | 0.2389%            |
| Utah\Box Elder           | 80969                       | 49161                                | 2174                                     | 1320177          | 3.89%                                          | 6.13%                                           | 0.2385%            |
| New Jersey\Mercer        | 8588                        | 131                                  |                                          | 21730            | 0.60%                                          | 39.52%                                          | 0.2383%            |
| Washington\Pend Oreille  | 4501                        | 1603                                 |                                          | 55109            | 2.91%                                          | 8.17%                                           | 0.2376%            |
| Montana\Toole            | 335804                      | 8782                                 |                                          | 1115019          | 0.79%                                          | 30.12%                                          | 0.2372%            |
| Indiana\Spencer          | 86634                       | 616                                  |                                          | 150244           | 0.41%                                          | 57.66%                                          | 0.2364%            |
| Kansas\Meade             | 162737                      | 5268                                 |                                          | 602281           | 0.87%                                          | 27.02%                                          | 0.2363%            |
| Massachusetts            | 41313                       | 9921                                 | 5416                                     | 517879           | 2.96%                                          | 7.98%                                           | 0.2362%            |
| Nevada\Lander            | 11645                       | 23245                                |                                          | 339091           | 6.86%                                          | 3.43%                                           | 0.2354%            |
| Kentucky\Warren          | 49827                       | 3204                                 | 104                                      | 265126           | 1.25%                                          | 18.79%                                          | 0.2345%            |
| Oregon\Wallowa           | 31946                       | 19777                                | 658                                      | 527957           | 3.87%                                          | 6.05%                                           | 0.2342%            |
| Illinois\Champaign       | 479029                      | 1475                                 |                                          | 550481           | 0.27%                                          | 87.02%                                          | 0.2332%            |
| Minnesota\Cass           | 8760                        | 6774                                 | 828                                      | 169160           | 4.49%                                          | 5.18%                                           | 0.2327%            |
| Kansas\Franklin          | 87644                       | 2057                                 | 543                                      | 313546           | 0.83%                                          | 27.95%                                          | 0.2318%            |
| Rhode Island\Bristol     | 247                         | 26                                   |                                          | 1665             | 1.56%                                          | 14.83%                                          | 0.2317%            |
| Missouri\Mercer          | 33711                       | 2543                                 | 243                                      | 201417           | 1.38%                                          | 16.74%                                          | 0.2315%            |
| Pennsylvania\Susquehanna | 6522                        | 4867                                 | 4012                                     | 158218           | 5.61%                                          | 4.12%                                           | 0.2313%            |
| Oklahoma\Caddo           | 174135                      | 7456                                 |                                          | 749918           | 0.99%                                          | 23.22%                                          | 0.2309%            |
| California\Lassen        | 24595                       | 19752                                |                                          | 459126           | 4.30%                                          | 5.36%                                           | 0.2305%            |
| Montana\Missoula         | 19932                       | 9158                                 |                                          | 281893           | 3.25%                                          | 7.07%                                           | 0.2297%            |
| Illinois\Marion          | 166683                      | 936                                  |                                          | 260679           | 0.36%                                          | 63.94%                                          | 0.2296%            |
| Colorado\Eagle           | 7918                        | 4405                                 |                                          | 124044           | 3.55%                                          | 6.38%                                           | 0.2267%            |
| Missouri\Christian       | 13041                       | 5913                                 | 254                                      | 189177           | 3.26%                                          | 6.89%                                           | 0.2247%            |
| Missouri\Saline          | 221231                      | 1696                                 | 349                                      | 449410           | 0.46%                                          | 49.23%                                          | 0.2240%            |
| Nebraska\Garfield        | 33868                       | 8824                                 |                                          | 365685           | 2.41%                                          | 9.26%                                           | 0.2235%            |
| Illinois\Hamilton        | 150031                      | 714                                  |                                          | 219873           | 0.32%                                          | 68.24%                                          | 0.2216%            |
| Illinois\Pulaski         | 68607                       | 330                                  |                                          | 101189           | 0.33%                                          | 67.80%                                          | 0.2211%            |
| Virginia\Prince William  | 6347                        | 375                                  |                                          | 32816            | 1.14%                                          | 19.34%                                          | 0.2210%            |
| Kansas\Wilson            | 116227                      | 2106                                 |                                          | 333202           | 0.63%                                          | 34.88%                                          | 0.2205%            |
| Maryland\Worcester       | 59990                       | 450                                  |                                          | 110847           | 0.41%                                          | 54.12%                                          | 0.2197%            |
| Missouri\Clay            | 34837                       | 1303                                 |                                          | 143853           | 0.91%                                          | 24.22%                                          | 0.2194%            |
| Washington\Clark         | 11306                       | 431                                  | 760                                      | 78359            | 1.52%                                          | 14.43%                                          | 0.2193%            |
| North Dakota\Cavalier    | 652326                      | 2564                                 |                                          | 873377           | 0.29%                                          | 74.69%                                          | 0.2193%            |

| County                  | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Kentucky\Boone          | 4635                        | 2302                                 | 329                                      | 74750            | 3.52%                                          | 6.20%                                           | 0.2182%            |
| Montana\Yellowstone     | 134243                      | 41666                                | 465                                      | 1615769          | 2.61%                                          | 8.31%                                           | 0.2166%            |
| Pennsylvania\McKean     | 2239                        | 1202                                 | 458                                      | 41466            | 4.00%                                          | 5.40%                                           | 0.2162%            |
| Utah\Garfield           | 1362                        | 9738                                 | 893                                      | 81866            | 12.99%                                         | 1.66%                                           | 0.2160%            |
| Kentucky\Marion         | 11358                       | 4566                                 | 341                                      | 160684           | 3.05%                                          | 7.07%                                           | 0.2159%            |
| Ohio\Meigs              | 4932                        | 1820                                 | 819                                      | 77755            | 3.39%                                          | 6.34%                                           | 0.2153%            |
| Florida\Gilchrist       | 5865                        | 1855                                 |                                          | 71098            | 2.61%                                          | 8.25%                                           | 0.2152%            |
| California\Contra Costa | 12485                       | 3696                                 |                                          | 146993           | 2.51%                                          | 8.49%                                           | 0.2136%            |
| Tennessee\Robertson     | 78638                       | 1392                                 |                                          | 227298           | 0.61%                                          | 34.60%                                          | 0.2119%            |
| Missouri\Franklin       | 49008                       | 3322                                 | 559                                      | 299730           | 1.29%                                          | 16.35%                                          | 0.2117%            |
| New Jersey\Atlantic     | 12729                       | 153                                  |                                          | 30372            | 0.50%                                          | 41.91%                                          | 0.2111%            |
| Connecticut\Middlesex   | 1605                        | 363                                  |                                          | 16623            | 2.18%                                          | 9.66%                                           | 0.2108%            |
| Colorado\Routt          | 35752                       | 16731                                |                                          | 533014           | 3.14%                                          | 6.71%                                           | 0.2105%            |
| Indiana\Tipton          | 133551                      | 432                                  |                                          | 165875           | 0.26%                                          | 80.51%                                          | 0.2097%            |
| Missouri\Randolph       | 43155                       | 2260                                 | 114                                      | 221647           | 1.07%                                          | 19.47%                                          | 0.2085%            |
| Kansas\Stevens          | 215758                      | 2445                                 |                                          | 503439           | 0.49%                                          | 42.86%                                          | 0.2081%            |
| Virginia\Culpeper       | 17707                       | 1457                                 |                                          | 111370           | 1.31%                                          | 15.90%                                          | 0.2080%            |
| Connecticut\New Haven   | 2637                        | 1560                                 | 75                                       | 45684            | 3.58%                                          | 5.77%                                           | 0.2066%            |
| Kentucky\Harrison       | 7417                        | 6957                                 | 326                                      | 161777           | 4.50%                                          | 4.58%                                           | 0.2064%            |
| Nebraska\Chase          | 234238                      | 2695                                 |                                          | 555971           | 0.48%                                          | 42.13%                                          | 0.2042%            |
| Montana\Jefferson       | 22682                       | 13747                                |                                          | 391248           | 3.51%                                          | 5.80%                                           | 0.2037%            |
| Texas\Castro            | 196955                      | 3323                                 |                                          | 567255           | 0.59%                                          | 34.72%                                          | 0.2034%            |
| Missouri\Chariton       | 155054                      | 1827                                 | 105                                      | 384499           | 0.50%                                          | 40.33%                                          | 0.2026%            |
| Montana\Petroleum       | 31115                       | 26304                                | 400                                      | 640707           | 4.17%                                          | 4.86%                                           | 0.2024%            |
| Maryland\Somerset       | 26325                       | 264                                  | 15                                       | 60255            | 0.46%                                          | 43.69%                                          | 0.2023%            |
| Maine\Kennebec          | 3932                        | 618                                  | 2867                                     | 82457            | 4.23%                                          | 4.77%                                           | 0.2015%            |
| Colorado\Otero          | 24335                       | 31811                                | 288                                      | 624123           | 5.14%                                          | 3.90%                                           | 0.2005%            |
| Montana\Carbon          | 36111                       | 34963                                |                                          | 793628           | 4.41%                                          | 4.55%                                           | 0.2005%            |
| Maine\Penobscot         | 10474                       | 1193                                 | 1298                                     | 114607           | 2.17%                                          | 9.14%                                           | 0.1986%            |
| Ohio\Morgan             | 3158                        | 6239                                 | 328                                      | 102271           | 6.42%                                          | 3.09%                                           | 0.1983%            |
| Virginia\Frederick      | 9512                        | 2009                                 |                                          | 98278            | 2.04%                                          | 9.68%                                           | 0.1979%            |
| Kansas\Cheyenne         | 152080                      | 4309                                 |                                          | 576831           | 0.75%                                          | 26.36%                                          | 0.1969%            |
| South Dakota\Butte      | 52756                       | 46953                                | 1493                                     | 1140405          | 4.25%                                          | 4.63%                                           | 0.1965%            |
| Vermont\Caledonia       | 2636                        | 1244                                 | 3752                                     | 81946            | 6.10%                                          | 3.22%                                           | 0.1961%            |
| Indiana\Brown           | 2819                        | 200                                  |                                          | 16959            | 1.18%                                          | 16.62%                                          | 0.1960%            |
| Kentucky\Henderson      | 112387                      | 642                                  | 24                                       | 195706           | 0.34%                                          | 57.43%                                          | 0.1954%            |
| Illinois\Wayne          | 215590                      | 1001                                 |                                          | 333255           | 0.30%                                          | 64.69%                                          | 0.1943%            |
| Kansas\Shawnee          | 91998                       | 896                                  |                                          | 206243           | 0.43%                                          | 44.61%                                          | 0.1938%            |
| North Carolina\Forsyth  | 10218                       | 358                                  |                                          | 43593            | 0.82%                                          | 23.44%                                          | 0.1925%            |
| Nebraska\Frontier       | 142862                      | 3031                                 |                                          | 475252           | 0.64%                                          | 30.06%                                          | 0.1917%            |
| Pennsylvania\Allegheny  | 1503                        | 1727                                 | 109                                      | 38023            | 4.83%                                          | 3.95%                                           | 0.1909%            |
| North Dakota\Sioux      | 25925                       | 38491                                | 725                                      | 730306           | 5.37%                                          | 3.55%                                           | 0.1906%            |
| Kentucky\Russell        | 8970                        | 1839                                 |                                          | 93039            | 1.98%                                          | 9.64%                                           | 0.1906%            |

| County                 | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Kansas\Butler          | 177145                      | 6389                                 | 250                                      | 787290           | 0.84%                                          | 22.50%                                          | 0.1897%            |
| Indiana\Dubois         | 103489                      | 608                                  |                                          | 182175           | 0.33%                                          | 56.81%                                          | 0.1896%            |
| Missouri\Bates         | 125736                      | 2508                                 | 876                                      | 473781           | 0.71%                                          | 26.54%                                          | 0.1896%            |
| Washington\Snohomish   | 13268                       | 632                                  | 211                                      | 76837            | 1.10%                                          | 17.27%                                          | 0.1894%            |
| Illinois\Clark         | 183687                      | 584                                  |                                          | 238706           | 0.24%                                          | 76.95%                                          | 0.1883%            |
| Rhode Island           | 7121                        | 1035                                 | 166                                      | 67819            | 1.77%                                          | 10.50%                                          | 0.1859%            |
| Montana\Silver Bow     | 5283                        | 3585                                 |                                          | 101081           | 3.55%                                          | 5.23%                                           | 0.1854%            |
| Missouri\Putnam        | 24090                       | 5717                                 |                                          | 272655           | 2.10%                                          | 8.84%                                           | 0.1853%            |
| Virginia\Fauquier      | 29557                       | 2696                                 | 397                                      | 222486           | 1.39%                                          | 13.28%                                          | 0.1847%            |
| Kentucky\Trimble       | 2448                        | 3136                                 | 51                                       | 65098            | 4.90%                                          | 3.76%                                           | 0.1841%            |
| Pennsylvania\Warren    | 5239                        | 2520                                 | 963                                      | 99582            | 3.50%                                          | 5.26%                                           | 0.1840%            |
| North Dakota\Billings  | 26555                       | 36360                                |                                          | 724532           | 5.02%                                          | 3.67%                                           | 0.1839%            |
| Colorado\Costilla      | 13889                       | 21281                                |                                          | 401147           | 5.31%                                          | 3.46%                                           | 0.1837%            |
| Kansas\Montgomery      | 94833                       | 1896                                 |                                          | 313947           | 0.60%                                          | 30.21%                                          | 0.1824%            |
| Virginia\Botetourt     | 6573                        | 1750                                 | 384                                      | 87913            | 2.43%                                          | 7.48%                                           | 0.1815%            |
| Massachusetts\Franklin | 5189                        | 1432                                 | 759                                      | 79465            | 2.76%                                          | 6.53%                                           | 0.1800%            |
| Missouri\Lawrence      | 36440                       | 4218                                 | 913                                      | 322822           | 1.59%                                          | 11.29%                                          | 0.1794%            |
| Kentucky\Scott         | 5834                        | 5270                                 | 658                                      | 139044           | 4.26%                                          | 4.20%                                           | 0.1789%            |
| California\Plumas      | 5035                        | 5118                                 |                                          | 120253           | 4.26%                                          | 4.19%                                           | 0.1782%            |
| New York\Greene        | 1272                        | 2553                                 | 197                                      | 44328            | 6.20%                                          | 2.87%                                           | 0.1780%            |
| Kansas\Scott           | 227232                      | 1592                                 |                                          | 453296           | 0.35%                                          | 50.13%                                          | 0.1761%            |
| Wisconsin\Forest       | 572                         | 3254                                 | 256                                      | 33805            | 10.38%                                         | 1.69%                                           | 0.1757%            |
| Kentucky\Daviess       | 143015                      | 808                                  |                                          | 256922           | 0.31%                                          | 55.66%                                          | 0.1751%            |
| Missouri\Moniteau      | 43958                       | 1690                                 | 657                                      | 242946           | 0.97%                                          | 18.09%                                          | 0.1748%            |
| Colorado\Kit Carson    | 351785                      | 9076                                 |                                          | 1352319          | 0.67%                                          | 26.01%                                          | 0.1746%            |
| Oklahoma\Murray        | 29991                       | 2254                                 |                                          | 197022           | 1.14%                                          | 15.22%                                          | 0.1741%            |
| Missouri\Adair         | 38752                       | 3518                                 |                                          | 279855           | 1.26%                                          | 13.85%                                          | 0.1741%            |
| New York\Schenectady   | 378                         | 1683                                 |                                          | 19129            | 8.80%                                          | 1.98%                                           | 0.1739%            |
| Massachusetts\Essex    | 1608                        | 485                                  | 346                                      | 27834            | 2.99%                                          | 5.78%                                           | 0.1725%            |
| Arizona\Greenlee       | 1900                        | 1126                                 |                                          | 35267            | 3.19%                                          | 5.39%                                           | 0.1720%            |
| Utah\Emery             | 4057                        | 17488                                | 243                                      | 204775           | 8.66%                                          | 1.98%                                           | 0.1715%            |
| Washington\Columbia    | 130409                      | 1284                                 |                                          | 313307           | 0.41%                                          | 41.62%                                          | 0.1706%            |
| Ohio\Athens            | 5070                        | 2264                                 |                                          | 82182            | 2.75%                                          | 6.17%                                           | 0.1700%            |
| Kansas\Coffey          | 87674                       | 2038                                 |                                          | 324827           | 0.63%                                          | 26.99%                                          | 0.1693%            |
| Kentucky\Jefferson     | 3643                        | 484                                  |                                          | 32296            | 1.50%                                          | 11.28%                                          | 0.1690%            |
| California\Butte       | 158149                      | 1349                                 | 142                                      | 373786           | 0.40%                                          | 42.31%                                          | 0.1688%            |
| Missouri\Dade          | 61820                       | 2070                                 |                                          | 276229           | 0.75%                                          | 22.38%                                          | 0.1677%            |
| Missouri\Stone         | 13603                       | 1678                                 | 148                                      | 121792           | 1.50%                                          | 11.17%                                          | 0.1675%            |
| Colorado\Arapahoe      | 40801                       | 2583                                 |                                          | 251812           | 1.03%                                          | 16.20%                                          | 0.1662%            |
| Oklahoma\Logan         | 64539                       | 3878                                 | 320                                      | 403810           | 1.04%                                          | 15.98%                                          | 0.1662%            |
| Nebraska\Keya Paha     | 24600                       | 15767                                |                                          | 483450           | 3.26%                                          | 5.09%                                           | 0.1660%            |
| Kansas\Wabaunsee       | 56909                       | 6150                                 | 276                                      | 470474           | 1.37%                                          | 12.10%                                          | 0.1652%            |
| Missouri\Cooper        | 87732                       | 1497                                 | 221                                      | 302429           | 0.57%                                          | 29.01%                                          | 0.1648%            |
| Montana\Deer Lodge     | 2480                        | 4150                                 |                                          | 79335            | 5.23%                                          | 3.13%                                           | 0.1635%            |
| Kansas\Osage           | 124337                      | 1831                                 | 45                                       | 380156           | 0.49%                                          | 32.71%                                          | 0.1614%            |

| County                   | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|--------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Vermont\Windham          | 2642                        | 247                                  | 1326                                     | 50764            | 3.10%                                          | 5.20%                                           | 0.1613%            |
| Oklahoma\Greer           | 51130                       | 4437                                 |                                          | 375447           | 1.18%                                          | 13.62%                                          | 0.1609%            |
| Colorado\Washington      | 307375                      | 9810                                 |                                          | 1375742          | 0.71%                                          | 22.34%                                          | 0.1593%            |
| Illinois\Clay            | 142230                      | 493                                  |                                          | 209834           | 0.23%                                          | 67.78%                                          | 0.1593%            |
| Massachusetts\Middlesex  | 1896                        | 884                                  | 76                                       | 33893            | 2.83%                                          | 5.59%                                           | 0.1584%            |
| Maryland\Prince George's | 9574                        | 224                                  |                                          | 37005            | 0.61%                                          | 25.87%                                          | 0.1566%            |
| Virginia\Smyth           | 10116                       | 2325                                 | 183                                      | 127307           | 1.97%                                          | 7.95%                                           | 0.1565%            |
| Texas\Dawson             | 237466                      | 2072                                 | 50                                       | 568036           | 0.37%                                          | 41.80%                                          | 0.1562%            |
| Kansas\Comanche          | 41718                       | 6392                                 | 598                                      | 432378           | 1.62%                                          | 9.65%                                           | 0.1560%            |
| Kansas\Neosho            | 71687                       | 2109                                 | 140                                      | 321520           | 0.70%                                          | 22.30%                                          | 0.1560%            |
| Oklahoma\Beckham         | 76018                       | 5527                                 |                                          | 519503           | 1.06%                                          | 14.63%                                          | 0.1557%            |
| Kentucky\Union           | 125321                      | 501                                  |                                          | 200839           | 0.25%                                          | 62.40%                                          | 0.1557%            |
| Wyoming\Washakie         | 21954                       | 15631                                |                                          | 469804           | 3.33%                                          | 4.67%                                           | 0.1555%            |
| Montana\Lewis and Clark  | 47246                       | 31028                                |                                          | 971240           | 3.19%                                          | 4.86%                                           | 0.1554%            |
| Utah\Washington          | 8606                        | 5031                                 | 447                                      | 174192           | 3.14%                                          | 4.94%                                           | 0.1554%            |
| Montana\Wheatland        | 43837                       | 22600                                | 1230                                     | 822253           | 2.90%                                          | 5.33%                                           | 0.1545%            |
| Maine\Aroostook          | 84666                       | 1602                                 | 970                                      | 375568           | 0.68%                                          | 22.54%                                          | 0.1544%            |
| Oregon\Benton            | 51736                       | 390                                  |                                          | 114558           | 0.34%                                          | 45.16%                                          | 0.1537%            |
| Illinois\Piatt           | 244238                      | 449                                  |                                          | 267265           | 0.17%                                          | 91.38%                                          | 0.1535%            |
| Montana\Phillips         | 151992                      | 40426                                | 66                                       | 2006068          | 2.02%                                          | 7.58%                                           | 0.1529%            |
| Oregon\Polk              | 86371                       | 342                                  | 148                                      | 166663           | 0.29%                                          | 51.82%                                          | 0.1524%            |
| Kansas\Ness              | 178974                      | 2939                                 | 332                                      | 619948           | 0.53%                                          | 28.87%                                          | 0.1523%            |
| Kentucky\Powell          | 3007                        | 542                                  |                                          | 32763            | 1.65%                                          | 9.18%                                           | 0.1518%            |
| Ohio\Cuyahoga            | 152                         | 84                                   |                                          | 2910             | 2.89%                                          | 5.22%                                           | 0.1508%            |
| Colorado\Elbert          | 68587                       | 28279                                |                                          | 1,134,199        | 2.49%                                          | 6.05%                                           | 0.1508%            |
| Illinois\White           | 236153                      | 562                                  |                                          | 296989           | 0.19%                                          | 79.52%                                          | 0.1505%            |
| Missouri\Ste. Genevieve  | 29202                       | 1829                                 |                                          | 188794           | 0.97%                                          | 15.47%                                          | 0.1498%            |
| Nebraska\Banner          | 58271                       | 3992                                 |                                          | 394906           | 1.01%                                          | 14.76%                                          | 0.1492%            |
| Kentucky\Bracken         | 3995                        | 3456                                 | 321                                      | 100660           | 3.75%                                          | 3.97%                                           | 0.1489%            |
| Colorado\Bent            | 34459                       | 33184                                |                                          | 877142           | 3.78%                                          | 3.93%                                           | 0.1486%            |
| Indiana\Pike             | 47780                       | 168                                  |                                          | 73612            | 0.23%                                          | 64.91%                                          | 0.1481%            |
| Virginia\Orange          | 13032                       | 1130                                 | 111                                      | 104606           | 1.19%                                          | 12.46%                                          | 0.1478%            |
| California\Yuba          | 44751                       | 850                                  |                                          | 160898           | 0.53%                                          | 27.81%                                          | 0.1469%            |
| South Dakota\Stanley     | 119086                      | 10430                                |                                          | 921110           | 1.13%                                          | 12.93%                                          | 0.1464%            |
| Vermont\Orange           | 5147                        | 631                                  | 2299                                     | 101645           | 2.88%                                          | 5.06%                                           | 0.1460%            |
| Minnesota\Carlton        | 1728                        | 6849                                 | 1205                                     | 97897            | 8.23%                                          | 1.77%                                           | 0.1452%            |
| Kentucky\Washington      | 8589                        | 4379                                 | 112                                      | 162993           | 2.76%                                          | 5.27%                                           | 0.1452%            |
| Missouri\Pettis          | 122005                      | 1130                                 | 853                                      | 408932           | 0.48%                                          | 29.84%                                          | 0.1447%            |
| Maine                    | 129544                      | 10089                                | 10036                                    | 1347566          | 1.49%                                          | 9.61%                                           | 0.1436%            |
| Texas\Robertson          | 117743                      | 2500                                 | 25                                       | 455308           | 0.55%                                          | 25.86%                                          | 0.1434%            |
| Vermont\Washington       | 1884                        | 973                                  | 1859                                     | 61029            | 4.64%                                          | 3.09%                                           | 0.1433%            |
| Utah\Wasatch             | 862                         | 7189                                 |                                          | 65935            | 10.90%                                         | 1.31%                                           | 0.1425%            |
| Virginia\Sussex          | 29711                       | 264                                  |                                          | 74224            | 0.36%                                          | 40.03%                                          | 0.1424%            |

| County                | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|-----------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Kansas\Barber         | 77104                       | 6510                                 | 386                                      | 611493           | 1.13%                                          | 12.61%                                          | 0.1422%            |
| Colorado\Montezuma    | 22045                       | 30799                                | 903                                      | 704261           | 4.50%                                          | 3.13%                                           | 0.1409%            |
| Virginia\Franklin     | 18838                       | 1601                                 | 469                                      | 166592           | 1.24%                                          | 11.31%                                          | 0.1405%            |
| Kansas\Thomas         | 374546                      | 1621                                 |                                          | 657471           | 0.25%                                          | 56.97%                                          | 0.1405%            |
| Oklahoma\Harmon       | 59936                       | 2416                                 |                                          | 322222           | 0.75%                                          | 18.60%                                          | 0.1395%            |
| Nebraska\Wheeler      | 50838                       | 3547                                 |                                          | 360200           | 0.98%                                          | 14.11%                                          | 0.1390%            |
| Missouri\Carroll      | 164580                      | 1336                                 |                                          | 401536           | 0.33%                                          | 40.99%                                          | 0.1364%            |
| Oklahoma\Haskell      | 46995                       | 2442                                 |                                          | 290260           | 0.84%                                          | 16.19%                                          | 0.1362%            |
| Virginia\Montgomery   | 6133                        | 1451                                 | 316                                      | 89411            | 1.98%                                          | 6.86%                                           | 0.1356%            |
| Kansas\Clark          | 64115                       | 4954                                 |                                          | 485996           | 1.02%                                          | 13.19%                                          | 0.1345%            |
| Oregon\Baker          | 30181                       | 22057                                | 480                                      | 711809           | 3.17%                                          | 4.24%                                           | 0.1342%            |
| Oklahoma\Woods        | 71193                       | 13060                                |                                          | 833775           | 1.57%                                          | 8.54%                                           | 0.1337%            |
| Louisiana\St. Landry  | 132474                      | 43                                   | 851                                      | 298369           | 0.30%                                          | 44.40%                                          | 0.1330%            |
| South Dakota\Harding  | 59543                       | 56869                                |                                          | 1596101          | 3.56%                                          | 3.73%                                           | 0.1329%            |
| Kentucky\Jessamine    | 3023                        | 2808                                 |                                          | 80116            | 3.50%                                          | 3.77%                                           | 0.1323%            |
| Kentucky\Bath         | 4783                        | 4586                                 |                                          | 129057           | 3.55%                                          | 3.71%                                           | 0.1317%            |
| Montana\Big Horn      | 157772                      | 70177                                |                                          | 2899620          | 2.42%                                          | 5.44%                                           | 0.1317%            |
| Texas\Hartley         | 175544                      | 6195                                 |                                          | 910965           | 0.68%                                          | 19.27%                                          | 0.1310%            |
| Colorado\Rio Blanco   | 26605                       | 7340                                 |                                          | 386577           | 1.90%                                          | 6.88%                                           | 0.1307%            |
| Oklahoma\Bryan        | 76736                       | 4071                                 |                                          | 490688           | 0.83%                                          | 15.64%                                          | 0.1297%            |
| Montana\Golden Valley | 27481                       | 21207                                |                                          | 671764           | 3.16%                                          | 4.09%                                           | 0.1291%            |
| Kansas\Chase          | 28199                       | 4674                                 |                                          | 319921           | 1.46%                                          | 8.81%                                           | 0.1288%            |
| Louisiana\Caddo       | 48104                       | 205                                  | 407                                      | 151215           | 0.40%                                          | 31.81%                                          | 0.1287%            |
| Missouri\Johnson      | 96603                       | 1923                                 | 465                                      | 424446           | 0.56%                                          | 22.76%                                          | 0.1281%            |
| Ohio\Monroe           | 2399                        | 4559                                 | 701                                      | 99306            | 5.30%                                          | 2.42%                                           | 0.1280%            |
| Virginia\Washington   | 12925                       | 3397                                 | 514                                      | 198850           | 1.97%                                          | 6.50%                                           | 0.1278%            |
| Kentucky\Pulaski      | 16876                       | 3609                                 | 426                                      | 231781           | 1.74%                                          | 7.28%                                           | 0.1268%            |
| Missouri\Newton       | 39780                       | 1522                                 | 398                                      | 245892           | 0.78%                                          | 16.18%                                          | 0.1263%            |
| West Virginia\Mason   | 8938                        | 2041                                 | 421                                      | 132227           | 1.86%                                          | 6.76%                                           | 0.1259%            |
| Montana\Sweet Grass   | 21518                       | 38484                                |                                          | 812759           | 4.73%                                          | 2.65%                                           | 0.1254%            |
| Colorado\Garfield     | 5899                        | 23802                                |                                          | 335331           | 7.10%                                          | 1.76%                                           | 0.1249%            |
| Ohio\Hocking          | 4179                        | 526                                  |                                          | 41992            | 1.25%                                          | 9.95%                                           | 0.1247%            |
| Missouri\Vernon       | 95640                       | 2583                                 | 107                                      | 455844           | 0.59%                                          | 20.98%                                          | 0.1238%            |
| Virginia\Spotsylvania | 5463                        | 475                                  | 139                                      | 52230            | 1.18%                                          | 10.46%                                          | 0.1230%            |
| Kentucky\Franklin     | 4241                        | 1686                                 |                                          | 76306            | 2.21%                                          | 5.56%                                           | 0.1228%            |
| Michigan\Roscommon    | 35                          | 791                                  |                                          | 4759             | 16.62%                                         | 0.74%                                           | 0.1222%            |
| Kentucky\Clinton      | 8284                        | 1210                                 |                                          | 91097            | 1.33%                                          | 9.09%                                           | 0.1208%            |
| Missouri\Morgan       | 23677                       | 1873                                 | 521                                      | 216641           | 1.11%                                          | 10.93%                                          | 0.1208%            |
| Maryland\Wicomico     | 31941                       | 323                                  |                                          | 92852            | 0.35%                                          | 34.40%                                          | 0.1197%            |
| New Mexico\Curry      | 112669                      | 7532                                 | 750                                      | 887491           | 0.93%                                          | 12.70%                                          | 0.1185%            |
| Illinois\Wabash       | 87383                       | 176                                  |                                          | 114361           | 0.15%                                          | 76.41%                                          | 0.1176%            |
| Kentucky\McLean       | 79557                       | 258                                  | 49                                       | 144193           | 0.21%                                          | 55.17%                                          | 0.1175%            |
| Virginia\Rockbridge   | 9431                        | 1968                                 | 400                                      | 138315           | 1.71%                                          | 6.82%                                           | 0.1167%            |
| Kentucky\Webster      | 71164                       | 393                                  |                                          | 154999           | 0.25%                                          | 45.91%                                          | 0.1164%            |
| Missouri\Stoddard     | 255280                      | 963                                  |                                          | 461275           | 0.21%                                          | 55.34%                                          | 0.1155%            |

| County                   | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|--------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Kentucky\Calloway        | 66782                       | 429                                  |                                          | 157761           | 0.27%                                          | 42.33%                                          | 0.1151%            |
| Tennessee\Sullivan       | 6421                        | 1171                                 | 35                                       | 82104            | 1.47%                                          | 7.82%                                           | 0.1149%            |
| Montana\Carter           | 48162                       | 68447                                |                                          | 1698363          | 4.03%                                          | 2.84%                                           | 0.1143%            |
| Kansas\Wyandotte         | 7849                        | 47                                   |                                          | 18107            | 0.26%                                          | 43.35%                                          | 0.1125%            |
| Illinois\Gallatin        | 155333                      | 248                                  |                                          | 185753           | 0.13%                                          | 83.62%                                          | 0.1116%            |
| California\Sierra        | 869                         | 1064                                 |                                          | 28782            | 3.70%                                          | 3.02%                                           | 0.1116%            |
| Oregon\Jefferson         | 35997                       | 15175                                | 397                                      | 708974           | 2.20%                                          | 5.08%                                           | 0.1115%            |
| Montana\Madison          | 51727                       | 47830                                | 832                                      | 1506824          | 3.23%                                          | 3.43%                                           | 0.1109%            |
| New York\Suffolk         | 10727                       | 122                                  |                                          | 34404            | 0.35%                                          | 31.18%                                          | 0.1106%            |
| Kentucky\Metcalfe        | 7731                        | 3193                                 |                                          | 149491           | 2.14%                                          | 5.17%                                           | 0.1105%            |
| North Carolina\Davidson  | 18395                       | 501                                  |                                          | 91475            | 0.55%                                          | 20.11%                                          | 0.1101%            |
| Colorado\Baca            | 231566                      | 8015                                 |                                          | 1300876          | 0.62%                                          | 17.80%                                          | 0.1097%            |
| Missouri\Polk            | 22875                       | 4680                                 | 1141                                     | 350293           | 1.66%                                          | 6.53%                                           | 0.1085%            |
| Missouri\Barry           | 31484                       | 2294                                 | 584                                      | 289626           | 0.99%                                          | 10.87%                                          | 0.1080%            |
| Oklahoma\Muskogee        | 86971                       | 1735                                 |                                          | 374372           | 0.46%                                          | 23.23%                                          | 0.1077%            |
| Kansas\Kiowa             | 91890                       | 2252                                 |                                          | 440473           | 0.51%                                          | 20.86%                                          | 0.1067%            |
| Oregon\Linn              | 160511                      | 829                                  | 110                                      | 376483           | 0.25%                                          | 42.63%                                          | 0.1063%            |
| North Carolina\Burke     | 6041                        | 148                                  |                                          | 29068            | 0.51%                                          | 20.78%                                          | 0.1058%            |
| Virginia\Pulaski         | 4739                        | 936                                  | 325                                      | 75457            | 1.67%                                          | 6.28%                                           | 0.1050%            |
| Kentucky\Taylor          | 12646                       | 1031                                 | 135                                      | 118712           | 0.98%                                          | 10.65%                                          | 0.1046%            |
| Oklahoma\Tulsa           | 17690                       | 1016                                 |                                          | 131154           | 0.77%                                          | 13.49%                                          | 0.1045%            |
| Arkansas\Benton          | 58740                       | 1058                                 | 94                                       | 254608           | 0.45%                                          | 23.07%                                          | 0.1044%            |
| Massachusetts\Worcester  | 5176                        | 1753                                 | 504                                      | 106357           | 2.12%                                          | 4.87%                                           | 0.1033%            |
| Missouri\Cole            | 19373                       | 1539                                 | 199                                      | 180840           | 0.96%                                          | 10.71%                                          | 0.1030%            |
| Nebraska\Sheridan        | 75805                       | 31224                                | 865                                      | 1540316          | 2.08%                                          | 4.92%                                           | 0.1025%            |
| Wyoming\Platte           | 57528                       | 30497                                |                                          | 1308165          | 2.33%                                          | 4.40%                                           | 0.1025%            |
| Maine\Somerset           | 5896                        | 664                                  | 1492                                     | 111371           | 1.94%                                          | 5.29%                                           | 0.1025%            |
| Missouri\Webster         | 10322                       | 5682                                 | 1618                                     | 271206           | 2.69%                                          | 3.81%                                           | 0.1024%            |
| New Hampshire\Rockingham | 1128                        | 790                                  | 221                                      | 33570            | 3.01%                                          | 3.36%                                           | 0.1012%            |
| California\Ventura       | 67367                       | 1001                                 |                                          | 259055           | 0.39%                                          | 26.00%                                          | 0.1005%            |
| North Carolina\Rowan     | 38818                       | 346                                  |                                          | 115942           | 0.30%                                          | 33.48%                                          | 0.0999%            |
| North Carolina\Yadkin    | 26379                       | 418                                  |                                          | 105170           | 0.40%                                          | 25.08%                                          | 0.0997%            |
| Kentucky\Boyle           | 4044                        | 2186                                 |                                          | 94233            | 2.32%                                          | 4.29%                                           | 0.0996%            |
| Kansas\Labette           | 111309                      | 1221                                 |                                          | 371115           | 0.33%                                          | 29.99%                                          | 0.0987%            |
| New Hampshire\Merrimack  | 2824                        | 895                                  | 559                                      | 64642            | 2.25%                                          | 4.37%                                           | 0.0983%            |
| Kentucky\Grayson         | 18572                       | 2475                                 |                                          | 216492           | 1.14%                                          | 8.58%                                           | 0.0981%            |
| Oklahoma\Payne           | 48621                       | 2560                                 |                                          | 356765           | 0.72%                                          | 13.63%                                          | 0.0978%            |
| Louisiana\Washington     | 12089                       | 702                                  | 66                                       | 97687            | 0.79%                                          | 12.38%                                          | 0.0973%            |
| Virginia\Carroll         | 5829                        | 1886                                 | 649                                      | 123678           | 2.05%                                          | 4.71%                                           | 0.0966%            |
| Arizona\Cochise          | 33332                       | 19621                                |                                          | 824226           | 2.38%                                          | 4.04%                                           | 0.0963%            |
| Oregon\Tillamook         | 3379                        | 326                                  | 80                                       | 37780            | 1.07%                                          | 8.94%                                           | 0.0961%            |
| Michigan\Iron            | 792                         | 932                                  |                                          | 27731            | 3.36%                                          | 2.86%                                           | 0.0960%            |
| Oklahoma\Texas           | 210802                      | 6611                                 |                                          | 1205978          | 0.55%                                          | 17.48%                                          | 0.0958%            |



| County                     | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|----------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Oklahoma\Pawnee            | 50694                       | 1667                                 |                                          | 297621           | 0.56%                                          | 17.03%                                          | 0.0954%            |
| North Carolina\Mecklenburg | 3754                        | 93                                   |                                          | 19135            | 0.49%                                          | 19.62%                                          | 0.0953%            |
| Ohio\Jackson               | 3687                        | 1150                                 | 185                                      | 71869            | 1.86%                                          | 5.13%                                           | 0.0953%            |
| Virginia\King and Queen    | 25827                       | 104                                  |                                          | 53125            | 0.20%                                          | 48.62%                                          | 0.0952%            |
| Indiana\Perry              | 15702                       | 270                                  | 30                                       | 70409            | 0.43%                                          | 22.30%                                          | 0.0950%            |
| Kansas\Johnson             | 18447                       | 423                                  | 247                                      | 114202           | 0.59%                                          | 16.15%                                          | 0.0948%            |
| Arkansas\Perry             | 13651                       | 366                                  |                                          | 72681            | 0.50%                                          | 18.78%                                          | 0.0946%            |
| Missouri\Dunklin           | 238702                      | 410                                  |                                          | 325095           | 0.13%                                          | 73.43%                                          | 0.0926%            |
| Alabama\DeKalb             | 60246                       | 832                                  | 18                                       | 235246           | 0.36%                                          | 25.61%                                          | 0.0925%            |
| Colorado\La Plata          | 18140                       | 16193                                | 367                                      | 570189           | 2.90%                                          | 3.18%                                           | 0.0924%            |
| Tennessee\Washington       | 8866                        | 1285                                 | 179                                      | 118595           | 1.23%                                          | 7.48%                                           | 0.0923%            |
| Colorado\Moffat            | 32160                       | 19818                                | 150                                      | 836564           | 2.39%                                          | 3.84%                                           | 0.0918%            |
| Oregon\Jackson             | 12765                       | 4127                                 | 115                                      | 244055           | 1.74%                                          | 5.23%                                           | 0.0909%            |
| Kentucky\Allen             | 13750                       | 1816                                 |                                          | 166663           | 1.09%                                          | 8.25%                                           | 0.0899%            |
| Kansas\Bourbon             | 47779                       | 1825                                 | 185                                      | 327534           | 0.61%                                          | 14.59%                                          | 0.0895%            |
| Alabama\Blount             | 26628                       | 719                                  | 50                                       | 151282           | 0.51%                                          | 17.60%                                          | 0.0895%            |
| North Carolina\Iredell     | 23397                       | 730                                  |                                          | 138416           | 0.53%                                          | 16.90%                                          | 0.0891%            |
| Wyoming\Fremont            | 33763                       | 85550                                |                                          | 1800538          | 4.75%                                          | 1.88%                                           | 0.0891%            |
| Kentucky\Breckinridge      | 26537                       | 2375                                 | 138                                      | 274473           | 0.92%                                          | 9.67%                                           | 0.0885%            |
| Arkansas\Lafayette         | 30491                       | 276                                  |                                          | 97628            | 0.28%                                          | 31.23%                                          | 0.0883%            |
| Kentucky\Marshall          | 20939                       | 401                                  |                                          | 97712            | 0.41%                                          | 21.43%                                          | 0.0879%            |
| Kansas\Linn                | 57162                       | 954                                  | 117                                      | 265319           | 0.40%                                          | 21.54%                                          | 0.0870%            |
| Texas\Falls                | 154609                      | 396                                  | 711                                      | 445217           | 0.25%                                          | 34.73%                                          | 0.0863%            |
| Oklahoma\McCurtain         | 47523                       | 2094                                 |                                          | 339615           | 0.62%                                          | 13.99%                                          | 0.0863%            |
| Washington\Thurston        | 6770                        | 307                                  | 515                                      | 80617            | 1.02%                                          | 8.40%                                           | 0.0856%            |
| West Virginia\Ohio         | 695                         | 1167                                 |                                          | 30804            | 3.79%                                          | 2.26%                                           | 0.0855%            |
| New Jersey\Middlesex       | 8315                        | 36                                   |                                          | 18717            | 0.19%                                          | 44.42%                                          | 0.0854%            |
| Virginia\Bland             | 3329                        | 1335                                 | 340                                      | 80786            | 2.07%                                          | 4.12%                                           | 0.0854%            |
| Oklahoma\Cimarron          | 169971                      | 5390                                 |                                          | 1044528          | 0.52%                                          | 16.27%                                          | 0.0840%            |
| Virginia\Warren            | 2958                        | 644                                  |                                          | 47635            | 1.35%                                          | 6.21%                                           | 0.0840%            |
| Alabama\Madison            | 66399                       | 418                                  | 79                                       | 199294           | 0.25%                                          | 33.32%                                          | 0.0831%            |
| South Carolina\Horry       | 46146                       | 482                                  |                                          | 163622           | 0.29%                                          | 28.20%                                          | 0.0831%            |
| Nebraska\Logan             | 24763                       | 4430                                 |                                          | 363453           | 1.22%                                          | 6.81%                                           | 0.0830%            |
| Kentucky\Carlisle          | 51512                       | 147                                  |                                          | 95713            | 0.15%                                          | 53.82%                                          | 0.0827%            |
| Oklahoma\Wagoner           | 64585                       | 878                                  |                                          | 262702           | 0.33%                                          | 24.58%                                          | 0.0822%            |
| Tennessee\Coffee           | 41141                       | 389                                  |                                          | 139945           | 0.28%                                          | 29.40%                                          | 0.0817%            |
| Illinois\Richland          | 162339                      | 206                                  |                                          | 202860           | 0.10%                                          | 80.03%                                          | 0.0813%            |
| Missouri\Sullivan          | 31043                       | 2428                                 | 490                                      | 333986           | 0.87%                                          | 9.29%                                           | 0.0812%            |
| Oklahoma\Choctaw           | 52607                       | 1634                                 |                                          | 326300           | 0.50%                                          | 16.12%                                          | 0.0807%            |
| Oklahoma\Sequoyah          | 38152                       | 968                                  | 170                                      | 231943           | 0.49%                                          | 16.45%                                          | 0.0807%            |
| Kansas\Cherokee            | 146126                      | 579                                  |                                          | 324383           | 0.18%                                          | 45.05%                                          | 0.0804%            |
| Oklahoma\Mayes             | 68107                       | 1157                                 |                                          | 313131           | 0.37%                                          | 21.75%                                          | 0.0804%            |
| Kentucky\Green             | 8309                        | 1944                                 | 101                                      | 145493           | 1.41%                                          | 5.71%                                           | 0.0803%            |
| Virginia\Floyd             | 3991                        | 3051                                 | 276                                      | 128872           | 2.58%                                          | 3.10%                                           | 0.0799%            |
| New Mexico\Eddy            | 27054                       | 35072                                | 1069                                     | 1107912          | 3.26%                                          | 2.44%                                           | 0.0797%            |

| County                  | Acres Using Herbicide | Harvested Acres of Alfalfa Hay | Harvested Acres Alfalfa Haylage | Acres in Farm | % of Farm Acres in Alfalfa Forage (a) | % of Farm Acres Using Herbicide (b) | (c) = (a) x (b) |
|-------------------------|-----------------------|--------------------------------|---------------------------------|---------------|---------------------------------------|-------------------------------------|-----------------|
| Texas\Henderson         | 47697                 | 1481                           | 178                             | 318452        | 0.52%                                 | 14.98%                              | 0.0780%         |
| Kentucky\McCracken      | 24160                 | 183                            |                                 | 75341         | 0.24%                                 | 32.07%                              | 0.0779%         |
| Kentucky\Ohio           | 40262                 | 548                            |                                 | 168602        | 0.33%                                 | 23.88%                              | 0.0776%         |
| Tennessee\Carter        | 4327                  | 196                            | 82                              | 39374         | 0.71%                                 | 10.99%                              | 0.0776%         |
| Oregon\Lane             | 60042                 | 737                            | 41                              | 245531        | 0.32%                                 | 24.45%                              | 0.0775%         |
| Montana\Musselshell     | 37041                 | 26499                          |                                 | 1133030       | 2.34%                                 | 3.27%                               | 0.0765%         |
| Kentucky\Campbell       | 1351                  | 1105                           | 159                             | 47335         | 2.67%                                 | 2.85%                               | 0.0762%         |
| Virginia\Amelia         | 13031                 | 489                            |                                 | 91456         | 0.53%                                 | 14.25%                              | 0.0762%         |
| Oklahoma\Pottawatomie   | 47217                 | 2510                           |                                 | 395065        | 0.64%                                 | 11.95%                              | 0.0759%         |
| Kentucky\Clark          | 5525                  | 2981                           | 74                              | 149201        | 2.05%                                 | 3.70%                               | 0.0758%         |
| Illinois\Lawrence       | 134530                | 212                            |                                 | 194035        | 0.11%                                 | 69.33%                              | 0.0758%         |
| Wyoming\Crook           | 23475                 | 77829                          | 443                             | 1569912       | 4.99%                                 | 1.50%                               | 0.0746%         |
| Minnesota\St. Louis     | 1898                  | 8191                           | 479                             | 148689        | 5.83%                                 | 1.28%                               | 0.0744%         |
| Kentucky\Edmonson       | 7172                  | 968                            |                                 | 96641         | 1.00%                                 | 7.42%                               | 0.0743%         |
| Texas\Moore             | 147607                | 1538                           |                                 | 553348        | 0.28%                                 | 26.68%                              | 0.0741%         |
| Washington\Okanogan     | 44751                 | 23253                          | 790                             | 1205229       | 1.99%                                 | 3.71%                               | 0.0741%         |
| New Hampshire           | 15200                 | 5373                           | 5456                            | 471911        | 2.29%                                 | 3.22%                               | 0.0739%         |
| Montana\Treasure        | 21596                 | 7278                           |                                 | 461790        | 1.58%                                 | 4.68%                               | 0.0737%         |
| Montana\Prairie         | 29243                 | 14352                          | 426                             | 767508        | 1.93%                                 | 3.81%                               | 0.0734%         |
| Nebraska\Garden         | 70933                 | 11324                          |                                 | 1048554       | 1.08%                                 | 6.76%                               | 0.0731%         |
| Missouri\Benton         | 24450                 | 1316                           | 155                             | 222303        | 0.66%                                 | 11.00%                              | 0.0728%         |
| Rhode Island\Washington | 3146                  | 140                            |                                 | 24651         | 0.57%                                 | 12.76%                              | 0.0725%         |
| Washington\Lewis        | 10575                 | 638                            | 548                             | 131554        | 0.90%                                 | 8.04%                               | 0.0725%         |
| Minnesota\Martin        | 337786                | 1771                           |                                 | 910687        | 0.19%                                 | 37.09%                              | 0.0721%         |
| Kentucky\Rockcastle     | 2877                  | 2038                           |                                 | 90435         | 2.25%                                 | 3.18%                               | 0.0717%         |
| Missouri\Osage          | 24531                 | 2007                           | 561                             | 297477        | 0.86%                                 | 8.25%                               | 0.0712%         |
| Kentucky\Owen           | 3318                  | 4980                           | 361                             | 157932        | 3.38%                                 | 2.10%                               | 0.0710%         |
| Virginia\Richmond       | 19656                 | 50                             |                                 | 37359         | 0.13%                                 | 52.61%                              | 0.0704%         |
| Oregon\Gilliam          | 163660                | 2312                           |                                 | 733387        | 0.32%                                 | 22.32%                              | 0.0703%         |
| Montana\Sanders         | 5966                  | 13685                          |                                 | 341913        | 4.00%                                 | 1.74%                               | 0.0698%         |
| North Carolina\Surry    | 21198                 | 426                            |                                 | 114491        | 0.37%                                 | 18.51%                              | 0.0689%         |
| Texas\Lubbock           | 211689                | 864                            |                                 | 515741        | 0.17%                                 | 41.05%                              | 0.0688%         |
| Texas\Hill              | 172372                | 680                            | 414                             | 524907        | 0.21%                                 | 32.84%                              | 0.0684%         |
| Texas\Leon              | 77384                 | 2568                           | 257                             | 569101        | 0.50%                                 | 13.60%                              | 0.0675%         |
| Texas\Washington        | 59088                 | 1299                           |                                 | 338384        | 0.38%                                 | 17.46%                              | 0.0670%         |
| Montana\Granite         | 7054                  | 8720                           |                                 | 302973        | 2.88%                                 | 2.33%                               | 0.0670%         |
| California\Tehama       | 35762                 | 5289                           |                                 | 532206        | 0.99%                                 | 6.72%                               | 0.0668%         |
| Kentucky\Casey          | 6530                  | 3477                           | 274                             | 191609        | 1.96%                                 | 3.41%                               | 0.0667%         |
| Oklahoma\Stephens       | 66212                 | 2222                           |                                 | 469700        | 0.47%                                 | 14.10%                              | 0.0667%         |
| Indiana\Crawford        | 3797                  | 360                            |                                 | 45401         | 0.79%                                 | 8.36%                               | 0.0663%         |
| Idaho\Valley            | 1957                  | 1304                           |                                 | 62044         | 2.10%                                 | 3.15%                               | 0.0663%         |
| New Hampshire\Cheshire  | 1782                  | 531                            | 332                             | 48241         | 1.79%                                 | 3.69%                               | 0.0661%         |
| Kentucky\Montgomery     | 2991                  | 2523                           |                                 | 106957        | 2.36%                                 | 2.80%                               | 0.0660%         |

| County                   | Acres Using Herbicide | Harvested Acres of Alfalfa Hay | Harvested Acres Alfalfa Haylage | Acres in Farm | % of Farm Acres in Alfalfa Forage (a) | % of Farm Acres Using Herbicide (b) | (c) = (a) x (b) |
|--------------------------|-----------------------|--------------------------------|---------------------------------|---------------|---------------------------------------|-------------------------------------|-----------------|
| Michigan\Ontonagon       | 388                   | 920                            | 680                             | 30830         | 5.19%                                 | 1.26%                               | 0.0653%         |
| Oregon\Clatsop           | 1575                  | 185                            |                                 | 21198         | 0.87%                                 | 7.43%                               | 0.0648%         |
| New Hampshire\Grafton    | 2555                  | 999                            | 1537                            | 99964         | 2.54%                                 | 2.56%                               | 0.0648%         |
| Kentucky\Hickman         | 85387                 | 127                            |                                 | 129752        | 0.10%                                 | 65.81%                              | 0.0644%         |
| Virginia\Greene          | 1085                  | 570                            |                                 | 31013         | 1.84%                                 | 3.50%                               | 0.0643%         |
| Kentucky\Monroe          | 11714                 | 1499                           | 189                             | 175766        | 0.96%                                 | 6.66%                               | 0.0640%         |
| Oklahoma\Le Flore        | 62691                 | 1973                           | 241                             | 466406        | 0.47%                                 | 13.44%                              | 0.0638%         |
| Kentucky\Adair           | 8929                  | 2448                           | 75                              | 187981        | 1.34%                                 | 4.75%                               | 0.0638%         |
| Kentucky\Wayne           | 15911                 | 815                            |                                 | 142827        | 0.57%                                 | 11.14%                              | 0.0636%         |
| Ohio\Belmont             | 1379                  | 6927                           | 746                             | 129106        | 5.94%                                 | 1.07%                               | 0.0635%         |
| Missouri\Scott           | 140154                | 236                            |                                 | 228379        | 0.10%                                 | 61.37%                              | 0.0634%         |
| Tennessee\Hamblen        | 8588                  | 355                            |                                 | 69383         | 0.51%                                 | 12.38%                              | 0.0633%         |
| Texas\Lamar              | 86899                 | 1464                           | 514                             | 521001        | 0.38%                                 | 16.68%                              | 0.0633%         |
| Kentucky\Gallatin        | 779                   | 922                            |                                 | 33816         | 2.73%                                 | 2.30%                               | 0.0628%         |
| New Hampshire\Strafford  | 611                   | 681                            |                                 | 25744         | 2.65%                                 | 2.37%                               | 0.0628%         |
| Tennessee\Jefferson      | 10663                 | 607                            |                                 | 101585        | 0.60%                                 | 10.50%                              | 0.0627%         |
| Nebraska\Sioux           | 34770                 | 30061                          |                                 | 1292053       | 2.33%                                 | 2.69%                               | 0.0626%         |
| Oklahoma\Lincoln         | 79117                 | 1509                           | 371                             | 487858        | 0.39%                                 | 16.22%                              | 0.0625%         |
| New Hampshire\Coos       | 2007                  | 182                            | 623                             | 50895         | 1.58%                                 | 3.94%                               | 0.0624%         |
| Kentucky\Garrard         | 1818                  | 4907                           | 160                             | 121673        | 4.16%                                 | 1.49%                               | 0.0622%         |
| North Carolina\Wake      | 24281                 | 184                            |                                 | 84956         | 0.22%                                 | 28.58%                              | 0.0619%         |
| Virginia\Giles           | 4530                  | 584                            |                                 | 65487         | 0.89%                                 | 6.92%                               | 0.0617%         |
| Texas\Foard              | 36880                 | 2359                           |                                 | 375790        | 0.63%                                 | 9.81%                               | 0.0616%         |
| North Carolina\Buncombe  | 4376                  | 593                            | 138                             | 72087         | 1.01%                                 | 6.07%                               | 0.0616%         |
| North Carolina\Alexander | 10201                 | 181                            |                                 | 54959         | 0.33%                                 | 18.56%                              | 0.0611%         |
| Virginia\Grayson         | 6930                  | 978                            | 665                             | 136752        | 1.20%                                 | 5.07%                               | 0.0609%         |
| Kentucky\Jackson         | 3262                  | 1273                           |                                 | 82614         | 1.54%                                 | 3.95%                               | 0.0608%         |
| Arkansas\Washington      | 44611                 | 1442                           | 16                              | 327225        | 0.45%                                 | 13.63%                              | 0.0607%         |
| Montana\Meagher          | 21538                 | 18583                          |                                 | 812412        | 2.29%                                 | 2.65%                               | 0.0606%         |
| Missouri\Bollinger       | 31323                 | 580                            | 255                             | 207881        | 0.40%                                 | 15.07%                              | 0.0605%         |
| Texas\Hood               | 25994                 | 951                            | 32                              | 205672        | 0.48%                                 | 12.64%                              | 0.0604%         |
| Missouri\Howell          | 18392                 | 4578                           | 204                             | 385188        | 1.24%                                 | 4.77%                               | 0.0593%         |
| Maryland\Calvert         | 7363                  | 56                             |                                 | 26443         | 0.21%                                 | 27.84%                              | 0.0590%         |
| Missouri\Hickory         | 8117                  | 1564                           |                                 | 146764        | 1.07%                                 | 5.53%                               | 0.0589%         |
| Nevada\Eureka            | 16186                 | 22340                          |                                 | 783440        | 2.85%                                 | 2.07%                               | 0.0589%         |
| Maryland\Allegany        | 957                   | 821                            |                                 | 36643         | 2.24%                                 | 2.61%                               | 0.0585%         |
| Oklahoma\Ottawa          | 48556                 | 680                            |                                 | 237986        | 0.29%                                 | 20.40%                              | 0.0583%         |
| Illinois\Hardin          | 3076                  | 227                            |                                 | 34733         | 0.65%                                 | 8.86%                               | 0.0579%         |
| New York\Sullivan        | 1240                  | 500                            | 686                             | 50443         | 2.35%                                 | 2.46%                               | 0.0578%         |
| New Mexico\Roosevelt     | 99766                 | 8435                           | 4492                            | 1494051       | 0.87%                                 | 6.68%                               | 0.0578%         |
| Tennessee\Obion          | 155096                | 236                            |                                 | 251844        | 0.09%                                 | 61.58%                              | 0.0577%         |
| Oklahoma\Dewey           | 60195                 | 3325                           |                                 | 588951        | 0.56%                                 | 10.22%                              | 0.0577%         |
| Nebraska\Loup            | 10418                 | 6958                           |                                 | 354688        | 1.96%                                 | 2.94%                               | 0.0576%         |
| Texas\Denton             | 64395                 | 848                            | 248                             | 350274        | 0.31%                                 | 18.38%                              | 0.0575%         |
| Vermont\Windsor          | 2235                  | 1108                           | 1259                            | 95972         | 2.47%                                 | 2.33%                               | 0.0574%         |

| County                     | Acres Using Herbicide | Harvested Acres of Alfalfa Hay | Harvested Acres Alfalfa Haylage | Acres in Farm | % of Farm Acres in Alfalfa Forage (a) | % of Farm Acres Using Herbicide (b) | (c) = (a) x (b) |
|----------------------------|-----------------------|--------------------------------|---------------------------------|---------------|---------------------------------------|-------------------------------------|-----------------|
| Missouri\Laclede           | 9493                  | 4136                           | 899                             | 288630        | 1.74%                                 | 3.29%                               | 0.0574%         |
| Idaho\Boise                | 738                   | 1471                           |                                 | 43672         | 3.37%                                 | 1.69%                               | 0.0569%         |
| Kentucky\Pendleton         | 2794                  | 2745                           | 504                             | 126368        | 2.57%                                 | 2.21%                               | 0.0568%         |
| Texas\Collin               | 67700                 | 562                            | 148                             | 290831        | 0.24%                                 | 23.28%                              | 0.0568%         |
| Wisconsin\Douglas          | 522                   | 5034                           | 710                             | 72686         | 7.90%                                 | 0.72%                               | 0.0568%         |
| Texas\Bailey               | 99232                 | 1290                           |                                 | 476176        | 0.27%                                 | 20.84%                              | 0.0565%         |
| Wyoming\Sheridan           | 17562                 | 45376                          | 2625                            | 1224625       | 3.92%                                 | 1.43%                               | 0.0562%         |
| Texas\Gray                 | 51181                 | 2846                           |                                 | 509367        | 0.56%                                 | 10.05%                              | 0.0561%         |
| Kentucky\Livingston        | 13700                 | 561                            |                                 | 117011        | 0.48%                                 | 11.71%                              | 0.0561%         |
| Virginia\Russell           | 9690                  | 1170                           | 158                             | 151564        | 0.88%                                 | 6.39%                               | 0.0560%         |
| North Carolina\Stanly      | 39815                 | 153                            |                                 | 104517        | 0.15%                                 | 38.09%                              | 0.0558%         |
| Utah\Tooele                | 5965                  | 5951                           |                                 | 252848        | 2.35%                                 | 2.36%                               | 0.0555%         |
| Maine\Lincoln              | 595                   | 755                            | 82                              | 29999         | 2.79%                                 | 1.98%                               | 0.0553%         |
| California\San Bernardino  | 13868                 | 9345                           | 1169                            | 514234        | 2.04%                                 | 2.70%                               | 0.0551%         |
| New Hampshire\Hillsborough | 1310                  | 517                            | 544                             | 50238         | 2.11%                                 | 2.61%                               | 0.0551%         |
| Montana\Powell             | 14053                 | 17602                          |                                 | 670354        | 2.63%                                 | 2.10%                               | 0.0550%         |
| Kentucky\Robertson         | 1301                  | 1061                           | 54                              | 51468         | 2.17%                                 | 2.53%                               | 0.0548%         |
| Tennessee\Greene           | 16371                 | 1588                           | 169                             | 229204        | 0.77%                                 | 7.14%                               | 0.0548%         |
| Virginia\Lee               | 5670                  | 1229                           | 105                             | 117776        | 1.13%                                 | 4.81%                               | 0.0545%         |
| North Carolina\Catawba     | 18898                 | 149                            |                                 | 71906         | 0.21%                                 | 26.28%                              | 0.0545%         |
| Florida\Okaloosa           | 10206                 | 231                            |                                 | 65874         | 0.35%                                 | 15.49%                              | 0.0543%         |
| Maine\Oxford               | 3402                  | 492                            | 261                             | 68719         | 1.10%                                 | 4.95%                               | 0.0542%         |
| Virginia\Tazewell          | 4839                  | 1783                           | 859                             | 153677        | 1.72%                                 | 3.15%                               | 0.0541%         |
| Kentucky\Crittenden        | 21317                 | 648                            |                                 | 160116        | 0.40%                                 | 13.31%                              | 0.0539%         |
| Oregon\Josephine           | 1649                  | 463                            |                                 | 37706         | 1.23%                                 | 4.37%                               | 0.0537%         |
| West Virginia\Preston      | 3966                  | 2124                           | 1000                            | 152276        | 2.05%                                 | 2.60%                               | 0.0534%         |
| Tennessee\Montgomery       | 31159                 | 393                            |                                 | 151461        | 0.26%                                 | 20.57%                              | 0.0534%         |
| West Virginia\Monroe       | 4204                  | 1590                           | 650                             | 132859        | 1.69%                                 | 3.16%                               | 0.0533%         |
| Maine\Waldo                | 2043                  | 570                            | 644                             | 68219         | 1.78%                                 | 2.99%                               | 0.0533%         |
| Illinois\Pope              | 10936                 | 180                            |                                 | 60809         | 0.30%                                 | 17.98%                              | 0.0532%         |
| Kentucky\Muhlenberg        | 25986                 | 406                            |                                 | 140834        | 0.29%                                 | 18.45%                              | 0.0532%         |
| Missouri\Butler            | 128819                | 259                            |                                 | 250653        | 0.10%                                 | 51.39%                              | 0.0531%         |
| Kansas\Logan               | 131184                | 1291                           |                                 | 566569        | 0.23%                                 | 23.15%                              | 0.0528%         |
| Oklahoma\Roger Mills       | 43517                 | 6267                           |                                 | 719356        | 0.87%                                 | 6.05%                               | 0.0527%         |
| Florida\Suwannee           | 19424                 | 755                            |                                 | 167493        | 0.45%                                 | 11.60%                              | 0.0523%         |
| Oklahoma\Nowata            | 65586                 | 996                            |                                 | 354636        | 0.28%                                 | 18.49%                              | 0.0519%         |
| Tennessee\Blount           | 15089                 | 333                            |                                 | 98403         | 0.34%                                 | 15.33%                              | 0.0519%         |
| Wyoming\Laramie            | 65378                 | 22606                          |                                 | 1691648       | 1.34%                                 | 3.86%                               | 0.0516%         |
| Oregon\Columbia            | 4990                  | 345                            |                                 | 57758         | 0.60%                                 | 8.64%                               | 0.0516%         |
| West Virginia\Greenbrier   | 4313                  | 1874                           | 1874                            | 176995        | 2.12%                                 | 2.44%                               | 0.0516%         |
| Missouri\McDonald          | 24571                 | 711                            | 122                             | 199780        | 0.42%                                 | 12.30%                              | 0.0513%         |
| Ohio\Gallia                | 4025                  | 1632                           | 102                             | 116945        | 1.48%                                 | 3.44%                               | 0.0510%         |
| Oklahoma\Harper            | 56775                 | 3421                           |                                 | 616947        | 0.55%                                 | 9.20%                               | 0.0510%         |

| County                   | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|--------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Ohio\Noble               | 1843                        | 1799                                 | 408                                      | 89298            | 2.47%                                          | 2.06%                                           | 0.0510%            |
| Kentucky\Grant           | 1622                        | 3836                                 | 277                                      | 114965           | 3.58%                                          | 1.41%                                           | 0.0505%            |
| Alabama\Colbert          | 36243                       | 231                                  |                                          | 128905           | 0.18%                                          | 28.12%                                          | 0.0504%            |
| Kentucky\Carroll         | 1057                        | 1665                                 | 267                                      | 63708            | 3.03%                                          | 1.66%                                           | 0.0503%            |
| Alabama\Cullman          | 60169                       | 299                                  | 142                                      | 229791           | 0.19%                                          | 26.18%                                          | 0.0503%            |
| Kentucky\Butler          | 22253                       | 683                                  |                                          | 173965           | 0.39%                                          | 12.79%                                          | 0.0502%            |
| Pennsylvania\Wayne       | 1860                        | 1526                                 | 804                                      | 92939            | 2.51%                                          | 2.00%                                           | 0.0502%            |
| Kentucky\Estill          | 1340                        | 1564                                 |                                          | 64780            | 2.41%                                          | 2.07%                                           | 0.0499%            |
| Virginia\Scott           | 6463                        | 1685                                 | 134                                      | 153881           | 1.18%                                          | 4.20%                                           | 0.0496%            |
| Missouri\St. Francois    | 5183                        | 1212                                 |                                          | 112551           | 1.08%                                          | 4.61%                                           | 0.0496%            |
| Maine\York               | 2210                        | 646                                  | 137                                      | 59335            | 1.32%                                          | 3.72%                                           | 0.0492%            |
| Oklahoma\Carter          | 59527                       | 1339                                 |                                          | 402831           | 0.33%                                          | 14.78%                                          | 0.0491%            |
| Virginia\Nelson          | 3309                        | 791                                  |                                          | 73149            | 1.08%                                          | 4.52%                                           | 0.0489%            |
| Vermont\Lamoille         | 1493                        | 674                                  | 133                                      | 49749            | 1.62%                                          | 3.00%                                           | 0.0487%            |
| Maine\Cumberland         | 901                         | 931                                  | 510                                      | 51727            | 2.79%                                          | 1.74%                                           | 0.0485%            |
| Virginia\Patrick         | 4531                        | 676                                  |                                          | 80027            | 0.84%                                          | 5.66%                                           | 0.0478%            |
| Montana\Garfield         | 88346                       | 30927                                |                                          | 2391958          | 1.29%                                          | 3.69%                                           | 0.0478%            |
| Tennessee\Gibson         | 148070                      | 39                                   | 226                                      | 286769           | 0.09%                                          | 51.63%                                          | 0.0477%            |
| North Carolina\Cleveland | 23136                       | 275                                  |                                          | 115637           | 0.24%                                          | 20.01%                                          | 0.0476%            |
| Washington\Garfield      | 113339                      | 394                                  |                                          | 308212           | 0.13%                                          | 36.77%                                          | 0.0470%            |
| Montana\Powder River     | 18099                       | 68080                                |                                          | 1620068          | 4.20%                                          | 1.12%                                           | 0.0469%            |
| Texas\Delta              | 38672                       | 214                                  |                                          | 132841           | 0.16%                                          | 29.11%                                          | 0.0469%            |
| Missouri\Henry           | 71016                       | 775                                  |                                          | 345019           | 0.22%                                          | 20.58%                                          | 0.0462%            |
| Montana\Beaverhead       | 16533                       | 42828                                |                                          | 1239068          | 3.46%                                          | 1.33%                                           | 0.0461%            |
| Kansas\Wallace           | 111884                      | 760                                  |                                          | 429533           | 0.18%                                          | 26.05%                                          | 0.0461%            |
| Oregon\Crook             | 14851                       | 17975                                |                                          | 761548           | 2.36%                                          | 1.95%                                           | 0.0460%            |
| Alabama\Etowah           | 15816                       | 258                                  |                                          | 94201            | 0.27%                                          | 16.79%                                          | 0.0460%            |
| Tennessee\Lawrence       | 42385                       | 496                                  | 119                                      | 238318           | 0.26%                                          | 17.79%                                          | 0.0459%            |
| South Carolina\Lancaster | 5141                        | 378                                  |                                          | 65210            | 0.58%                                          | 7.88%                                           | 0.0457%            |
| North Carolina\Haywood   | 4408                        | 326                                  |                                          | 56212            | 0.58%                                          | 7.84%                                           | 0.0455%            |
| Arkansas\Craighead       | 232268                      | 222                                  |                                          | 336919           | 0.07%                                          | 68.94%                                          | 0.0454%            |
| Oregon\Wasco             | 91917                       | 4451                                 |                                          | 949462           | 0.47%                                          | 9.68%                                           | 0.0454%            |
| Texas\Childress          | 41113                       | 1756                                 |                                          | 399383           | 0.44%                                          | 10.29%                                          | 0.0453%            |
| North Carolina\Cabarrus  | 21219                       | 95                                   |                                          | 66780            | 0.14%                                          | 31.77%                                          | 0.0452%            |
| Oklahoma\Cotton          | 74217                       | 813                                  |                                          | 366651           | 0.22%                                          | 20.24%                                          | 0.0449%            |
| North Carolina\Watauga   | 3262                        | 286                                  |                                          | 45782            | 0.62%                                          | 7.13%                                           | 0.0445%            |
| South Carolina\Newberry  | 13781                       | 328                                  |                                          | 100796           | 0.33%                                          | 13.67%                                          | 0.0445%            |
| Utah\Kane                | 3962                        | 1443                                 |                                          | 113417           | 1.27%                                          | 3.49%                                           | 0.0444%            |
| Kansas\Lane              | 115069                      | 613                                  |                                          | 401399           | 0.15%                                          | 28.67%                                          | 0.0438%            |
| Virginia\King William    | 19258                       | 48                                   |                                          | 46065            | 0.10%                                          | 41.81%                                          | 0.0436%            |
| Missouri\St. Clair       | 31908                       | 740                                  | 218                                      | 265009           | 0.36%                                          | 12.04%                                          | 0.0435%            |
| Utah\Morgan              | 4122                        | 9406                                 | 115                                      | 301095           | 3.16%                                          | 1.37%                                           | 0.0433%            |
| Georgia\Gordon           | 16031                       | 165                                  |                                          | 79128            | 0.21%                                          | 20.26%                                          | 0.0422%            |
| North Carolina\McDowell  | 2488                        | 89                                   |                                          | 22968            | 0.39%                                          | 10.83%                                          | 0.0420%            |
| Kansas\Greenwood         | 61298                       | 2536                                 |                                          | 608891           | 0.42%                                          | 10.07%                                          | 0.0419%            |

| County                     | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|----------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Tennessee\Hawkins          | 8679                        | 1032                                 | 65                                       | 151042           | 0.73%                                          | 5.75%                                           | 0.0417%            |
| Tennessee\Sumner           | 21259                       | 659                                  |                                          | 183419           | 0.36%                                          | 11.59%                                          | 0.0416%            |
| Oklahoma\Craig             | 81576                       | 1066                                 |                                          | 457292           | 0.23%                                          | 17.84%                                          | 0.0416%            |
| Oklahoma\Creek             | 31281                       | 1853                                 | 39                                       | 377437           | 0.50%                                          | 8.29%                                           | 0.0415%            |
| Tennessee\Cheatham         | 9139                        | 180                                  |                                          | 63122            | 0.29%                                          | 14.48%                                          | 0.0413%            |
| Tennessee\Johnson          | 2073                        | 377                                  |                                          | 43543            | 0.87%                                          | 4.76%                                           | 0.0412%            |
| North Carolina\Alamance    | 13690                       | 231                                  |                                          | 87888            | 0.26%                                          | 15.58%                                          | 0.0409%            |
| Michigan\Chippewa          | 1000                        | 3575                                 | 424                                      | 98967            | 4.04%                                          | 1.01%                                           | 0.0408%            |
| Missouri\Douglas           | 11494                       | 1879                                 | 395                                      | 254283           | 0.89%                                          | 4.52%                                           | 0.0404%            |
| Oklahoma\McIntosh          | 47017                       | 519                                  |                                          | 246730           | 0.21%                                          | 19.06%                                          | 0.0401%            |
| North Carolina\Ashe        | 11349                       | 379                                  | 36                                       | 108452           | 0.38%                                          | 10.46%                                          | 0.0400%            |
| Tennessee\McMinn           | 11126                       | 214                                  | 325                                      | 122502           | 0.44%                                          | 9.08%                                           | 0.0400%            |
| Alabama\Limestone          | 92621                       | 241                                  |                                          | 237188           | 0.10%                                          | 39.05%                                          | 0.0397%            |
| West Virginia\Brooke       | 175                         | 538                                  |                                          | 15408            | 3.49%                                          | 1.14%                                           | 0.0397%            |
| Oklahoma\Ellis             | 41904                       | 4878                                 |                                          | 718058           | 0.68%                                          | 5.84%                                           | 0.0396%            |
| Tennessee\Maury            | 31119                       | 650                                  |                                          | 226404           | 0.29%                                          | 13.74%                                          | 0.0395%            |
| Kentucky\Rowan             | 1683                        | 585                                  |                                          | 49963            | 1.17%                                          | 3.37%                                           | 0.0394%            |
| Missouri\Dallas            | 8865                        | 1607                                 | 603                                      | 222900           | 0.99%                                          | 3.98%                                           | 0.0394%            |
| Texas\Randall              | 90649                       | 1223                                 | 205                                      | 575076           | 0.25%                                          | 15.76%                                          | 0.0391%            |
| Texas\Marion               | 3777                        | 185                                  |                                          | 42270            | 0.44%                                          | 8.94%                                           | 0.0391%            |
| Massachusetts\Barnstable   | 880                         | 12                                   |                                          | 5233             | 0.23%                                          | 16.82%                                          | 0.0386%            |
| Kentucky\Graves            | 105860                      | 280                                  |                                          | 277881           | 0.10%                                          | 38.10%                                          | 0.0384%            |
| Tennessee\Grainger         | 7542                        | 402                                  | 27                                       | 91862            | 0.47%                                          | 8.21%                                           | 0.0383%            |
| Kansas\Chautauqua          | 25270                       | 1358                                 | 74                                       | 308232           | 0.46%                                          | 8.20%                                           | 0.0381%            |
| Louisiana\East Baton Rouge | 8941                        | 220                                  |                                          | 72165            | 0.30%                                          | 12.39%                                          | 0.0378%            |
| North Carolina\Montgomery  | 4934                        | 138                                  |                                          | 42523            | 0.32%                                          | 11.60%                                          | 0.0377%            |
| Missouri\Wright            | 7075                        | 3647                                 | 653                                      | 284271           | 1.51%                                          | 2.49%                                           | 0.0376%            |
| Texas\Rockwall             | 5254                        | 100                                  |                                          | 37433            | 0.27%                                          | 14.04%                                          | 0.0375%            |
| Nebraska\Brown             | 50015                       | 3281                                 |                                          | 661606           | 0.50%                                          | 7.56%                                           | 0.0375%            |
| Washington\Douglas         | 179347                      | 1624                                 |                                          | 883094           | 0.18%                                          | 20.31%                                          | 0.0373%            |
| North Carolina\Guilford    | 21918                       | 157                                  |                                          | 96519            | 0.16%                                          | 22.71%                                          | 0.0369%            |
| Oklahoma\Hughes            | 61617                       | 1166                                 |                                          | 441040           | 0.26%                                          | 13.97%                                          | 0.0369%            |
| Colorado\San Miguel        | 2614                        | 3181                                 |                                          | 150947           | 2.11%                                          | 1.73%                                           | 0.0365%            |
| Washington\Asotin          | 40446                       | 673                                  |                                          | 273860           | 0.25%                                          | 14.77%                                          | 0.0363%            |
| Texas\Smith                | 41914                       | 610                                  | 180                                      | 302359           | 0.26%                                          | 13.86%                                          | 0.0362%            |
| Missouri\Texas             | 20107                       | 2271                                 |                                          | 355194           | 0.64%                                          | 5.66%                                           | 0.0362%            |
| Tennessee\Henry            | 62904                       | 215                                  |                                          | 193416           | 0.11%                                          | 32.52%                                          | 0.0362%            |
| Utah\Carbon                | 2857                        | 5786                                 | 86                                       | 215557           | 2.72%                                          | 1.33%                                           | 0.0361%            |
| Colorado\Lincoln           | 205370                      | 3432                                 |                                          | 1400054          | 0.25%                                          | 14.67%                                          | 0.0360%            |
| Missouri\Crawford          | 9455                        | 1225                                 | 98                                       | 186999           | 0.71%                                          | 5.06%                                           | 0.0358%            |
| Tennessee\Marshall         | 11771                       | 652                                  | 44                                       | 151583           | 0.46%                                          | 7.77%                                           | 0.0357%            |
| Tennessee\Franklin         | 39163                       | 189                                  |                                          | 144252           | 0.13%                                          | 27.15%                                          | 0.0356%            |
| Texas\Williamson           | 169472                      | 612                                  |                                          | 541618           | 0.11%                                          | 31.29%                                          | 0.0354%            |

| County                    | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|---------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Louisiana\Rapides         | 67047                       | 165                                  |                                          | 177300           | 0.09%                                          | 37.82%                                          | 0.0352%            |
| Virginia\Louisa           | 5732                        | 377                                  |                                          | 78512            | 0.48%                                          | 7.30%                                           | 0.0351%            |
| Oregon\Lincoln            | 2616                        | 130                                  |                                          | 31179            | 0.42%                                          | 8.39%                                           | 0.0350%            |
| Montana\Custer            | 37996                       | 41624                                |                                          | 2127013          | 1.96%                                          | 1.79%                                           | 0.0350%            |
| South Carolina\York       | 10039                       | 536                                  |                                          | 124176           | 0.43%                                          | 8.08%                                           | 0.0349%            |
| Virginia\Dinwiddie        | 22315                       | 97                                   |                                          | 78840            | 0.12%                                          | 28.30%                                          | 0.0348%            |
| Tennessee\Rhea            | 4325                        | 183                                  | 71                                       | 56182            | 0.45%                                          | 7.70%                                           | 0.0348%            |
| North Carolina\Lincoln    | 18231                       | 67                                   |                                          | 59360            | 0.11%                                          | 30.71%                                          | 0.0347%            |
| Oklahoma\Seminole         | 25602                       | 850                                  |                                          | 250751           | 0.34%                                          | 10.21%                                          | 0.0346%            |
| Texas\Carson              | 135961                      | 735                                  |                                          | 537445           | 0.14%                                          | 25.30%                                          | 0.0346%            |
| Alabama\Lauderdale        | 39161                       | 390                                  | 65                                       | 227692           | 0.20%                                          | 17.20%                                          | 0.0344%            |
| Texas\Grayson             | 73242                       | 503                                  | 245                                      | 400414           | 0.19%                                          | 18.29%                                          | 0.0342%            |
| Kentucky\Kenton           | 400                         | 1419                                 | 124                                      | 42544            | 3.63%                                          | 0.94%                                           | 0.0341%            |
| Kentucky\Anderson         | 1535                        | 1610                                 | 94                                       | 87617            | 1.94%                                          | 1.75%                                           | 0.0341%            |
| California\Sonoma         | 50199                       | 925                                  | 981                                      | 530895           | 0.36%                                          | 9.46%                                           | 0.0339%            |
| Tennessee\Weakley         | 123759                      | 179                                  |                                          | 255550           | 0.07%                                          | 48.43%                                          | 0.0339%            |
| Texas\Hardeman            | 52735                       | 874                                  |                                          | 370113           | 0.24%                                          | 14.25%                                          | 0.0336%            |
| Texas\Lee                 | 63046                       | 419                                  | 145                                      | 325643           | 0.17%                                          | 19.36%                                          | 0.0335%            |
| Oklahoma\Beaver           | 112639                      | 3786                                 |                                          | 1128871          | 0.34%                                          | 9.98%                                           | 0.0335%            |
| Missouri\Gasconade        | 19980                       | 755                                  |                                          | 212641           | 0.36%                                          | 9.40%                                           | 0.0334%            |
| Tennessee\Lauderdale      | 84901                       | 145                                  |                                          | 192232           | 0.08%                                          | 44.17%                                          | 0.0333%            |
| Kentucky\Madison          | 4756                        | 3334                                 |                                          | 218194           | 1.53%                                          | 2.18%                                           | 0.0333%            |
| Texas\Limestone           | 79380                       | 1072                                 |                                          | 505846           | 0.21%                                          | 15.69%                                          | 0.0333%            |
| Tennessee\Claiborne       | 9277                        | 484                                  | 72                                       | 124757           | 0.45%                                          | 7.44%                                           | 0.0331%            |
| Missouri\Oregon           | 14007                       | 1351                                 |                                          | 239390           | 0.56%                                          | 5.85%                                           | 0.0330%            |
| Texas\Milam               | 163378                      | 408                                  | 174                                      | 538678           | 0.11%                                          | 30.33%                                          | 0.0328%            |
| Virginia\Bedford          | 7548                        | 1806                                 | 147                                      | 212237           | 0.92%                                          | 3.56%                                           | 0.0327%            |
| Virginia\Cumberland       | 2685                        | 172                                  | 220                                      | 56817            | 0.69%                                          | 4.73%                                           | 0.0326%            |
| North Carolina\Rutherford | 5262                        | 268                                  |                                          | 65898            | 0.41%                                          | 7.99%                                           | 0.0325%            |
| Texas\Dallam              | 184494                      | 1538                                 |                                          | 936886           | 0.16%                                          | 19.69%                                          | 0.0323%            |
| Nebraska\Rock             | 49433                       | 2605                                 |                                          | 631940           | 0.41%                                          | 7.82%                                           | 0.0322%            |
| Texas\Cherokee            | 45134                       | 535                                  | 83                                       | 294383           | 0.21%                                          | 15.33%                                          | 0.0322%            |
| Pennsylvania\Greene       | 2065                        | 3170                                 | 339                                      | 150203           | 2.34%                                          | 1.37%                                           | 0.0321%            |
| Oklahoma\Rogers           | 61796                       | 606                                  | 107                                      | 371349           | 0.19%                                          | 16.64%                                          | 0.0320%            |
| Alabama\Morgan            | 32465                       | 255                                  |                                          | 161531           | 0.16%                                          | 20.10%                                          | 0.0317%            |
| Arkansas\Scott            | 8170                        | 360                                  |                                          | 96465            | 0.37%                                          | 8.47%                                           | 0.0316%            |
| Tennessee\Shelby          | 43316                       | 62                                   |                                          | 92299            | 0.07%                                          | 46.93%                                          | 0.0315%            |
| West Virginia\Morgan      | 735                         | 215                                  |                                          | 22440            | 0.96%                                          | 3.28%                                           | 0.0314%            |
| Texas\Fannin              | 69271                       | 919                                  | 84                                       | 473853           | 0.21%                                          | 14.62%                                          | 0.0309%            |
| Virginia\Powhatan         | 2442                        | 112                                  |                                          | 29792            | 0.38%                                          | 8.20%                                           | 0.0308%            |
| Texas\Martin              | 127741                      | 505                                  |                                          | 457990           | 0.11%                                          | 27.89%                                          | 0.0308%            |
| Texas\Ellis               | 101110                      | 575                                  | 21                                       | 442656           | 0.13%                                          | 22.84%                                          | 0.0308%            |
| North Carolina\Harnett    | 47396                       | 81                                   |                                          | 111770           | 0.07%                                          | 42.40%                                          | 0.0307%            |
| Missouri\Miller           | 13676                       | 1352                                 |                                          | 245500           | 0.55%                                          | 5.57%                                           | 0.0307%            |
| Tennessee\Dyer            | 114784                      | 151                                  |                                          | 238614           | 0.06%                                          | 48.10%                                          | 0.0304%            |

| County                    | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|---------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| South Dakota\Custer       | 12896                       | 8523                                 |                                          | 601129           | 1.42%                                          | 2.15%                                           | 0.0304%            |
| South Carolina\Lexington  | 24082                       | 103                                  |                                          | 90324            | 0.11%                                          | 26.66%                                          | 0.0304%            |
| North Carolina\Rockingham | 15280                       | 272                                  |                                          | 117113           | 0.23%                                          | 13.05%                                          | 0.0303%            |
| Texas\Hidalgo             | 164466                      | 962                                  |                                          | 722582           | 0.13%                                          | 22.76%                                          | 0.0303%            |
| North Carolina\Davie      | 11638                       | 127                                  |                                          | 69872            | 0.18%                                          | 16.66%                                          | 0.0303%            |
| California\Shasta         | 9333                        | 4894                                 | 36                                       | 390812           | 1.26%                                          | 2.39%                                           | 0.0301%            |
| California\Amador         | 4956                        | 1613                                 |                                          | 163482           | 0.99%                                          | 3.03%                                           | 0.0299%            |
| Oklahoma\Woodward         | 63660                       | 2879                                 |                                          | 783200           | 0.37%                                          | 8.13%                                           | 0.0299%            |
| Virginia\Halifax          | 8932                        | 1167                                 | 82                                       | 193683           | 0.64%                                          | 4.61%                                           | 0.0297%            |
| Arkansas\Lincoln          | 93178                       | 110                                  |                                          | 186024           | 0.06%                                          | 50.09%                                          | 0.0296%            |
| Oregon\Douglas            | 24126                       | 1928                                 |                                          | 396984           | 0.49%                                          | 6.08%                                           | 0.0295%            |
| West Virginia             | 108454                      | 28465                                | 8734                                     | 3697606          | 1.01%                                          | 2.93%                                           | 0.0295%            |
| Tennessee\Tipton          | 82632                       | 103                                  |                                          | 170182           | 0.06%                                          | 48.56%                                          | 0.0294%            |
| Ohio\Lawrence             | 1914                        | 480                                  | 175                                      | 65740            | 1.00%                                          | 2.91%                                           | 0.0290%            |
| Tennessee\Putnam          | 11277                       | 276                                  |                                          | 103679           | 0.27%                                          | 10.88%                                          | 0.0290%            |
| Texas\Wise                | 49013                       | 1013                                 | 144                                      | 442753           | 0.26%                                          | 11.07%                                          | 0.0289%            |
| West Virginia\Hardy       | 8176                        | 542                                  | 96                                       | 134357           | 0.47%                                          | 6.09%                                           | 0.0289%            |
| Texas\Camp                | 9401                        | 144                                  |                                          | 68552            | 0.21%                                          | 13.71%                                          | 0.0288%            |
| Kentucky\Lee              | 315                         | 782                                  |                                          | 29419            | 2.66%                                          | 1.07%                                           | 0.0285%            |
| Missouri\Phelps           | 5180                        | 1623                                 | 76                                       | 175849           | 0.97%                                          | 2.95%                                           | 0.0285%            |
| West Virginia\Pendleton   | 5185                        | 1086                                 | 495                                      | 169876           | 0.93%                                          | 3.05%                                           | 0.0284%            |
| Alabama\Lawrence          | 59180                       | 236                                  |                                          | 222401           | 0.11%                                          | 26.61%                                          | 0.0282%            |
| Utah\Duchesne             | 9576                        | 33357                                | 719                                      | 1076470          | 3.17%                                          | 0.89%                                           | 0.0282%            |
| Virginia\Charlotte        | 6031                        | 585                                  | 144                                      | 125531           | 0.58%                                          | 4.80%                                           | 0.0279%            |
| Kentucky\Hopkins          | 52478                       | 11                                   | 124                                      | 159366           | 0.08%                                          | 32.93%                                          | 0.0279%            |
| North Carolina\Graham     | 141                         | 102                                  |                                          | 7182             | 1.42%                                          | 1.96%                                           | 0.0279%            |
| Oklahoma\Delaware         | 52691                       | 352                                  | 149                                      | 308970           | 0.16%                                          | 17.05%                                          | 0.0277%            |
| California\Inyo           | 7160                        | 3273                                 |                                          | 292552           | 1.12%                                          | 2.45%                                           | 0.0274%            |
| Texas\Bell                | 109626                      | 401                                  | 65                                       | 431945           | 0.11%                                          | 25.38%                                          | 0.0274%            |
| Alabama\Marshall          | 36905                       | 162                                  | 15                                       | 154548           | 0.11%                                          | 23.88%                                          | 0.0273%            |
| Kentucky\Laurel           | 2410                        | 841                                  | 349                                      | 102489           | 1.16%                                          | 2.35%                                           | 0.0273%            |
| Texas\Gonzales            | 112984                      | 1032                                 |                                          | 654077           | 0.16%                                          | 17.27%                                          | 0.0273%            |
| New Hampshire\Belknap     | 387                         | 384                                  |                                          | 23378            | 1.64%                                          | 1.66%                                           | 0.0272%            |
| Texas\Burleson            | 72654                       | 487                                  |                                          | 361022           | 0.13%                                          | 20.12%                                          | 0.0271%            |
| Texas\McLennan            | 177453                      | 429                                  |                                          | 529621           | 0.08%                                          | 33.51%                                          | 0.0271%            |
| Montana\Rosebud           | 55733                       | 35367                                |                                          | 2714024          | 1.30%                                          | 2.05%                                           | 0.0268%            |
| Alabama\Calhoun           | 11876                       | 130                                  |                                          | 76201            | 0.17%                                          | 15.59%                                          | 0.0266%            |
| Texas\Van Zandt           | 62383                       | 651                                  | 85                                       | 415983           | 0.18%                                          | 15.00%                                          | 0.0265%            |
| Texas\Collingsworth       | 60048                       | 1160                                 |                                          | 512537           | 0.23%                                          | 11.72%                                          | 0.0265%            |
| North Carolina\Bladen     | 46004                       | 92                                   |                                          | 127171           | 0.07%                                          | 36.17%                                          | 0.0262%            |
| North Carolina\Yancey     | 1643                        | 177                                  |                                          | 33431            | 0.53%                                          | 4.91%                                           | 0.0260%            |
| North Carolina\Randolph   | 22363                       | 251                                  |                                          | 147316           | 0.17%                                          | 15.18%                                          | 0.0259%            |
| Washington\Grays Harbor   | 6366                        | 108                                  | 468                                      | 119267           | 0.48%                                          | 5.34%                                           | 0.0258%            |



| County                   | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|--------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Oregon\Sherman           | 161529                      | 421                                  |                                          | 514004           | 0.08%                                          | 31.43%                                          | 0.0257%            |
| Texas\Floyd              | 188056                      | 535                                  |                                          | 627686           | 0.09%                                          | 29.96%                                          | 0.0255%            |
| Arizona\Mohave           | 18053                       | 10374                                |                                          | 858392           | 1.21%                                          | 2.10%                                           | 0.0254%            |
| Virginia\Chesterfield    | 3431                        | 34                                   |                                          | 21527            | 0.16%                                          | 15.94%                                          | 0.0252%            |
| Colorado\Jefferson       | 1908                        | 1061                                 | 80                                       | 93294            | 1.22%                                          | 2.05%                                           | 0.0250%            |
| North Carolina\Chatham   | 14329                       | 189                                  |                                          | 104171           | 0.18%                                          | 13.76%                                          | 0.0250%            |
| Alabama\Jackson          | 53819                       | 271                                  |                                          | 242850           | 0.11%                                          | 22.16%                                          | 0.0247%            |
| Virginia\Appomattox      | 2733                        | 520                                  |                                          | 75874            | 0.69%                                          | 3.60%                                           | 0.0247%            |
| Virginia\Fluvanna        | 2783                        | 211                                  |                                          | 48883            | 0.43%                                          | 5.69%                                           | 0.0246%            |
| Virginia\Pittsylvania    | 18684                       | 887                                  | 102                                      | 274289           | 0.36%                                          | 6.81%                                           | 0.0246%            |
| Tennessee\Bradley        | 10376                       | 215                                  |                                          | 95602            | 0.22%                                          | 10.85%                                          | 0.0244%            |
| Tennessee\Warren         | 29707                       | 210                                  |                                          | 160583           | 0.13%                                          | 18.50%                                          | 0.0242%            |
| Oregon\Harney            | 11331                       | 45514                                |                                          | 1461508          | 3.11%                                          | 0.78%                                           | 0.0241%            |
| South Dakota\Shannon     | 43706                       | 9094                                 | 660                                      | 1333708          | 0.73%                                          | 3.28%                                           | 0.0240%            |
| Mississippi\Yazoo        | 137515                      | 220                                  |                                          | 355528           | 0.06%                                          | 38.68%                                          | 0.0239%            |
| North Carolina\Wilkes    | 11949                       | 241                                  |                                          | 109970           | 0.22%                                          | 10.87%                                          | 0.0238%            |
| Arkansas\Madison         | 27364                       | 585                                  |                                          | 259540           | 0.23%                                          | 10.54%                                          | 0.0238%            |
| Virginia\Roanoke         | 1312                        | 154                                  |                                          | 29214            | 0.53%                                          | 4.49%                                           | 0.0237%            |
| North Carolina\Caldwell  | 4411                        | 57                                   |                                          | 32593            | 0.17%                                          | 13.53%                                          | 0.0237%            |
| Texas\Upshur             | 19015                       | 310                                  | 178                                      | 198131           | 0.25%                                          | 9.60%                                           | 0.0236%            |
| Virginia\Mecklenburg     | 12500                       | 422                                  | 43                                       | 157317           | 0.30%                                          | 7.95%                                           | 0.0235%            |
| West Virginia\Raleigh    | 1561                        | 283                                  |                                          | 43401            | 0.65%                                          | 3.60%                                           | 0.0235%            |
| Missouri\Wayne           | 7808                        | 337                                  |                                          | 106055           | 0.32%                                          | 7.36%                                           | 0.0234%            |
| New Mexico\Valencia      | 4886                        | 12201                                | 24                                       | 505682           | 2.42%                                          | 0.97%                                           | 0.0234%            |
| Texas\Austin             | 46501                       | 482                                  | 77                                       | 333928           | 0.17%                                          | 13.93%                                          | 0.0233%            |
| Colorado\El Paso         | 11377                       | 7772                                 |                                          | 616418           | 1.26%                                          | 1.85%                                           | 0.0233%            |
| Texas\Franklin           | 18828                       | 220                                  |                                          | 133528           | 0.16%                                          | 14.10%                                          | 0.0232%            |
| Arkansas\Hempstead       | 26057                       | 395                                  |                                          | 210571           | 0.19%                                          | 12.37%                                          | 0.0232%            |
| South Carolina\Pickens   | 3313                        | 184                                  |                                          | 51264            | 0.36%                                          | 6.46%                                           | 0.0232%            |
| Tennessee\Van Buren      | 4886                        | 57                                   |                                          | 34844            | 0.16%                                          | 14.02%                                          | 0.0229%            |
| Nebraska\Blaine          | 11238                       | 3995                                 |                                          | 443257           | 0.90%                                          | 2.54%                                           | 0.0229%            |
| Texas\Brazoria           | 74728                       | 787                                  | 67                                       | 528957           | 0.16%                                          | 14.13%                                          | 0.0228%            |
| Kentucky\Lewis           | 1822                        | 2652                                 | 38                                       | 146761           | 1.83%                                          | 1.24%                                           | 0.0228%            |
| Arkansas\Miller          | 50348                       | 138                                  |                                          | 174931           | 0.08%                                          | 28.78%                                          | 0.0227%            |
| Oklahoma\Osage           | 119464                      | 2902                                 | 250                                      | 1290680          | 0.24%                                          | 9.26%                                           | 0.0226%            |
| Georgia\Morgan           | 11356                       | 170                                  |                                          | 92433            | 0.18%                                          | 12.29%                                          | 0.0226%            |
| Utah\Rich                | 3210                        | 9270                                 |                                          | 363567           | 2.55%                                          | 0.88%                                           | 0.0225%            |
| West Virginia\Pocahontas | 2717                        | 821                                  | 404                                      | 121878           | 1.01%                                          | 2.23%                                           | 0.0224%            |
| Texas\Ochiltree          | 181900                      | 412                                  |                                          | 579476           | 0.07%                                          | 31.39%                                          | 0.0223%            |
| North Carolina\Jackson   | 2643                        | 15                                   |                                          | 13338            | 0.11%                                          | 19.82%                                          | 0.0223%            |
| West Virginia\Summers    | 1450                        | 462                                  | 83                                       | 59628            | 0.91%                                          | 2.43%                                           | 0.0222%            |
| Alabama\Mobile           | 27604                       | 104                                  |                                          | 113653           | 0.09%                                          | 24.29%                                          | 0.0222%            |
| Virginia\Amherst         | 2327                        | 743                                  |                                          | 88430            | 0.84%                                          | 2.63%                                           | 0.0221%            |
| Arkansas\Nevada          | 7830                        | 120                                  |                                          | 65215            | 0.18%                                          | 12.01%                                          | 0.0221%            |
| Tennessee\Cannon         | 20328                       | 148                                  |                                          | 116720           | 0.13%                                          | 17.42%                                          | 0.0221%            |

| County                    | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|---------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| North Carolina\Stokes     | 7097                        | 255                                  |                                          | 91014            | 0.28%                                          | 7.80%                                           | 0.0218%            |
| Virginia\Albemarle        | 6195                        | 881                                  |                                          | 158314           | 0.56%                                          | 3.91%                                           | 0.0218%            |
| South Carolina\Orangeburg | 96609                       | 144                                  | 42                                       | 287524           | 0.06%                                          | 33.60%                                          | 0.0217%            |
| Texas\Caldwell            | 54927                       | 327                                  | 39                                       | 304737           | 0.12%                                          | 18.02%                                          | 0.0216%            |
| South Carolina\Aiken      | 21527                       | 255                                  |                                          | 159312           | 0.16%                                          | 13.51%                                          | 0.0216%            |
| West Virginia\Mineral     | 1017                        | 992                                  | 292                                      | 77957            | 1.65%                                          | 1.30%                                           | 0.0215%            |
| Virginia\Lunenburg        | 3260                        | 137                                  | 317                                      | 83232            | 0.55%                                          | 3.92%                                           | 0.0214%            |
| Tennessee\Williamson      | 18250                       | 305                                  |                                          | 161851           | 0.19%                                          | 11.28%                                          | 0.0212%            |
| Colorado\Archuleta        | 3179                        | 1476                                 |                                          | 149584           | 0.99%                                          | 2.13%                                           | 0.0210%            |
| Alabama\Walker            | 7527                        | 138                                  |                                          | 70382            | 0.20%                                          | 10.69%                                          | 0.0210%            |
| Arkansas\White            | 81932                       | 433                                  |                                          | 411404           | 0.11%                                          | 19.92%                                          | 0.0210%            |
| Arkansas\Carroll          | 24712                       | 496                                  |                                          | 242506           | 0.20%                                          | 10.19%                                          | 0.0208%            |
| Texas\Wharton             | 219675                      | 359                                  |                                          | 615851           | 0.06%                                          | 35.67%                                          | 0.0208%            |
| Washington\Pierce         | 4493                        | 105                                  |                                          | 47677            | 0.22%                                          | 9.42%                                           | 0.0208%            |
| Colorado\Crowley          | 6330                        | 6671                                 |                                          | 451225           | 1.48%                                          | 1.40%                                           | 0.0207%            |
| Virginia\Brunswick        | 8780                        | 177                                  |                                          | 86700            | 0.20%                                          | 10.13%                                          | 0.0207%            |
| Kentucky\Whitley          | 1372                        | 673                                  | 137                                      | 73414            | 1.10%                                          | 1.87%                                           | 0.0206%            |
| Utah\Summit               | 4754                        | 7361                                 | 70                                       | 414928           | 1.79%                                          | 1.15%                                           | 0.0205%            |
| North Carolina\Wayne      | 93975                       | 67                                   |                                          | 175265           | 0.04%                                          | 53.62%                                          | 0.0205%            |
| Arkansas\Crawford         | 16636                       | 174                                  |                                          | 119227           | 0.15%                                          | 13.95%                                          | 0.0204%            |
| Kansas\Wichita            | 174627                      | 314                                  |                                          | 519858           | 0.06%                                          | 33.59%                                          | 0.0203%            |
| Virginia\Buckingham       | 2429                        | 499                                  |                                          | 77293            | 0.65%                                          | 3.14%                                           | 0.0203%            |
| Louisiana\Livingston      | 3040                        | 60                                   |                                          | 29987            | 0.20%                                          | 10.14%                                          | 0.0203%            |
| Texas\Madison             | 50076                       | 302                                  |                                          | 273109           | 0.11%                                          | 18.34%                                          | 0.0203%            |
| Texas\Parker              | 29915                       | 889                                  | 428                                      | 441575           | 0.30%                                          | 6.77%                                           | 0.0202%            |
| Texas\Willacy             | 123392                      | 187                                  |                                          | 338048           | 0.06%                                          | 36.50%                                          | 0.0202%            |
| Tennessee\Monroe          | 9130                        | 189                                  |                                          | 92570            | 0.20%                                          | 9.86%                                           | 0.0201%            |
| Tennessee\Grundy          | 8124                        | 45                                   |                                          | 42668            | 0.11%                                          | 19.04%                                          | 0.0201%            |
| Arkansas\Pope             | 29519                       | 159                                  |                                          | 153693           | 0.10%                                          | 19.21%                                          | 0.0199%            |
| Missouri\Maries           | 7532                        | 1349                                 | 175                                      | 240376           | 0.63%                                          | 3.13%                                           | 0.0199%            |
| Tennessee\Carroll         | 55798                       | 114                                  |                                          | 179703           | 0.06%                                          | 31.05%                                          | 0.0197%            |
| Missouri\Ozark            | 13853                       | 859                                  |                                          | 247815           | 0.35%                                          | 5.59%                                           | 0.0194%            |
| Oklahoma\Cherokee         | 38482                       | 302                                  |                                          | 246421           | 0.12%                                          | 15.62%                                          | 0.0191%            |
| Tennessee\Sevier          | 5038                        | 121                                  |                                          | 56449            | 0.21%                                          | 8.92%                                           | 0.0191%            |
| Kansas\Elk                | 30359                       | 630                                  |                                          | 316707           | 0.20%                                          | 9.59%                                           | 0.0191%            |
| Virginia\Campbell         | 7118                        | 527                                  |                                          | 140359           | 0.38%                                          | 5.07%                                           | 0.0190%            |
| Tennessee\Giles           | 32433                       | 350                                  | 51                                       | 261411           | 0.15%                                          | 12.41%                                          | 0.0190%            |
| Arkansas\Boone            | 30539                       | 365                                  |                                          | 242042           | 0.15%                                          | 12.62%                                          | 0.0190%            |
| Oklahoma\Love             | 39775                       | 328                                  |                                          | 261875           | 0.13%                                          | 15.19%                                          | 0.0190%            |
| Texas\Anderson            | 46327                       | 393                                  | 94                                       | 346142           | 0.14%                                          | 13.38%                                          | 0.0188%            |
| Virginia\Prince Edward    | 3902                        | 326                                  |                                          | 82329            | 0.40%                                          | 4.74%                                           | 0.0188%            |
| North Carolina\Moore      | 12663                       | 95                                   |                                          | 80075            | 0.12%                                          | 15.81%                                          | 0.0188%            |
| Texas\Travis              | 35720                       | 360                                  |                                          | 262481           | 0.14%                                          | 13.61%                                          | 0.0187%            |

| County                     | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|----------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Colorado\Pueblo            | 13165                       | 11185                                | 562                                      | 910566           | 1.29%                                          | 1.45%                                           | 0.0187%            |
| Tennessee\Humphreys        | 15376                       | 126                                  | 42                                       | 118412           | 0.14%                                          | 12.99%                                          | 0.0184%            |
| Tennessee\Loudon           | 10273                       | 106                                  |                                          | 77040            | 0.14%                                          | 13.33%                                          | 0.0183%            |
| Georgia\Greene             | 3578                        | 156                                  |                                          | 55334            | 0.28%                                          | 6.47%                                           | 0.0182%            |
| Mississippi\Lafayette      | 9760                        | 244                                  |                                          | 114378           | 0.21%                                          | 8.53%                                           | 0.0182%            |
| Oklahoma\Washington        | 45889                       | 203                                  |                                          | 226568           | 0.09%                                          | 20.25%                                          | 0.0181%            |
| Florida\Washington         | 5462                        | 178                                  |                                          | 73836            | 0.24%                                          | 7.40%                                           | 0.0178%            |
| Georgia\Franklin           | 16810                       | 70                                   |                                          | 81364            | 0.09%                                          | 20.66%                                          | 0.0178%            |
| North Carolina\Johnston    | 88707                       | 75                                   |                                          | 194090           | 0.04%                                          | 45.70%                                          | 0.0177%            |
| Texas\Fayette              | 91707                       | 396                                  | 220                                      | 565708           | 0.11%                                          | 16.21%                                          | 0.0177%            |
| Arkansas\Clark             | 9798                        | 120                                  |                                          | 81808            | 0.15%                                          | 11.98%                                          | 0.0176%            |
| Mississippi\Pike           | 7958                        | 119                                  |                                          | 73422            | 0.16%                                          | 10.84%                                          | 0.0176%            |
| Texas\Panola               | 19679                       | 298                                  | 124                                      | 217757           | 0.19%                                          | 9.04%                                           | 0.0175%            |
| Mississippi\Panola         | 75997                       | 122                                  | 44                                       | 269806           | 0.06%                                          | 28.17%                                          | 0.0173%            |
| West Virginia\Wood         | 2021                        | 516                                  | 162                                      | 88991            | 0.76%                                          | 2.27%                                           | 0.0173%            |
| Virginia\Wise              | 431                         | 147                                  | 50                                       | 22169            | 0.89%                                          | 1.94%                                           | 0.0173%            |
| Alabama\Talladega          | 18106                       | 135                                  |                                          | 119042           | 0.11%                                          | 15.21%                                          | 0.0172%            |
| Kentucky\Wolfe             | 1023                        | 554                                  |                                          | 57701            | 0.96%                                          | 1.77%                                           | 0.0170%            |
| Virginia\Craig             | 900                         | 325                                  |                                          | 41630            | 0.78%                                          | 2.16%                                           | 0.0169%            |
| Texas\Cameron              | 111033                      | 182                                  | 3                                        | 349479           | 0.05%                                          | 31.77%                                          | 0.0168%            |
| Oklahoma\Okmulgee          | 48505                       | 298                                  |                                          | 294324           | 0.10%                                          | 16.48%                                          | 0.0167%            |
| Texas\Dickens              | 37540                       | 1444                                 |                                          | 574273           | 0.25%                                          | 6.54%                                           | 0.0164%            |
| Oklahoma\Atoka             | 52087                       | 524                                  |                                          | 408444           | 0.13%                                          | 12.75%                                          | 0.0164%            |
| Florida\Jackson            | 63926                       | 247                                  |                                          | 311398           | 0.08%                                          | 20.53%                                          | 0.0163%            |
| Tennessee\Bedford          | 26828                       | 324                                  |                                          | 231206           | 0.14%                                          | 11.60%                                          | 0.0163%            |
| Texas\Shelby               | 23909                       | 266                                  |                                          | 197791           | 0.13%                                          | 12.09%                                          | 0.0163%            |
| Oklahoma\Latimer           | 25427                       | 290                                  |                                          | 213411           | 0.14%                                          | 11.91%                                          | 0.0162%            |
| Colorado\Kiowa             | 253201                      | 585                                  |                                          | 957937           | 0.06%                                          | 26.43%                                          | 0.0161%            |
| Georgia\Pierce             | 22226                       | 37                                   |                                          | 71750            | 0.05%                                          | 30.98%                                          | 0.0160%            |
| Texas\Waller               | 31518                       | 179                                  | 192                                      | 271004           | 0.14%                                          | 11.63%                                          | 0.0159%            |
| South Carolina\Spartanburg | 10926                       | 175                                  |                                          | 109917           | 0.16%                                          | 9.94%                                           | 0.0158%            |
| Tennessee\Rutherford       | 21021                       | 203                                  |                                          | 164411           | 0.12%                                          | 12.79%                                          | 0.0158%            |
| Tennessee\Campbell         | 1821                        | 101                                  |                                          | 34174            | 0.30%                                          | 5.33%                                           | 0.0157%            |
| Arkansas\Lawrence          | 134927                      | 81                                   |                                          | 263615           | 0.03%                                          | 51.18%                                          | 0.0157%            |
| Florida\Marion             | 25168                       | 438                                  |                                          | 266571           | 0.16%                                          | 9.44%                                           | 0.0155%            |
| Tennessee\Overton          | 13603                       | 149                                  |                                          | 114800           | 0.13%                                          | 11.85%                                          | 0.0154%            |
| Oklahoma\Pittsburg         | 67012                       | 681                                  |                                          | 547050           | 0.12%                                          | 12.25%                                          | 0.0152%            |
| North Carolina\Person      | 17493                       | 84                                   |                                          | 98521            | 0.09%                                          | 17.76%                                          | 0.0151%            |
| South Dakota\Fall River    | 15786                       | 8596                                 |                                          | 949697           | 0.91%                                          | 1.66%                                           | 0.0150%            |
| West Virginia\Randolph     | 3056                        | 535                                  |                                          | 104441           | 0.51%                                          | 2.93%                                           | 0.0150%            |
| Virginia\Bath              | 1735                        | 125                                  |                                          | 38412            | 0.33%                                          | 4.52%                                           | 0.0147%            |
| Arkansas\Conway            | 42435                       | 119                                  |                                          | 187142           | 0.06%                                          | 22.68%                                          | 0.0144%            |
| Tennessee\Houston          | 4952                        | 64                                   |                                          | 47190            | 0.14%                                          | 10.49%                                          | 0.0142%            |
| Georgia\Carroll            | 17287                       | 76                                   |                                          | 96197            | 0.08%                                          | 17.97%                                          | 0.0142%            |
| Virginia\Buchanan          | 199                         | 62                                   |                                          | 9331             | 0.66%                                          | 2.13%                                           | 0.0142%            |

| County                 | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Texas\Dallas           | 16521                       | 66                                   |                                          | 88010            | 0.07%                                          | 18.77%                                          | 0.0141%            |
| Oklahoma\Okfuskee      | 39368                       | 317                                  |                                          | 298814           | 0.11%                                          | 13.17%                                          | 0.0140%            |
| Tennessee\Cumberland   | 9752                        | 189                                  | 25                                       | 122554           | 0.17%                                          | 7.96%                                           | 0.0139%            |
| Tennessee\Lincoln      | 63815                       | 147                                  |                                          | 260874           | 0.06%                                          | 24.46%                                          | 0.0138%            |
| Texas\Houston          | 63282                       | 419                                  |                                          | 440462           | 0.10%                                          | 14.37%                                          | 0.0137%            |
| Texas\Bowie            | 31412                       | 243                                  | 126                                      | 291674           | 0.13%                                          | 10.77%                                          | 0.0136%            |
| Texas\Karnes           | 74985                       | 316                                  |                                          | 417484           | 0.08%                                          | 17.96%                                          | 0.0136%            |
| South Carolina\Lee     | 67006                       | 40                                   |                                          | 141037           | 0.03%                                          | 47.51%                                          | 0.0135%            |
| Tennessee\Smith        | 21976                       | 99                                   |                                          | 127108           | 0.08%                                          | 17.29%                                          | 0.0135%            |
| Florida\Pasco          | 16693                       | 180                                  |                                          | 149963           | 0.12%                                          | 11.13%                                          | 0.0134%            |
| Florida\Lafayette      | 5466                        | 161                                  |                                          | 81277            | 0.20%                                          | 6.73%                                           | 0.0133%            |
| Florida\Walton         | 21260                       | 100                                  |                                          | 126841           | 0.08%                                          | 16.76%                                          | 0.0132%            |
| Tennessee\White        | 27216                       | 84                                   |                                          | 131652           | 0.06%                                          | 20.67%                                          | 0.0132%            |
| Missouri\Washington    | 3006                        | 826                                  |                                          | 137304           | 0.60%                                          | 2.19%                                           | 0.0132%            |
| Oklahoma\Pushmataha    | 22304                       | 497                                  |                                          | 290409           | 0.17%                                          | 7.68%                                           | 0.0131%            |
| Missouri\Ripley        | 12789                       | 193                                  |                                          | 137258           | 0.14%                                          | 9.32%                                           | 0.0131%            |
| Louisiana\St. Helena   | 5697                        | 62                                   |                                          | 52363            | 0.12%                                          | 10.88%                                          | 0.0129%            |
| Texas\Polk             | 5125                        | 208                                  | 224                                      | 131664           | 0.33%                                          | 3.89%                                           | 0.0128%            |
| Tennessee\Knox         | 6074                        | 144                                  |                                          | 82938            | 0.17%                                          | 7.32%                                           | 0.0127%            |
| Texas\Hopkins          | 36505                       | 371                                  | 155                                      | 390466           | 0.13%                                          | 9.35%                                           | 0.0126%            |
| Massachusetts\Norfolk  | 224                         | 76                                   |                                          | 11654            | 0.65%                                          | 1.92%                                           | 0.0125%            |
| Mississippi\Amite      | 7187                        | 110                                  | 100                                      | 109969           | 0.19%                                          | 6.54%                                           | 0.0125%            |
| New Mexico\Chaves      | 34851                       | 20207                                | 1208                                     | 2454564          | 0.87%                                          | 1.42%                                           | 0.0124%            |
| Kentucky\Magoffin      | 876                         | 534                                  |                                          | 61620            | 0.87%                                          | 1.42%                                           | 0.0123%            |
| New Mexico\Luna        | 16919                       | 3103                                 |                                          | 653558           | 0.47%                                          | 2.59%                                           | 0.0123%            |
| Texas\Wood             | 20232                       | 332                                  |                                          | 233796           | 0.14%                                          | 8.65%                                           | 0.0123%            |
| Tennessee\Anderson     | 3528                        | 56                                   |                                          | 40135            | 0.14%                                          | 8.79%                                           | 0.0123%            |
| California\Santa Clara | 9027                        | 1213                                 |                                          | 299866           | 0.40%                                          | 3.01%                                           | 0.0122%            |
| Texas\Trinity          | 7052                        | 205                                  |                                          | 108974           | 0.19%                                          | 6.47%                                           | 0.0122%            |
| Texas\Donley           | 24040                       | 1743                                 |                                          | 588947           | 0.30%                                          | 4.08%                                           | 0.0121%            |
| Tennessee\Hancock      | 4523                        | 98                                   |                                          | 60646            | 0.16%                                          | 7.46%                                           | 0.0121%            |
| North Carolina\Gaston  | 4998                        | 34                                   |                                          | 37561            | 0.09%                                          | 13.31%                                          | 0.0120%            |
| Kentucky\Owsley        | 458                         | 338                                  |                                          | 35857            | 0.94%                                          | 1.28%                                           | 0.0120%            |
| Arkansas\Crittenden    | 196565                      | 60                                   |                                          | 313688           | 0.02%                                          | 62.66%                                          | 0.0120%            |
| Georgia\Jackson        | 14359                       | 60                                   |                                          | 84869            | 0.07%                                          | 16.92%                                          | 0.0120%            |
| West Virginia\Harrison | 1705                        | 495                                  | 375                                      | 111657           | 0.78%                                          | 1.53%                                           | 0.0119%            |
| Texas\Guadalupe        | 68144                       | 143                                  | 115                                      | 385015           | 0.07%                                          | 17.70%                                          | 0.0119%            |
| West Virginia\Gilmer   | 1907                        | 252                                  |                                          | 64033            | 0.39%                                          | 2.98%                                           | 0.0117%            |
| Mississippi\Jackson    | 5154                        | 39                                   |                                          | 41445            | 0.09%                                          | 12.44%                                          | 0.0117%            |
| Alabama\Monroe         | 17243                       | 95                                   |                                          | 118805           | 0.08%                                          | 14.51%                                          | 0.0116%            |
| California\Placer      | 11816                       | 170                                  |                                          | 132221           | 0.13%                                          | 8.94%                                           | 0.0115%            |
| Colorado\Huerfano      | 3923                        | 7774                                 |                                          | 518619           | 1.50%                                          | 0.76%                                           | 0.0113%            |
| West Virginia\Braxton  | 2223                        | 293                                  | 27                                       | 79437            | 0.40%                                          | 2.80%                                           | 0.0113%            |

| County                    | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|---------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Texas\Cass                | 14394                       | 202                                  | 40                                       | 176645           | 0.14%                                          | 8.15%                                           | 0.0112%            |
| Arkansas\Izard            | 16093                       | 201                                  |                                          | 170415           | 0.12%                                          | 9.44%                                           | 0.0111%            |
| North Carolina\Columbus   | 66293                       | 39                                   |                                          | 152387           | 0.03%                                          | 43.50%                                          | 0.0111%            |
| Arkansas\Sharp            | 16841                       | 224                                  |                                          | 184105           | 0.12%                                          | 9.15%                                           | 0.0111%            |
| Georgia\Coffee            | 55054                       | 69                                   |                                          | 184947           | 0.04%                                          | 29.77%                                          | 0.0111%            |
| Texas\Cooke               | 71051                       | 302                                  | 19                                       | 455393           | 0.07%                                          | 15.60%                                          | 0.0110%            |
| Georgia\Jefferson         | 36244                       | 36                                   |                                          | 108932           | 0.03%                                          | 33.27%                                          | 0.0110%            |
| North Carolina\Vance      | 8337                        | 40                                   |                                          | 55091            | 0.07%                                          | 15.13%                                          | 0.0110%            |
| Missouri\Cedar            | 14398                       | 272                                  |                                          | 190528           | 0.14%                                          | 7.56%                                           | 0.0108%            |
| Texas\Briscoe             | 59559                       | 540                                  |                                          | 546734           | 0.10%                                          | 10.89%                                          | 0.0108%            |
| Tennessee\Jackson         | 7437                        | 82                                   |                                          | 75642            | 0.11%                                          | 9.83%                                           | 0.0107%            |
| Georgia\Polk              | 5119                        | 40                                   |                                          | 43869            | 0.09%                                          | 11.67%                                          | 0.0106%            |
| Texas\Bastrop             | 74256                       | 228                                  | 3                                        | 402079           | 0.06%                                          | 18.47%                                          | 0.0106%            |
| Nebraska\Arthur           | 5529                        | 3934                                 |                                          | 453615           | 0.87%                                          | 1.22%                                           | 0.0106%            |
| Tennessee\Crockett        | 83621                       | 28                                   |                                          | 149227           | 0.02%                                          | 56.04%                                          | 0.0105%            |
| Arkansas\Polk             | 13943                       | 134                                  |                                          | 133351           | 0.10%                                          | 10.46%                                          | 0.0105%            |
| Texas\Hamilton            | 30285                       | 415                                  | 337                                      | 470850           | 0.16%                                          | 6.43%                                           | 0.0103%            |
| New Mexico\Quay           | 68071                       | 3343                                 |                                          | 1489686          | 0.22%                                          | 4.57%                                           | 0.0103%            |
| Missouri\Dent             | 4306                        | 739                                  |                                          | 176601           | 0.42%                                          | 2.44%                                           | 0.0102%            |
| Oklahoma\Pontotoc         | 35864                       | 409                                  |                                          | 379236           | 0.11%                                          | 9.46%                                           | 0.0102%            |
| Oklahoma\Adair            | 33114                       | 190                                  |                                          | 249280           | 0.08%                                          | 13.28%                                          | 0.0101%            |
| Kentucky\Clay             | 1400                        | 189                                  |                                          | 51194            | 0.37%                                          | 2.73%                                           | 0.0101%            |
| Mississippi\Pearl River   | 10865                       | 170                                  |                                          | 135676           | 0.13%                                          | 8.01%                                           | 0.0100%            |
| Tennessee\Hamilton        | 4204                        | 71                                   |                                          | 54599            | 0.13%                                          | 7.70%                                           | 0.0100%            |
| Oklahoma\Coal             | 27938                       | 260                                  |                                          | 269401           | 0.10%                                          | 10.37%                                          | 0.0100%            |
| Mississippi\Forrest       | 4704                        | 44                                   |                                          | 45532            | 0.10%                                          | 10.33%                                          | 0.0100%            |
| Washington\Jefferson      | 209                         | 77                                   |                                          | 12717            | 0.61%                                          | 1.64%                                           | 0.0100%            |
| Arkansas\Logan            | 38637                       | 66                                   |                                          | 160380           | 0.04%                                          | 24.09%                                          | 0.0099%            |
| North Carolina\Granville  | 8304                        | 195                                  |                                          | 128366           | 0.15%                                          | 6.47%                                           | 0.0098%            |
| Texas\Scurry              | 65724                       | 402                                  |                                          | 519550           | 0.08%                                          | 12.65%                                          | 0.0098%            |
| Texas\Tyler               | 3776                        | 184                                  |                                          | 84253            | 0.22%                                          | 4.48%                                           | 0.0098%            |
| Kentucky\Menifee          | 432                         | 420                                  |                                          | 43110            | 0.97%                                          | 1.00%                                           | 0.0098%            |
| Utah\Uintah               | 8488                        | 36019                                | 869                                      | 1799785          | 2.05%                                          | 0.47%                                           | 0.0097%            |
| Texas\Morris              | 11908                       | 45                                   | 14                                       | 85666            | 0.07%                                          | 13.90%                                          | 0.0096%            |
| Kentucky\Greenup          | 1057                        | 659                                  | 102                                      | 91853            | 0.83%                                          | 1.15%                                           | 0.0095%            |
| South Carolina\Greenville | 7972                        | 61                                   |                                          | 72645            | 0.08%                                          | 10.97%                                          | 0.0092%            |
| Texas\Grimes              | 70935                       | 178                                  | 69                                       | 437140           | 0.06%                                          | 16.23%                                          | 0.0092%            |
| Missouri\Camden           | 3015                        | 632                                  |                                          | 144379           | 0.44%                                          | 2.09%                                           | 0.0091%            |
| Alabama\Henry             | 38860                       | 64                                   |                                          | 165699           | 0.04%                                          | 23.45%                                          | 0.0091%            |
| Tennessee\Macon           | 11093                       | 133                                  |                                          | 127801           | 0.10%                                          | 8.68%                                           | 0.0090%            |
| South Carolina\Anderson   | 17938                       | 150                                  |                                          | 173149           | 0.09%                                          | 10.36%                                          | 0.0090%            |
| Texas\Harrison            | 14729                       | 222                                  | 23                                       | 200875           | 0.12%                                          | 7.33%                                           | 0.0089%            |
| West Virginia\Hampshire   | 2096                        | 588                                  | 124                                      | 129190           | 0.55%                                          | 1.62%                                           | 0.0089%            |
| Kentucky\Carter           | 1380                        | 1015                                 |                                          | 125503           | 0.81%                                          | 1.10%                                           | 0.0089%            |
| Wyoming\Uinta             | 7841                        | 6251                                 |                                          | 742809           | 0.84%                                          | 1.06%                                           | 0.0089%            |

| County                   | Acres Using Herbicide | Harvested Acres of Alfalfa Hay | Harvested Acres Alfalfa Haylage | Acres in Farm | % of Farm Acres in Alfalfa Forage (a) | % of Farm Acres Using Herbicide (b) | (c) = (a) x (b) |
|--------------------------|-----------------------|--------------------------------|---------------------------------|---------------|---------------------------------------|-------------------------------------|-----------------|
| Texas\Hunt               | 50382                 | 195                            | 71                              | 388422        | 0.07%                                 | 12.97%                              | 0.0089%         |
| West Virginia\Cabell     | 943                   | 212                            |                                 | 47625         | 0.45%                                 | 1.98%                               | 0.0088%         |
| Maine\Hancock            | 3945                  | 62                             |                                 | 52749         | 0.12%                                 | 7.48%                               | 0.0088%         |
| Alabama\Covington        | 32994                 | 106                            |                                 | 200141        | 0.05%                                 | 16.49%                              | 0.0087%         |
| Tennessee\Trousdale      | 7318                  | 23                             |                                 | 44006         | 0.05%                                 | 16.63%                              | 0.0087%         |
| Texas\Cottle             | 26717                 | 919                            |                                 | 534519        | 0.17%                                 | 5.00%                               | 0.0086%         |
| Georgia\Cook             | 22780                 | 16                             |                                 | 65138         | 0.02%                                 | 34.97%                              | 0.0086%         |
| Alabama\Hale             | 9922                  | 248                            |                                 | 169287        | 0.15%                                 | 5.86%                               | 0.0086%         |
| Colorado\Custer          | 2093                  | 777                            |                                 | 137799        | 0.56%                                 | 1.52%                               | 0.0086%         |
| Texas\DeWitt             | 80725                 | 320                            |                                 | 549237        | 0.06%                                 | 14.70%                              | 0.0086%         |
| Arkansas\Faulkner        | 22910                 | 135                            |                                 | 190089        | 0.07%                                 | 12.05%                              | 0.0086%         |
| Florida\Alachua          | 21989                 | 115                            |                                 | 172843        | 0.07%                                 | 12.72%                              | 0.0085%         |
| Nebraska\McPherson       | 2153                  | 3895                           |                                 | 315210        | 1.24%                                 | 0.68%                               | 0.0084%         |
| Missouri\Pulaski         | 1863                  | 681                            |                                 | 123074        | 0.55%                                 | 1.51%                               | 0.0084%         |
| Florida\Santa Rosa       | 14721                 | 28                             |                                 | 70179         | 0.04%                                 | 20.98%                              | 0.0084%         |
| Tennessee\Roane          | 2617                  | 88                             |                                 | 52582         | 0.17%                                 | 4.98%                               | 0.0083%         |
| West Virginia\Grant      | 1113                  | 350                            | 526                             | 108839        | 0.80%                                 | 1.02%                               | 0.0082%         |
| Maine\Sagadahoc          | 140                   | 202                            |                                 | 18616         | 1.09%                                 | 0.75%                               | 0.0082%         |
| Tennessee\Cocke          | 4847                  | 69                             |                                 | 64163         | 0.11%                                 | 7.55%                               | 0.0081%         |
| West Virginia\Nicholas   | 410                   | 311                            | 211                             | 51332         | 1.02%                                 | 0.80%                               | 0.0081%         |
| North Carolina\Madison   | 1956                  | 184                            |                                 | 66734         | 0.28%                                 | 2.93%                               | 0.0081%         |
| West Virginia\Barbour    | 1033                  | 646                            |                                 | 91017         | 0.71%                                 | 1.13%                               | 0.0081%         |
| Kentucky\McCreary        | 351                   | 52                             |                                 | 15056         | 0.35%                                 | 2.33%                               | 0.0081%         |
| Wyoming\Campbell         | 9586                  | 45631                          | 277                             | 2345915       | 1.96%                                 | 0.41%                               | 0.0080%         |
| Texas\Johnson            | 41893                 | 170                            | 39                              | 331347        | 0.06%                                 | 12.64%                              | 0.0080%         |
| Texas\Navarro            | 90512                 | 302                            |                                 | 586936        | 0.05%                                 | 15.42%                              | 0.0079%         |
| Wyoming\Converse         | 15217                 | 28914                          | 262                             | 2366020       | 1.23%                                 | 0.64%                               | 0.0079%         |
| Tennessee\Moore          | 5711                  | 37                             |                                 | 51814         | 0.07%                                 | 11.02%                              | 0.0079%         |
| Kentucky\Morgan          | 1609                  | 812                            | 94                              | 136303        | 0.66%                                 | 1.18%                               | 0.0078%         |
| Alabama\Washington       | 6319                  | 86                             |                                 | 83610         | 0.10%                                 | 7.56%                               | 0.0078%         |
| Oregon\Grant             | 5023                  | 8796                           | 177                             | 761541        | 1.18%                                 | 0.66%                               | 0.0078%         |
| Texas\Angelina           | 9252                  | 110                            |                                 | 115258        | 0.10%                                 | 8.03%                               | 0.0077%         |
| Texas\Bosque             | 36482                 | 598                            | 39                              | 550995        | 0.12%                                 | 6.62%                               | 0.0077%         |
| California\Mendocino     | 18867                 | 1218                           | 278                             | 608674        | 0.25%                                 | 3.10%                               | 0.0076%         |
| Alabama\Baldwin          | 62245                 | 44                             |                                 | 189815        | 0.02%                                 | 32.79%                              | 0.0076%         |
| Texas\Freestone          | 59984                 | 148                            | 54                              | 399584        | 0.05%                                 | 15.01%                              | 0.0076%         |
| Tennessee\Hardeman       | 34557                 | 48                             |                                 | 147951        | 0.03%                                 | 23.36%                              | 0.0076%         |
| Alabama\Franklin         | 9992                  | 150                            |                                 | 140861        | 0.11%                                 | 7.09%                               | 0.0076%         |
| California\Napa          | 30092                 | 125                            |                                 | 223246        | 0.06%                                 | 13.48%                              | 0.0075%         |
| California\Santa Barbara | 47128                 | 841                            |                                 | 727050        | 0.12%                                 | 6.48%                               | 0.0075%         |
| Arkansas\Cleburne        | 14033                 | 90                             |                                 | 129815        | 0.07%                                 | 10.81%                              | 0.0075%         |
| Tennessee\Union          | 2305                  | 68                             |                                 | 45917         | 0.15%                                 | 5.02%                               | 0.0074%         |
| Texas\Erath              | 45726                 | 324                            | 304                             | 622923        | 0.10%                                 | 7.34%                               | 0.0074%         |

| County                   | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|--------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| Texas\Harris             | 22186                       | 222                                  |                                          | 259039           | 0.09%                                          | 8.56%                                           | 0.0073%            |
| North Carolina\Sampson   | 123790                      | 61                                   |                                          | 321454           | 0.02%                                          | 38.51%                                          | 0.0073%            |
| Texas\Bexar              | 34421                       | 385                                  |                                          | 425909           | 0.09%                                          | 8.08%                                           | 0.0073%            |
| Arkansas\Stone           | 10198                       | 145                                  |                                          | 142397           | 0.10%                                          | 7.16%                                           | 0.0073%            |
| Mississippi\Jones        | 11771                       | 74                                   |                                          | 109837           | 0.07%                                          | 10.72%                                          | 0.0072%            |
| North Carolina\Franklin  | 22912                       | 40                                   |                                          | 112871           | 0.04%                                          | 20.30%                                          | 0.0072%            |
| North Carolina\Mitchell  | 1541                        | 24                                   |                                          | 22787            | 0.11%                                          | 6.76%                                           | 0.0071%            |
| Tennessee\Fentress       | 6601                        | 76                                   |                                          | 84371            | 0.09%                                          | 7.82%                                           | 0.0070%            |
| Arkansas\Marion          | 9728                        | 123                                  |                                          | 130445           | 0.09%                                          | 7.46%                                           | 0.0070%            |
| Tennessee\Pickett        | 3607                        | 28                                   |                                          | 37916            | 0.07%                                          | 9.51%                                           | 0.0070%            |
| Tennessee\Lewis          | 1190                        | 74                                   |                                          | 35566            | 0.21%                                          | 3.35%                                           | 0.0070%            |
| West Virginia\Lincoln    | 360                         | 202                                  |                                          | 32393            | 0.62%                                          | 1.11%                                           | 0.0069%            |
| Alabama\Chilton          | 8644                        | 79                                   |                                          | 100217           | 0.08%                                          | 8.63%                                           | 0.0068%            |
| Mississippi\Tippah       | 20526                       | 62                                   |                                          | 137434           | 0.05%                                          | 14.94%                                          | 0.0067%            |
| West Virginia\Monongalia | 294                         | 614                                  | 185                                      | 59257            | 1.35%                                          | 0.50%                                           | 0.0067%            |
| Nebraska\Cherry          | 42861                       | 22021                                |                                          | 3759629          | 0.59%                                          | 1.14%                                           | 0.0067%            |
| Georgia\Irwin            | 61280                       | 23                                   |                                          | 145432           | 0.02%                                          | 42.14%                                          | 0.0067%            |
| Arkansas\Independence    | 61950                       | 67                                   |                                          | 249653           | 0.03%                                          | 24.81%                                          | 0.0067%            |
| South Carolina\Barnwell  | 22861                       | 25                                   |                                          | 92679            | 0.03%                                          | 24.67%                                          | 0.0067%            |
| Texas\Nacogdoches        | 20332                       | 189                                  | 40                                       | 265131           | 0.09%                                          | 7.67%                                           | 0.0066%            |
| Texas\Wheeler            | 34809                       | 642                                  |                                          | 583522           | 0.11%                                          | 5.97%                                           | 0.0066%            |
| Virginia\Highland        | 1583                        | 244                                  |                                          | 76764            | 0.32%                                          | 2.06%                                           | 0.0066%            |
| Texas\Lavaca             | 87769                       | 236                                  |                                          | 566648           | 0.04%                                          | 15.49%                                          | 0.0065%            |
| West Virginia\Jackson    | 1606                        | 670                                  |                                          | 129466           | 0.52%                                          | 1.24%                                           | 0.0064%            |
| West Virginia\Mercer     | 1211                        | 154                                  |                                          | 53971            | 0.29%                                          | 2.24%                                           | 0.0064%            |
| Oregon\Wheeler           | 9171                        | 4006                                 |                                          | 757780           | 0.53%                                          | 1.21%                                           | 0.0064%            |
| Texas\Comanche           | 45935                       | 62                                   | 398                                      | 578943           | 0.08%                                          | 7.93%                                           | 0.0063%            |
| Virginia\Nottoway        | 3486                        | 76                                   |                                          | 65321            | 0.12%                                          | 5.34%                                           | 0.0062%            |
| Tennessee\Wilson         | 21984                       | 103                                  |                                          | 192920           | 0.05%                                          | 11.40%                                          | 0.0061%            |
| Tennessee\Dickson        | 5647                        | 207                                  |                                          | 139176           | 0.15%                                          | 4.06%                                           | 0.0060%            |
| Kentucky\Elliott         | 585                         | 428                                  | 30                                       | 66843            | 0.69%                                          | 0.88%                                           | 0.0060%            |
| Texas\Montague           | 46898                       | 319                                  | 10                                       | 507690           | 0.06%                                          | 9.24%                                           | 0.0060%            |
| Tennessee\Hickman        | 8652                        | 87                                   |                                          | 112187           | 0.08%                                          | 7.71%                                           | 0.0060%            |
| Missouri\Taney           | 4211                        | 161                                  |                                          | 106536           | 0.15%                                          | 3.95%                                           | 0.0060%            |
| Wyoming\Natrona          | 11242                       | 25269                                |                                          | 2181451          | 1.16%                                          | 0.52%                                           | 0.0060%            |
| Texas\Tarrant            | 9042                        | 157                                  |                                          | 154377           | 0.10%                                          | 5.86%                                           | 0.0060%            |
| Texas\Walker             | 22817                       | 131                                  |                                          | 224050           | 0.06%                                          | 10.18%                                          | 0.0060%            |
| Wyoming\Weston           | 4806                        | 21847                                |                                          | 1328294          | 1.64%                                          | 0.36%                                           | 0.0060%            |
| Kentucky\Perry           | 66                          | 102                                  |                                          | 10661            | 0.96%                                          | 0.62%                                           | 0.0059%            |
| Texas\Medina             | 57332                       | 471                                  | 100                                      | 748144           | 0.08%                                          | 7.66%                                           | 0.0058%            |
| Alabama\Pickens          | 7882                        | 126                                  |                                          | 130751           | 0.10%                                          | 6.03%                                           | 0.0058%            |
| Texas\Liberty            | 29008                       | 105                                  | 72                                       | 297855           | 0.06%                                          | 9.74%                                           | 0.0058%            |
| Florida\Hernando         | 4964                        | 36                                   |                                          | 56237            | 0.06%                                          | 8.83%                                           | 0.0057%            |
| Kentucky\Cumberland      | 2273                        | 265                                  |                                          | 103368           | 0.26%                                          | 2.20%                                           | 0.0056%            |
| Kentucky\Lawrence        | 365                         | 513                                  | 41                                       | 60220            | 0.92%                                          | 0.61%                                           | 0.0056%            |

| County                   | Acres Using Herbicide | Harvested Acres of Alfalfa Hay | Harvested Acres Alfalfa Haylage | Acres in Farm | % of Farm Acres in Alfalfa Forage (a) | % of Farm Acres Using Herbicide (b) | (c) = (a) x (b) |
|--------------------------|-----------------------|--------------------------------|---------------------------------|---------------|---------------------------------------|-------------------------------------|-----------------|
| Arkansas\Newton          | 5104                  | 139                            |                                 | 112985        | 0.12%                                 | 4.52%                               | 0.0056%         |
| Kentucky\Johnson         | 168                   | 254                            |                                 | 27766         | 0.91%                                 | 0.61%                               | 0.0055%         |
| Alabama\Marengo          | 9042                  | 192                            |                                 | 178157        | 0.11%                                 | 5.08%                               | 0.0055%         |
| Texas\Red River          | 48733                 | 220                            |                                 | 449525        | 0.05%                                 | 10.84%                              | 0.0053%         |
| California\San Diego     | 26680                 | 183                            |                                 | 303889        | 0.06%                                 | 8.78%                               | 0.0053%         |
| New Mexico\Torrance      | 13985                 | 12152                          |                                 | 1796048       | 0.68%                                 | 0.78%                               | 0.0053%         |
| Texas\Swisher            | 140112                | 119                            |                                 | 563067        | 0.02%                                 | 24.88%                              | 0.0053%         |
| Texas\Victoria           | 85417                 | 150                            |                                 | 493823        | 0.03%                                 | 17.30%                              | 0.0053%         |
| Wyoming\Johnson          | 8942                  | 21923                          |                                 | 1946197       | 1.13%                                 | 0.46%                               | 0.0052%         |
| Tennessee\Morgan         | 2579                  | 55                             |                                 | 53335         | 0.10%                                 | 4.84%                               | 0.0050%         |
| West Virginia\Marshall   | 488                   | 895                            | 39                              | 95814         | 0.97%                                 | 0.51%                               | 0.0050%         |
| Texas\Jasper             | 7201                  | 63                             |                                 | 95928         | 0.07%                                 | 7.51%                               | 0.0049%         |
| Texas\Rusk               | 20369                 | 185                            | 33                              | 300900        | 0.07%                                 | 6.77%                               | 0.0049%         |
| Alabama\Tuscaloosa       | 12925                 | 46                             |                                 | 110588        | 0.04%                                 | 11.69%                              | 0.0049%         |
| Colorado\Las Animas      | 18375                 | 12028                          | 448                             | 2179242       | 0.57%                                 | 0.84%                               | 0.0048%         |
| West Virginia\Putnam     | 1326                  | 157                            |                                 | 66416         | 0.24%                                 | 2.00%                               | 0.0047%         |
| Kentucky\Boyd            | 808                   | 48                             |                                 | 28738         | 0.17%                                 | 2.81%                               | 0.0047%         |
| West Virginia\Fayette    | 382                   | 87                             |                                 | 26677         | 0.33%                                 | 1.43%                               | 0.0047%         |
| Texas\Lipscomb           | 40813                 | 369                            |                                 | 571057        | 0.06%                                 | 7.15%                               | 0.0046%         |
| West Virginia\Calhoun    | 890                   | 161                            |                                 | 56006         | 0.29%                                 | 1.59%                               | 0.0046%         |
| Texas\Kaufman            | 64799                 | 125                            |                                 | 421803        | 0.03%                                 | 15.36%                              | 0.0046%         |
| Colorado\Fremont         | 748                   | 5122                           | 126                             | 295893        | 1.77%                                 | 0.25%                               | 0.0045%         |
| Georgia\Walker           | 8069                  | 28                             |                                 | 71152         | 0.04%                                 | 11.34%                              | 0.0045%         |
| Wyoming\Sweetwater       | 4621                  | 20607                          | 700                             | 1486395       | 1.43%                                 | 0.31%                               | 0.0045%         |
| Texas\Montgomery         | 15178                 | 48                             | 36                              | 169914        | 0.05%                                 | 8.93%                               | 0.0044%         |
| Tennessee\Bledsoe        | 8406                  | 44                             |                                 | 92043         | 0.05%                                 | 9.13%                               | 0.0044%         |
| Oregon\Coos              | 3415                  | 268                            |                                 | 145675        | 0.18%                                 | 2.34%                               | 0.0043%         |
| Alabama\Crenshaw         | 7466                  | 100                            |                                 | 132385        | 0.08%                                 | 5.64%                               | 0.0043%         |
| Maine\Washington         | 3885                  | 274                            |                                 | 158459        | 0.17%                                 | 2.45%                               | 0.0042%         |
| Oklahoma\Jefferson       | 29583                 | 303                            |                                 | 460207        | 0.07%                                 | 6.43%                               | 0.0042%         |
| South Carolina\Greenwood | 2810                  | 75                             |                                 | 70698         | 0.11%                                 | 3.97%                               | 0.0042%         |
| West Virginia\Lewis      | 2214                  | 160                            |                                 | 92160         | 0.17%                                 | 2.40%                               | 0.0042%         |
| Texas\Gillespie          | 26101                 | 681                            |                                 | 652940        | 0.10%                                 | 4.00%                               | 0.0042%         |
| Texas\Hardin             | 4081                  | 84                             |                                 | 91189         | 0.09%                                 | 4.48%                               | 0.0041%         |
| Alabama\Marion           | 10277                 | 55                             |                                 | 117206        | 0.05%                                 | 8.77%                               | 0.0041%         |
| West Virginia\Webster    | 121                   | 45                             |                                 | 11530         | 0.39%                                 | 1.05%                               | 0.0041%         |
| Nevada\Elko              | 14305                 | 12076                          |                                 | 2085135       | 0.58%                                 | 0.69%                               | 0.0040%         |
| Mississippi\Leake        | 8756                  | 71                             |                                 | 127443        | 0.06%                                 | 6.87%                               | 0.0038%         |
| Texas\Atascosa           | 37976                 | 412                            |                                 | 643594        | 0.06%                                 | 5.90%                               | 0.0038%         |
| West Virginia\Taylor     | 1138                  | 96                             |                                 | 53806         | 0.18%                                 | 2.12%                               | 0.0038%         |
| Mississippi\Madison      | 27872                 | 66                             |                                 | 222627        | 0.03%                                 | 12.52%                              | 0.0037%         |
| New Mexico\Santa Fe      | 3811                  | 3070                           | 39                              | 569404        | 0.55%                                 | 0.67%                               | 0.0037%         |
| Alabama\Lamar            | 3117                  | 83                             |                                 | 84645         | 0.10%                                 | 3.68%                               | 0.0036%         |



| County                  | Acres Using Herbicide | Harvested Acres of Alfalfa Hay | Harvested Acres Alfalfa Haylage | Acres in Farm | % of Farm Acres in Alfalfa Forage (a) | % of Farm Acres Using Herbicide (b) | (c) = (a) x (b) |
|-------------------------|-----------------------|--------------------------------|---------------------------------|---------------|---------------------------------------|-------------------------------------|-----------------|
| Missouri\Shannon        | 2235                  | 197                            |                                 | 110905        | 0.18%                                 | 2.02%                               | 0.0036%         |
| Mississippi\Tishomingo  | 3976                  | 29                             |                                 | 56764         | 0.05%                                 | 7.00%                               | 0.0036%         |
| Texas\Clay              | 58791                 | 226                            | 39                              | 661617        | 0.04%                                 | 8.89%                               | 0.0036%         |
| Texas\Brown             | 28456                 | 392                            |                                 | 560065        | 0.07%                                 | 5.08%                               | 0.0036%         |
| Texas\Coryell           | 55406                 | 153                            |                                 | 488358        | 0.03%                                 | 11.35%                              | 0.0036%         |
| Wyoming\Sublette        | 2277                  | 5485                           |                                 | 599289        | 0.92%                                 | 0.38%                               | 0.0035%         |
| Texas\Jones             | 91555                 | 124                            |                                 | 573323        | 0.02%                                 | 15.97%                              | 0.0035%         |
| Missouri\Madison        | 2142                  | 155                            |                                 | 98229         | 0.16%                                 | 2.18%                               | 0.0034%         |
| Kentucky\Knox           | 1502                  | 59                             |                                 | 51115         | 0.12%                                 | 2.94%                               | 0.0034%         |
| Tennessee\Benton        | 7312                  | 24                             |                                 | 72522         | 0.03%                                 | 10.08%                              | 0.0033%         |
| Texas\Taylor            | 50066                 | 199                            | 21                              | 579484        | 0.04%                                 | 8.64%                               | 0.0033%         |
| Nevada\Washoe           | 1860                  | 4134                           |                                 | 485893        | 0.85%                                 | 0.38%                               | 0.0033%         |
| Texas\Somervell         | 4696                  | 47                             |                                 | 82615         | 0.06%                                 | 5.68%                               | 0.0032%         |
| Texas\Hudspeth          | 13888                 | 11711                          |                                 | 2257579       | 0.52%                                 | 0.62%                               | 0.0032%         |
| Maine\Knox              | 1650                  | 17                             |                                 | 30100         | 0.06%                                 | 5.48%                               | 0.0031%         |
| West Virginia\Pleasants | 151                   | 135                            |                                 | 25778         | 0.52%                                 | 0.59%                               | 0.0031%         |
| California\Monterey     | 125399                | 428                            |                                 | 1327972       | 0.03%                                 | 9.44%                               | 0.0030%         |
| Texas\Wilson            | 75428                 | 87                             |                                 | 467187        | 0.02%                                 | 16.15%                              | 0.0030%         |
| Utah\San Juan           | 12929                 | 5300                           | 168                             | 1546914       | 0.35%                                 | 0.84%                               | 0.0030%         |
| Texas\Jackson           | 143082                | 50                             |                                 | 492580        | 0.01%                                 | 29.05%                              | 0.0029%         |
| Texas\Brazos            | 49734                 | 45                             |                                 | 275752        | 0.02%                                 | 18.04%                              | 0.0029%         |
| Georgia\Meriwether      | 6232                  | 31                             |                                 | 81489         | 0.04%                                 | 7.65%                               | 0.0029%         |
| West Virginia\Roane     | 1731                  | 168                            | 64                              | 117517        | 0.20%                                 | 1.47%                               | 0.0029%         |
| California\Lake         | 7611                  | 58                             |                                 | 124199        | 0.05%                                 | 6.13%                               | 0.0029%         |
| Texas\Cochran           | 148228                | 46                             |                                 | 489051        | 0.01%                                 | 30.31%                              | 0.0029%         |
| Arkansas\Baxter         | 9817                  | 27                             |                                 | 97150         | 0.03%                                 | 10.10%                              | 0.0028%         |
| Mississippi\Wilkinson   | 5126                  | 70                             |                                 | 113243        | 0.06%                                 | 4.53%                               | 0.0028%         |
| New Mexico\Lea          | 21907                 | 6516                           | 454                             | 2365168       | 0.29%                                 | 0.93%                               | 0.0027%         |
| Louisiana\St. Tammany   | 1943                  | 29                             |                                 | 45506         | 0.06%                                 | 4.27%                               | 0.0027%         |
| Texas\Hays              | 9547                  | 150                            |                                 | 235568        | 0.06%                                 | 4.05%                               | 0.0026%         |
| South Carolina\Laurens  | 6054                  | 72                             |                                 | 130057        | 0.06%                                 | 4.65%                               | 0.0026%         |
| Tennessee\Scott         | 1010                  | 24                             |                                 | 31086         | 0.08%                                 | 3.25%                               | 0.0025%         |
| Tennessee\Clay          | 3257                  | 46                             |                                 | 77779         | 0.06%                                 | 4.19%                               | 0.0025%         |
| Texas\Eastland          | 28911                 | 227                            |                                 | 520132        | 0.04%                                 | 5.56%                               | 0.0024%         |
| Texas\Matagorda         | 121029                | 66                             |                                 | 577594        | 0.01%                                 | 20.95%                              | 0.0024%         |
| California\San Benito   | 16438                 | 489                            |                                 | 579851        | 0.08%                                 | 2.83%                               | 0.0024%         |
| Washington\Ferry        | 3445                  | 3866                           |                                 | 749452        | 0.52%                                 | 0.46%                               | 0.0024%         |
| Florida\Leon            | 2425                  | 80                             |                                 | 90732         | 0.09%                                 | 2.67%                               | 0.0024%         |
| Alabama\Pike            | 13644                 | 54                             |                                 | 179175        | 0.03%                                 | 7.61%                               | 0.0023%         |
| Texas\Baylor            | 43369                 | 153                            |                                 | 547029        | 0.03%                                 | 7.93%                               | 0.0022%         |
| West Virginia\Marion    | 275                   | 180                            | 80                              | 58015         | 0.45%                                 | 0.47%                               | 0.0021%         |
| Texas\Hemphill          | 15788                 | 400                            |                                 | 548746        | 0.07%                                 | 2.88%                               | 0.0021%         |
| Arizona\Graham          | 18277                 | 1973                           |                                 | 1345629       | 0.15%                                 | 1.36%                               | 0.0020%         |
| South Carolina\Kershaw  | 9566                  | 15                             |                                 | 85527         | 0.02%                                 | 11.18%                              | 0.0020%         |
| Florida\Polk            | 106760                | 54                             |                                 | 549071        | 0.01%                                 | 19.44%                              | 0.0019%         |

| County                 | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|------------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| West Virginia\Wirt     | 167                         | 187                                  |                                          | 41205            | 0.45%                                          | 0.41%                                           | 0.0018%            |
| Mississippi\Kemper     | 3825                        | 55                                   | 34                                       | 136134           | 0.07%                                          | 2.81%                                           | 0.0018%            |
| Alabama\Montgomery     | 11866                       | 75                                   |                                          | 223079           | 0.03%                                          | 5.32%                                           | 0.0018%            |
| Texas\Runnels          | 105290                      | 73                                   |                                          | 656204           | 0.01%                                          | 16.05%                                          | 0.0018%            |
| Texas\Mitchell         | 61666                       | 95                                   |                                          | 574995           | 0.02%                                          | 10.72%                                          | 0.0018%            |
| Nebraska\Grant         | 4137                        | 1040                                 |                                          | 495493           | 0.21%                                          | 0.83%                                           | 0.0018%            |
| New Mexico\Socorro     | 3915                        | 8699                                 | 298                                      | 1429970          | 0.63%                                          | 0.27%                                           | 0.0017%            |
| Texas\Goliad           | 62936                       | 60                                   |                                          | 469513           | 0.01%                                          | 13.40%                                          | 0.0017%            |
| New Mexico\De Baca     | 3852                        | 4923                                 |                                          | 1070531          | 0.46%                                          | 0.36%                                           | 0.0017%            |
| Texas\Fort Bend        | 88575                       | 26                                   |                                          | 382740           | 0.01%                                          | 23.14%                                          | 0.0016%            |
| Texas\Culberson        | 9446                        | 3065                                 |                                          | 1374032          | 0.22%                                          | 0.69%                                           | 0.0015%            |
| West Virginia\Ritchie  | 536                         | 236                                  |                                          | 90836            | 0.26%                                          | 0.59%                                           | 0.0015%            |
| Virginia\Henry         | 1155                        | 34                                   |                                          | 50779            | 0.07%                                          | 2.27%                                           | 0.0015%            |
| New Mexico\Colfax      | 9344                        | 7526                                 |                                          | 2152343          | 0.35%                                          | 0.43%                                           | 0.0015%            |
| North Carolina\Caswell | 6239                        | 25                                   |                                          | 102299           | 0.02%                                          | 6.10%                                           | 0.0015%            |
| Alabama\Geneva         | 24770                       | 29                                   |                                          | 220676           | 0.01%                                          | 11.22%                                          | 0.0015%            |
| Alabama\Choctaw        | 1217                        | 36                                   |                                          | 55016            | 0.07%                                          | 2.21%                                           | 0.0014%            |
| Tennessee\Wayne        | 4453                        | 42                                   |                                          | 115307           | 0.04%                                          | 3.86%                                           | 0.0014%            |
| Texas\Callahan         | 29939                       | 52                                   | 67                                       | 532595           | 0.02%                                          | 5.62%                                           | 0.0013%            |
| Wyoming\Carbon         | 4127                        | 14065                                | 124                                      | 2172544          | 0.65%                                          | 0.19%                                           | 0.0012%            |
| Texas\Coleman          | 33247                       | 178                                  |                                          | 699452           | 0.03%                                          | 4.75%                                           | 0.0012%            |
| Texas\Lampasas         | 18091                       | 114                                  |                                          | 416018           | 0.03%                                          | 4.35%                                           | 0.0012%            |
| Texas\Starr            | 30682                       | 160                                  |                                          | 652780           | 0.02%                                          | 4.70%                                           | 0.0012%            |
| Texas\Reeves           | 3109                        | 3940                                 |                                          | 1040344          | 0.38%                                          | 0.30%                                           | 0.0011%            |
| New Mexico\Rio Arriba  | 2063                        | 10691                                | 984                                      | 1460186          | 0.80%                                          | 0.14%                                           | 0.0011%            |
| New Mexico\Union       | 36605                       | 1481                                 |                                          | 2192690          | 0.07%                                          | 1.67%                                           | 0.0011%            |
| Texas\Mason            | 19248                       | 165                                  |                                          | 536402           | 0.03%                                          | 3.59%                                           | 0.0011%            |
| Texas\Tom Green        | 106744                      | 87                                   |                                          | 923509           | 0.01%                                          | 11.56%                                          | 0.0011%            |
| Florida\Sumter         | 7594                        | 33                                   |                                          | 159789           | 0.02%                                          | 4.75%                                           | 0.0010%            |
| Texas\Jefferson        | 29858                       | 36                                   |                                          | 333255           | 0.01%                                          | 8.96%                                           | 0.0010%            |
| Alabama\Barbour        | 14617                       | 26                                   |                                          | 199129           | 0.01%                                          | 7.34%                                           | 0.0010%            |
| California\Humboldt    | 2382                        | 997                                  | 370                                      | 597477           | 0.23%                                          | 0.40%                                           | 0.0009%            |
| Texas\Jack             | 16620                       | 175                                  |                                          | 576091           | 0.03%                                          | 2.88%                                           | 0.0009%            |
| Hawaii\Hawaii          | 45872                       | 89                                   |                                          | 683819           | 0.01%                                          | 6.71%                                           | 0.0009%            |
| Wyoming\Albany         | 4309                        | 6972                                 |                                          | 1856054          | 0.38%                                          | 0.23%                                           | 0.0009%            |
| Alabama\Sumter         | 4428                        | 62                                   |                                          | 180931           | 0.03%                                          | 2.45%                                           | 0.0008%            |
| Missouri\Iron          | 722                         | 56                                   |                                          | 69801            | 0.08%                                          | 1.03%                                           | 0.0008%            |
| Texas\Blanco           | 13047                       | 87                                   |                                          | 395667           | 0.02%                                          | 3.30%                                           | 0.0007%            |
| Nebraska\Thomas        | 703                         | 1523                                 |                                          | 424918           | 0.36%                                          | 0.17%                                           | 0.0006%            |
| Texas\Palo Pinto       | 22811                       | 77                                   |                                          | 551494           | 0.01%                                          | 4.14%                                           | 0.0006%            |
| New Mexico\Otero       | 12409                       | 573                                  |                                          | 1126432          | 0.05%                                          | 1.10%                                           | 0.0006%            |
| Texas\Kendall          | 5919                        | 102                                  |                                          | 342515           | 0.03%                                          | 1.73%                                           | 0.0005%            |
| New Mexico\Sierra      | 3302                        | 2346                                 | 75                                       | 1344339          | 0.18%                                          | 0.25%                                           | 0.0004%            |

| County               | Acres<br>Using<br>Herbicide | Harvested<br>Acres of<br>Alfalfa Hay | Harvested<br>Acres<br>Alfalfa<br>Haylage | Acres in<br>Farm | % of Farm<br>Acres in<br>Alfalfa<br>Forage (a) | % of Farm<br>Acres<br>Using<br>Herbicide<br>(b) | (c) = (a)<br>x (b) |
|----------------------|-----------------------------|--------------------------------------|------------------------------------------|------------------|------------------------------------------------|-------------------------------------------------|--------------------|
| New Mexico\Taos      | 100                         | 8948                                 | 129                                      | 456932           | 1.99%                                          | 0.02%                                           | 0.0004%            |
| New Mexico\Mora      | 508                         | 6610                                 | 382                                      | 914549           | 0.76%                                          | 0.06%                                           | 0.0004%            |
| Missouri\Reynolds    | 754                         | 63                                   |                                          | 107281           | 0.06%                                          | 0.70%                                           | 0.0004%            |
| New Mexico\Guadalupe | 7881                        | 1019                                 |                                          | 1405030          | 0.07%                                          | 0.56%                                           | 0.0004%            |
| Texas\Presidio       | 7315                        | 932                                  |                                          | 1559722          | 0.06%                                          | 0.47%                                           | 0.0003%            |
| Nebraska\Hooker      | 360                         | 1460                                 |                                          | 456758           | 0.32%                                          | 0.08%                                           | 0.0003%            |
| Texas\Ward           | 548                         | 658                                  |                                          | 432920           | 0.15%                                          | 0.13%                                           | 0.0002%            |
| Texas\Maverick       | 2852                        | 112                                  |                                          | 473683           | 0.02%                                          | 0.60%                                           | 0.0001%            |
| Texas\Ector          | 1234                        | 158                                  |                                          | 423919           | 0.04%                                          | 0.29%                                           | 0.0001%            |
| Texas\La Salle       | 6434                        | 60                                   |                                          | 649126           | 0.01%                                          | 0.99%                                           | 0.0001%            |
| New Mexico\Grant     | 740                         | 280                                  |                                          | 1213349          | 0.02%                                          | 0.06%                                           | 0.0000%            |
| Arizona\Navajo       | 950                         | 2694                                 |                                          | 4502752          | 0.06%                                          | 0.02%                                           | 0.0000%            |
| New Mexico\McKinley  | 431                         | 2509                                 |                                          | 3172899          | 0.08%                                          | 0.01%                                           | 0.0000%            |
| New Mexico\Cibola    | 88                          | 1184                                 |                                          | 1478697          | 0.08%                                          | 0.01%                                           | 0.0000%            |
| New Mexico\San Juan  |                             | 28587                                | 52                                       | 1630556          | 1.76%                                          | 0.00%                                           | 0.0000%            |
| Wyoming\Niobrara     |                             | 12974                                |                                          | 1449111          | 0.90%                                          | 0.00%                                           | 0.0000%            |
| Wyoming\Hot Springs  |                             | 9766                                 |                                          | 547084           | 1.79%                                          | 0.00%                                           | 0.0000%            |
| Nevada\Clark         |                             | 1742                                 |                                          | 88381            | 1.97%                                          | 0.00%                                           | 0.0000%            |
| Minnesota\Cook       |                             | 157                                  |                                          | 2402             | 6.54%                                          | 0.00%                                           | 0.0000%            |



**Appendix L.      Health and Safety Risks from  
Increased Glyphosate and Other  
Chemical Usage on Humans  
(Exclusive of Field Workers)**

# **Health and Safety Risks from Increased Glyphosate and Other Chemical Usage on Humans (Exclusive of Field Workers)**

## **Executive Summary**

In an effort to assess the potential health and safety risks from increased glyphosate and other chemical usage on humans (exclusive of field workers) due to the deregulation of glyphosate-tolerant alfalfa by the U.S. Department of Agriculture (USDA) in 2005, a human health risk and safety assessment was conducted for glyphosate usage on glyphosate-tolerant (GT) alfalfa. Conservative hazard estimates suggest that the majority of the population is not at risk for adverse health effects associated with acute exposure to glyphosate. Based on upper estimates of exposure, however, infants consuming fruit and all age groups consuming vegetables may be at risk for adverse effects associated with acute exposure to glyphosate. More details on the toxicity and risk of glyphosate are discussed in this technical report.

Glyphosate is a broad spectrum herbicide. It is a systemic, post-emergence herbicide widely used on agricultural commodities (food uses) and non-agriculture sites. Glyphosate absorbs directly through plant leaves and rapidly spreads throughout the plant. The use of surfactants enables greater leaf penetration. Glyphosate's mode of action is as a potent and specific inhibitor of the enzyme, 5-enolpyruvylshikimate 3-phosphate synthase. This enzyme is located in the shikimate pathway and is essential for the biosynthesis of aromatic amino acids and other aromatic compounds in algae, higher plants, bacteria, fungi, and apicomplexan parasites. The shikimate pathway is absent in mammals.

Glyphosate is among the most widely used pesticides by volume in the United States and other glyphosate products are available; however, use data for GT alfalfa were only found for Monsanto products. The only products approved and that have a subsequent proposed maximum use rate for GT alfalfa are the following Monsanto glyphosate herbicide products: Honcho, Honcho Plus, Roundup Original MAX, Roundup WeatherMAX, and Roundup Ultra MAX II. Glyphosate products can be formulated to have different concentrations of glyphosate acid per gallon of product. To improve handling, performance, and concentration, the glyphosate acid is formulated as a salt compound. The term acid equivalent (a.e.) refers to the weight of the glyphosate acid, which is herbicidally active, while the term active ingredient (a.i.) is the weight of the glyphosate acid plus the salt. It is best to refer to a.e. when comparing glyphosate products and rates.

The United States Environmental Protection Agency (US EPA) and the states (usually the state's agriculture office) are responsible for registering or licensing pesticides for use in the United States. US EPA receives its authority to register pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Glyphosate was registered as an herbicide pesticide within the United States through the US EPA. The US EPA's toxicological database on

glyphosate is considered adequate and complete (US EPA, 2006; 1993), and based on this data, glyphosate is considered to be a toxicologically low-risk herbicide (Cerdeira and Duke, 2006). According to the Reregistration Eligibility Decision document for glyphosate (US EPA, 1993), glyphosate is of relatively low oral and dermal acute toxicity. For this reason, glyphosate has been assigned to Toxicity Categories III and IV for these effects (i.e., Toxicity Category I indicates the highest degree of acute toxicity, and Category IV the lowest). Furthermore, an acute inhalation study was waived by the US EPA because glyphosate is a non-volatile solid and the studies conducted on the end-use product formulation are considered sufficient. In terms of subchronic and chronic toxicity, one of the more consistent effects of exposure to glyphosate is loss of body weight. This observed weight loss may be consistent with experimental data indicating glyphosate's mechanism of action. Other general and non-specific signs of toxicity from subchronic and chronic exposure to glyphosate include changes in liver weight, blood chemistry (may suggest mild liver toxicity), liver pathology, and pituitary weight (USDA, 2003). Glyphosate is not considered a carcinogen; it has been classified by the US EPA as a Group E carcinogen (evidence of non-carcinogenicity for humans) (US EPA, 2006; 1993).

The general public may be exposed to herbicides used on glyphosate-tolerant (GT) alfalfa if they consume crops that were grown near GT alfalfa fields. Acute oral exposure estimates from fruit ingestion for adults ranged from zero to 1.25 mg/kg body weight per day. For elderly people, acute oral exposure estimates from fruit ingestion ranged from 0.0125 to 0.45 mg/kg body weight per day. For infants, acute oral exposure estimates from fruit ingestion ranged from zero to 6.32 mg/kg bodyweight per day. Acute oral exposure estimates from vegetable ingestion for adults ranged from 0.185 to 4.61 mg/kg body weight per day. For elderly people, acute oral exposure estimates from vegetable ingestion ranged from 0.222 to 5.11 mg/kg body weight per day. For infants, acute oral exposure estimates from vegetable ingestion ranged from 0 to 12.1 mg/kg body weight per day.

Central and lower hazard quotient (HQ) estimates were all under 1, suggesting that the majority of the population is not at risk of adverse health effects associated with acute exposure to glyphosate. Based on upper estimates of exposure, however, infants consuming fruit and all age groups consuming vegetables may be at risk of adverse effects associated with acute exposure to glyphosate. The age group at highest risk is infants under one year of age, which is consistent with US EPA's findings (US EPA, 2006; 1993). The upper estimate HQ for infants with acute exposure to fruit was approximately 3. The upper estimate HQs for all age groups with acute exposure to vegetables ranged from approximately 2 to 6. These results are all over 1, suggesting the potential for adverse health effects associated with glyphosate. It should be noted, though, that the upper estimates of risk are based on highly conservative fruit and vegetable intake rates; thus it is anticipated that only a very small number of individuals will have this magnitude of exposure and therefore be at this level of risk.

Chronic oral exposure estimates from fruit ingestion for adults ranged from 0 to 0.683 mg/kg body weight per day. For elderly people, chronic oral exposure estimates from fruit ingestion ranged from 0.00682 to 0.246 mg/kg body weight per day. For infants, chronic oral exposure estimates from fruit ingestion ranged from 0 to 3.46 mg/kg body weight per day. Chronic oral exposure estimates from vegetable ingestion for adults ranged from 0.101 to 2.52 mg/kg body weight per day. For elderly people, chronic oral exposure estimates from vegetable ingestion

ranged from 0.122 to 2.80 mg/kg body weight per day. For infants, chronic oral exposure estimates from vegetable ingestion ranged from zero to 6.65 mg/kg body weight per day.

Central and lower HQ estimates were all under 1, suggesting that the majority of the population is not at risk of adverse health effects associated with chronic exposure to glyphosate. Based on upper estimates of exposure, however, infants consuming fruit and all age groups consuming vegetables may be at risk of adverse effects associated with chronic exposure to glyphosate. The age group at highest risk is infants under one year of age, which is consistent with US EPA's findings (1993, 2006). The upper estimate HQ for infants with chronic exposure to fruit was approximately 2. The upper estimate HQs for all age groups with chronic exposure to vegetables ranged from approximately 1 to 3. These results are all greater than or equal to one, suggesting the potential for adverse health effects associated with glyphosate. It should be noted, though, that the upper estimates of risk are based on highly conservative fruit and vegetable intake rates; thus it is anticipated that only a very small number of individuals will have this magnitude of exposure and, therefore, be at this level of risk.



## 1.0 Introduction

### 1.1 Background

In June 2005, the United States Department of Agriculture (USDA) approved the use of Roundup Ready® alfalfa, the only commercially available genetically engineered alfalfa on the market. The Monsanto Company (Monsanto) produced this glyphosate tolerant (GT) alfalfa variety in partnership with the largest alfalfa seed company, Forage Genetics International. This genetically engineered alfalfa is resistant to the herbicide glyphosate (i.e., the alfalfa is able to survive applications of the herbicides containing glyphosate), the active ingredient in the Monsanto Company's trademark herbicide, Roundup®. The transgene responsible for glyphosate resistance was first introduced in soybeans in 1996, and has been commercialized in several other crops (e.g., corn, canola, and cotton) since then. Alfalfa is the first perennial GT crop that was approved for commercial planting in the United States. In 2005 when GT alfalfa was introduced commercially, only 0.2% of the total harvested alfalfa was GT alfalfa; however, in 2006, three million pounds of seed was made available for planting (Gianessi and Reigner, 2006).

Glyphosate was first introduced as an herbicide under the trade name of Roundup by Monsanto in 1974. Glyphosate is a non-selective herbicide registered for use on many food and non-food field crops as well as non-crop areas where total vegetation control is desired. Glyphosate is among the most widely used pesticides by volume (US EPA, 1993). Glyphosate use increased more than six-fold between 1992 and 2002, to become the most used herbicide in the United States, in most part due to approval of several GT crops (Gianessi and Reigner, 2006). In 1997, it was listed on the Agency of Toxic Substances and Disease Registry's (ATSDR) 100 most frequently released substances (ATSDR, 1997).

A controversy exists over whether glyphosate usage has increased as a result of GT crops. A few studies have claimed that the volume of herbicide use is greater due to GT crops (Benbrook, 2004; 2003; 2001). On the other hand, others, such as Heimlich et al. (2000) have indicated there has not been a significant increase in the amount of glyphosate usage since emergence of GT crops. Heimlich et al. (2000) noted that using glyphosate has resulted in the replacement of herbicides that are at least three times as toxic and persist almost twice as long as glyphosate. For example, in cotton and soybeans fields, for the most part, several herbicides were replaced by glyphosate (million pounds reduction): bentazon (-4.4), disodium methanearsenate (DSMA; -0.8), fluometuron (-4.5), imazethapyr (-1.0), metribuzin (-1.5), methylarsonic acid sodium salt (MSMA) (-1.7), paraquat (-2.9), pendimethalin (-14.0), sethoxydim (-1.1), and trifluralin (-13.0). Furthermore, prior to 2002, metolachlor, which accounted for 67 million pounds of herbicide used in 1997, was voluntarily withdrawn from the market prior to 2002; R/S Metolachlor was voluntarily cancelled, but S-Metolachlor replaced it on the market. Glyphosate was adopted on many soybean acres that were previously treated with metolachlor. Cyanazine, which accounted for 20 million pounds of herbicide used in 1997, was also voluntarily withdrawn from the market prior to 2002 and replaced by glyphosate for use on cotton and corn. In addition to glyphosate, corn producers replaced cyanazine with the herbicides mesotrione, rimsulfuron, and simazine (Gianessi and Reigner, 2006).

Additionally, Trewavas and Leaver (2001) conducted an analysis which revealed that 3.27 million kg of other herbicides have been replaced with 2.45 million kg of glyphosate in soybean fields in the U.S. Carpenter and Gianessi (2003) concluded that the introduction of GT soybeans has resulted in a decrease in the total volume of herbicides used. Gianessi (2005) estimates that averaged over all GT crops, GT technology has reduced herbicide use by 17 million kg/year in the U.S. However, Gianessi's (2005) calculations indicate that if GT sugarbeets were adopted, reduction in herbicide use would not be as great as for combined GT crops, because the herbicides used now in non-transgenic sugarbeets are mainly low use rate compounds in the U.S.

## 1.2 Methodology

In the preparation of this human health risk assessment, literature searches of glyphosate toxicity and exposure were conducted in the open literature using the literature search strategy presented in appendix L-2 of this technical report. This human health risk assessment is not a comprehensive summary of all of the available information and does not cite all of the available literature. As USDA determined in 2003, an all inclusive and detailed review of each study would tend to obscure rather than inform. Therefore this document relies on the information that is likely to impact the risk assessment. Primary sources of data were obtained from the following three documents: the United States Environmental Protection Agency (US EPA) 1993 Reregistration Eligibility Decision (RED) document on glyphosate (US EPA, 1993); the U.S. EPA's Glyphosate Human Health Risk Assessment for Proposed Use on Indian Mulberry and Amended Use on Pea, Dry (US EPA, 2006); and the USDA, Forest Service 2003 human health and ecological risk assessment on glyphosate (USDA, 2003). However, several DIALOG databases were searched, and Google, and Google Scholar search engines supplemented the DIALOG search. References were selected from the extensive list of literature based on requesting the abstracts and determining if the open literature data were not included in the three primary documents listed below or provided contrary or controversial information to these documents.

Additionally, for the exposure assessment, the application rate of glyphosate on GT alfalfa was determined by reviewing the five glyphosate herbicide formulations that are labeled for use on GT alfalfa and report the maximum daily and yearly use rate on GT alfalfa. These formulations are all Monsanto Company products, as GT alfalfa is also a Monsanto product. To develop the quantitative risk assessment the maximum use rate was determined to be 1.99 lb a.e./acre for a single use (rounded to 2 lb a.e./acre in calculations), with minimum reapplication within seven days and not to exceed 7.98 lb a.e./acre in a year. The maximum label rate for a single ground use of Roundup® products used on GT alfalfa is 1.55 lb a.e./acre. Thus, the risk assessment is a conservative one. Furthermore, it should be noted that in this technical report, the term a.e. refers to the weight of the glyphosate acid, which is herbicidally active, while the term active ingredient (a.i.) is the weight of the glyphosate acid plus the salt.

## 2.0 Overview of Glyphosate

### 2.1 Glyphosate

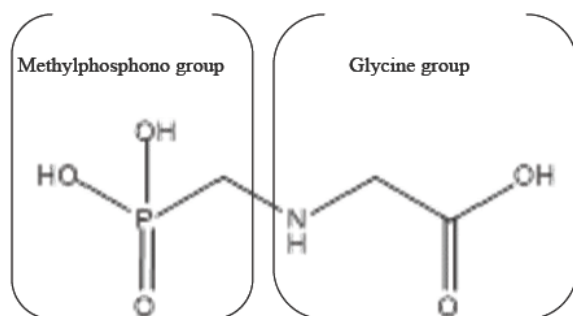
Glyphosate is a systemic, post-emergence herbicide widely used on agricultural commodities (food uses) and non-agriculture sites. Glyphosate salts serve as the source of *N*-(phosphonomethyl)glycine. Several salts of glyphosate with different counter cations are currently marketed. Each salt has a different “glyphosate equivalent”, which is defined as the ratio of the molecular weight of *N*-(phosphonomethyl)-glycine to the molecular weight of the salt. While GT alfalfa could tolerate other herbicides formulated with glyphosate, there are only certain glyphosate herbicides approved for use on GT alfalfa. The five currently approved glyphosate-containing herbicides are presented in table L-1. For the remainder of this report, these products will be referred to simply as glyphosate formulations.

**Table L-1. End Use Products Approved for Use on Glyphosate-Tolerant Alfalfa**

| Product Name             | % Salt | Glyphosate salt CAS No.           | USEPA PC Code | Surfactant                                           | Manufacture     |
|--------------------------|--------|-----------------------------------|---------------|------------------------------------------------------|-----------------|
| Honcho®                  | 41     | Isopropylamine<br>CAS: 38641-94-0 | 103601        | Alkyl Tallow<br>Ethoxylated Amines<br>CAS 61791-26-2 | Monsanto, 2007a |
| Honcho Plus®             | 41     | Isopropylamine<br>CAS: 38641-94-0 | 103601        | Trade Secret                                         | Monsanto, 2007b |
| Roundup Original<br>MAX® | 48.7   | Potassium<br>CAS: 70901-12-1      | 103613        | Trade Secret                                         | Monsanto, 2007c |
| Roundup<br>WeatherMAX®   | 48.8   | Potassium<br>CAS: 70901-12-1      | 103613        | Trade Secret                                         | Monsanto, 2007d |
| Roundup Ultra<br>MAX II® | 48.8   | Potassium<br>CAS: 70901-12-1      | 103613        | Trade Secret                                         | Monsanto, 2004  |

#### *Structure and Nomenclature*

Glyphosate is a substituted glycine, the simplest amino acid. The glyphosate molecule has a methylphosphono group bonded to the nitrogen atom of the amino group of glycine as denoted in figure L-1 below.



**Figure L-1: Glyphosate molecular structure**

Glyphosate's structure and nomenclature are presented in table L-2 below.

**Table L-2. Glyphosate Structure and Nomenclature**

| Property                                               | Value                                           | Source             |
|--------------------------------------------------------|-------------------------------------------------|--------------------|
| Common Name                                            | Glyphosate                                      | US EPA, 2006; 1993 |
| International Union of Pure and Applied Chemistry Name | <i>N</i> -(phosphonomethyl)glycine              | US EPA, 2006; 1993 |
| Chemical Abstract Registry Number                      | 1071-83-6                                       | US EPA, 1993       |
| Empirical Formula                                      | C <sub>3</sub> H <sub>8</sub> NO <sub>5</sub> P | US EPA, 2006       |
| Smiles notation                                        | OC(=O)CNC(P(O)(O)=O                             | EPI Suite          |
| PC Code                                                | 417300                                          | US EPA, 1993       |

### 2.1.2 Physical and Chemical Properties

Physical and chemical properties of glyphosate are in table L-3 below.

**Table L-1. Physical and Chemical Properties of Glyphosate**

| Property                                                                          | Value                                                                                                                     | Source       |
|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|--------------|
| Molecular Weight g                                                                | 169.07                                                                                                                    | USDA, 2003   |
| Density at 25°C                                                                   | 1.7                                                                                                                       | US EPA, 1993 |
| Solubility in water at 25°C                                                       | 12,000 mg/L                                                                                                               | US EPA, 1993 |
| pKa                                                                               | 0.8 first phosphonic acid<br>2.3 carboxylate<br>6.0 second phosphonic acid<br>11.0 amine                                  |              |
| Vapor Pressure at 25°C, Pa                                                        | $1.3 \times 10^{-7}$                                                                                                      | US EPA, 1993 |
| Henry's Law Constant (Pa m <sup>3</sup> /mol)                                     | $2.1 \times 10^{-9}$                                                                                                      | US EPA, 1993 |
| Log Kow                                                                           | -3                                                                                                                        | US EPA, 1993 |
| Hydrolysis                                                                        | Stable ≥30 days at pH 3, 6, and 9 at 5 and 35°C                                                                           | US EPA, 1993 |
| Photolysis                                                                        | Does not absorb light energy pH 5, 7, and 9                                                                               | US EPA, 1993 |
| Metabolism in soil, half life                                                     | 1.85 – 2.06 day                                                                                                           | US EPA, 1993 |
| Metabolism water-sediment system, half life                                       | Aerobic: 7 days<br>Anaerobic: 8.1 – 199 days                                                                              | US EPA, 1993 |
| Soil Mobility, K <sub>ads, Freundlich</sub>                                       | 9.4 – 700 mL/g                                                                                                            | US EPA, 1993 |
| Soil water partition coefficient K <sub>d (adsorption)</sub>                      | 62 Drummer silty clay loam<br>90 Ray silt<br>70 Spinks sandy loam<br>22 Lintonia sandy loam<br>175 Cattail swamp sediment | US EPA, 1993 |
| Soil adsorption K <sub>oc</sub>                                                   | 2100 (500 – 2600) (L/kg)<br>2600 – 4900 (L/kg)<br>8 to >500,000 (L/kg)<br>54 (L/kg)                                       | USDA, 2003   |
| Metabolite                                                                        | aminomethyl phosphonic acid (AMPA)                                                                                        | US EPA, 1993 |
| Field dissipation (application rate: 7.95 lb ae/acre, 10.7 lb ai/acre), half life | 13.9 days (median)<br>2.6 days in Texas<br>140.6 days Iowa                                                                | US EPA, 1993 |
| Aquatic field dissipation, half life                                              | 7.5 days and 120 days                                                                                                     | US EPA, 1993 |
| Bioaccumulation in fish                                                           | 0.38X edible tissue<br>0.63X nonedible tissue<br>0.52X whole fish                                                         | US EPA, 1993 |

## 2.2 Summary of Findings

Glyphosate is a systemic, post-emergence herbicide widely used on agricultural commodities (food uses) and non-agriculture sites. Glyphosate salts serve as the source of *N*-(phosphonomethyl)glycine. Several salts of glyphosate with different counter cations are currently marketed. At ambient temperatures, glyphosate is a white crystalline substance that is not volatile with high water solubility. In the crystalline form, glyphosate has both positive and negative regions of charge these dipolar ion species are sometimes referred to as a zwitterion. In aqueous solutions, the hydrogen atoms of the carboxylic acid (COOH) and phosphate (PO<sub>2</sub>H<sub>2</sub>) groups may be associated or dissociated depending on the pH of the solution. These dipolar ion species are the regions expected to bond to carbon containing molecules in the soil. Glyphosate is in a liquid form for herbicide formulations; generally, the composition of the herbicide is considered a trade secret. One formulation of glyphosate, Honcho®, has a tallow amine surfactant (Monsanto, 2007a). This and other surfactants are added to the herbicide formulations to increase leaf penetration.

## 3.0 Human Health Risk Assessment

### 3.1 Hazard Identification

This general public risk assessment focuses on risks associated with exposure to herbicides recommended for use on GT alfalfa, all of which contain the active ingredient glyphosate. The risk assessment is presented in four sections including a hazard identification section in which toxicological data on glyphosate are reviewed and summarized, an exposure assessment section, in which exposure estimates for the general public are presented, a dose-response assessment section, in which health benchmarks for glyphosate are reviewed and recommended for different exposure scenarios, and, finally, a risk characterization section, in which worker exposure estimates are compared to health benchmarks to determine the potential for adverse health effects associated with general exposures to glyphosate.

#### 3.1.1 Overview

According to the US EPA, the existing toxicity database for glyphosate is complete and without data gaps. There is high confidence in the quality of the existing studies and the reliability of the toxicity endpoints identified for use in risk assessment (US EPA, 2006; 1993). In general, the herbicidal activity of glyphosate is due primarily to a metabolic pathway that does not occur in humans or other animals, and, thus, this mechanism of action is not directly relevant to the human health risk assessment. However, little has been elucidated regarding glyphosate's mechanism of action in humans or experimental animals. Nonetheless, the US EPA considers glyphosate to be of low acute toxicity by oral, dermal, and ocular routes of exposure, since all studies are classified as Toxicity Category III (slightly toxic) or IV (practically non-toxic). Furthermore, an acute inhalation study was waived by the US EPA because glyphosate is a non-volatile solid and the studies conducted on its end-use product (EUP) formulations are considered sufficient (US EPA, 2006; 1993).

In terms of subchronic and chronic toxicity, one of the more consistent effects of exposure to glyphosate is loss of body weight. This observed weight loss may be consistent with experimental data indicating glyphosate's mechanism of action as an uncoupler of oxidative phosphorylation (see section 3.1.2). Other general and non-specific signs of toxicity from subchronic and chronic exposure to glyphosate include changes in liver weight, blood chemistry (may suggest mild liver toxicity), liver pathology, and in pituitary weight (USDA, 2003). Glyphosate is not a carcinogen, however, and has been classified by the US EPA as a Group E carcinogen (evidence of non-carcinogenicity for humans) (US EPA, 2006; 1993). Glyphosate's toxicity database and its mechanism of action are discussed in greater detail in the following sections. Additionally, a summary table of the toxicology studies included in the USDA (2003) and US EPA (1993) documents is included in appendix L-3 of this technical report.

### 3.1.2 Mechanisms of Action

In plants, glyphosate is a potent and specific inhibitor of the enzyme 5-enolpyruvylshikimate 3-phosphate synthase (EPSPS) in plants. EPSPS is the sixth enzyme on the shikimate pathway and it is essential for the biosynthesis of aromatic amino acids and other aromatic compounds in algae, higher plants, bacteria, fungi, and apicomplexan parasites. However, this metabolic pathway does not exist in humans or other animals (USDA, 2003; US EPA 1993).

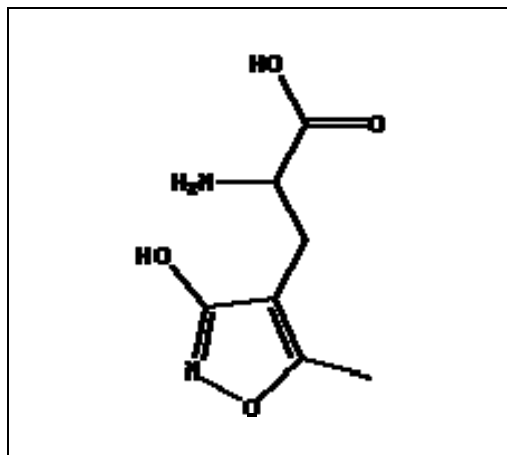
While its mechanism of action in plants is well understood, not much is known about glyphosate's ability to cause toxic effects in humans or experimental animals. Corrosive effects on the gastric mucosa, as well as other tissues, are a consistent response following acute oral exposure to high doses of glyphosate or polyethoxylated tallow amine (POEA), a surfactant included in some glyphosate formulations. However, it is speculated that the biochemical pathway leading to mucosal effects differs for each glyphosate and POEA. At present, there are two proposed biochemical mechanisms of action in humans for glyphosate: uncoupling of oxidative phosphorylation and inhibition of hepatic mixed function oxidases (USDA, 2003).

Oxidative phosphorylation is a process where nutrients are oxidized to yield metabolic energy which is then transferred to high-energy phosphate bonds and stored. Glyphosate appears to be an uncoupler of oxidative phosphorylation based on the results of a series of experiments using rat liver mitochondria that was exposed to glyphosate (USDA, 2003). When glyphosate uncouples this process, the result is a loss of energy and eventually death. Symptoms such as increased heart and respiratory rate, labored breathing, profuse sweating, fever, metabolic acidosis, and weight loss may occur in response to the uncoupling of oxidative phosphorylation. Uncoupling of the oxidative phosphorylation process has been seen after experimental animals were given intraperitoneal doses as low as 15 mg/kg. However, it has not been determined if uncoupling of oxidative phosphorylation plays a major role in acute exposures (USDA, 2003).

Inhibition of hepatic mixed-function oxidases may also account for some of the toxic effects observed following glyphosate exposure. Hepatic mixed-function enzymes are comprised of various isozymes of cytochrome P-450, which is involved in the metabolism of a variety of endogenous compounds as well as xenobiotics. In a study by Hietanen et al. (1983), a decrease in hepatic mixed-function oxidase activity was observed in rats after a 500 mg/kg/day dose of glyphosate for four days followed by doses of 300 mg/kg/day for six days. While, this decrease in hepatic mixed-function oxidase activity is only indicative of cytochrome P-450 inhibition, it has been suggested that this effect may be due to glyphosate's inhibition of cytochrome P-450, since glyphosate has caused inhibition in plants (USDA, 2003).

### 3.1.3 Kinetics and Metabolism

The residue of concern for risk assessment purposes is glyphosate *per se*. Glyphosate's only known metabolite, aminomethylphosphonate (AMPA; see figure L-2), is not included in either the tolerance expression or the risk assessment (US EPA, 2006). While AMPA is a common environmental metabolite, only trace amounts of it are formed in mammals, with the remainder being excreted unchanged. For this reason, direct exposures to AMPA, as an endogenous metabolite in animals, are encompassed by the existing toxicity data on glyphosate.



**Figure L-2: Chemical structure of AMPA**

Since glyphosate is rapidly eliminated from the body and shows a lack of degradation into toxic metabolites, dose levels expressed in mg/kg/day display analogous effects over broad periods of exposure (USDA, 2003). For the general public, the majority of exposures to glyphosate are via the oral and dermal route. Select results from both oral and dermal absorption studies are discussed below.

According to experimental studies, glyphosate is not completely absorbed following oral administration. Much of the reviewed literature has revealed that only about 30% of glyphosate is absorbed from the gastrointestinal tract after oral exposure (USDA, 2003). One metabolism study available at the time of the 1993 reregistration of glyphosate involved a single or repeated dose of radiolabeled  $^{14}\text{C}$ -glyphosate administered orally to Sprague-Dawley rats. Of this dose, 30-36% was absorbed, <0.27% was eliminated as  $\text{CO}_2$ , 97.5% was excreted in the urine and feces as parent compound, and 0.4-0.7% was excreted in the urine and feces as AMPA. Repeated dosing did not significantly change the metabolism (US EPA, 1993).

Furthermore, studies conducted by Davies (1996e), indicate that the majority of unabsorbed glyphosate remains in the gastrointestinal tract, while the absorbed glyphosate is widely distributed throughout the body. The highest concentrations of glyphosate are found in the bone relative to other tissues, although glyphosate does not significantly concentrate or persist in any tissue (US EPA, 1993). A second metabolism study available at the time of the 1993 reregistration of glyphosate involved dosing Sprague-Dawley rats with a single 1150 mg/kg intraperitoneal injection of radiolabeled  $^{14}\text{C}$ -glyphosate. Approximately 0.0044-0.0072% of this dose was found in the bone marrow after 30 minutes. The half-life of glyphosate in bone marrow was 7.6 hours for males and 4.2 hours for females. In addition, the study determined that the half life of glyphosate in plasma was 1 hour for both sexes (US EPA, 1993).

Glyphosate is also poorly absorbed following dermal applications. Two dermal absorption studies performed by Wester et al. (1991; 1996) indicate that glyphosate is poorly absorbed



across the skin. One of the studies was performed using skin from human cadavers. In this study, the cadaver skin was exposed to an undiluted glyphosate herbicide formulation (i.e., Roundup) for eight hours and diluted formulations (i.e., 1:20 and 1:32 dilutions of Roundup) for up to 16 hours. In general, formulations generally contain more of the POEA surfactant than the active ingredient, glyphosate. Based on 16-hours of exposure to the diluted formulations, first-order dermal absorption rates ranged from  $1.3 \times 10^{-4}$  to  $1.0 \times 10^{-3} \text{ h}^{-1}$  (average:  $4.1 \times 10^{-4} \text{ h}^{-1}$ ), while first-order dermal absorption rates after 8-hours of exposure to the more concentrated formulation ranged from  $7.5 \times 10^{-5}$  to  $5.1 \times 10^{-4}$  (USDA, 2003). The results of this study indicated that glyphosate containing more of the POEA surfactant (i.e., the undiluted formulation) did not absorb more rapidly than a glyphosate formulation with a less concentrated solution of surfactant. A second study was performed on monkeys and found that after 12 hours of exposure approximately 1.5% of the glyphosate was absorbed in 12 hours, which is equivalent to a first-order dermal absorption rate of  $1.3 \times 10^{-3} \text{ hour}^{-1}$  (Wester, 1991). These experimental measurements and methods are consistent with other derived values and standard methods used to estimate first-order dermal absorption rates (USDA, 2003)

### *3.1.4 Acute Systemic Toxicology*

As is common with most chemicals, acute exposure to glyphosate and its commercial formulation may be toxic at sufficiently high levels. For example, an experiment performed by Williams et al. (2000) on rats and mice found that acute oral LD<sub>50</sub> values (the lethal dosage required to kill 50 percent of a population of test animals) of glyphosate range from approximately 2,000 to 6,000 mg/kg and acute oral intraperitoneal LD<sub>50</sub> values, which are about 10 times lower in value, range from 134 to 234 mg/kg (USDA, 2003). Additionally, systemic differences in toxicity do not appear to exist among species when doses of glyphosate are expressed in units of mg/kg body weight.

Documentation suggests that exposure to glyphosate with a POEA surfactant is a common means of suicide, and this fact can be used to make a determination about its effects on humans. In an analysis of suicide cases in Taiwan, doses of glyphosate/surfactant formulations in the range of  $330 \pm 42 \text{ mL}$  were associated with fatalities and the survivors were correlated with doses of  $122 \pm 12 \text{ mL}$ . Gastrointestinal effects (vomiting, abdominal pain, diarrhea), irritation, congestion, or other forms of damage to the respiratory tract, pulmonary edema, decreased urinary output sometimes accompanied by acute renal tubular necrosis, hypotension, metabolic acidosis, and electrolyte imbalances, probably secondary to the gastrointestinal and renal effects, are seen in human cases of glyphosate/surfactant exposure. It is speculated that the POEA surfactant component in the glyphosate formulations may be the dominant contributing factor leading to the effects seen in these suicide cases (USDA, 2003).

In terms of this risk assessment, however, only the increased use of glyphosate as an herbicide is being considered. According to the US EPA, glyphosate is considered to be of low acute toxicity by oral, dermal, and ocular routes of exposure, since all studies are in Toxicity Category III or IV, considered slightly to practically non-toxic, respectively. Furthermore, an acute inhalation study was waived by the U.S. EPA because glyphosate is a non-volatile solid and the studies conducted on the end-use product formulation are considered sufficient (US EPA, 2006; 1993). Additionally, according to the World Health Organization (WHO), glyphosate has been

classified as unlikely to present an acute hazard in normal use (WHO, 1996). The US EPA's acute toxicity profile for glyphosate is presented in table L-4.

**Table L-4. Acute Toxicity Profile of Glyphosate (US EPA, 2006)**

| <b>US EPA Guideline No.</b> | <b>Study Type</b>       | <b>MRID(s)</b> | <b>Results</b>                                                            | <b>Toxicity Category</b> |
|-----------------------------|-------------------------|----------------|---------------------------------------------------------------------------|--------------------------|
| 870.1100                    | Acute oral              | 41400601       | LD <sub>50</sub> > 5,000 mg/kg                                            | IV                       |
| 870.1200                    | Acute dermal            | 41400602       | LD <sub>50</sub> > 5,000 mg/kg                                            | IV                       |
| 870.1300                    | Acute inhalation        | None           | The requirement for an acute inhalation LC <sub>50</sub> study was waived | None                     |
| 870.2400                    | Acute eye irritation    | 41400603       | Corneal opacity or irritation clearing in 7 days or less                  | III                      |
| 870.2500                    | Acute dermal irritation | 41400604       | Mild or slight irritant                                                   | IV                       |
| 870.2600                    | Skin sensitization      | 41642307       | Not a sensitizer                                                          | None                     |

### *3.1.5 General Subchronic and Chronic Systemic Toxicology*

One of the more consistent signs of subchronic or chronic exposure to glyphosate is loss of body weight. This effect has been noted in mice, rats, dogs, and rabbits. This observed weight loss is consistent with experimental data indicating that glyphosate may be an uncoupler of oxidative phosphorylation. Additionally, the loss of body weight observed was not associated with a significant decrease in food consumption. Other general and non-specific signs of toxicity include liver weight, blood chemistry (may suggests mild liver toxicity), liver pathology, and changes in pituitary weight (USDA, 2003). The results of several subchronic and chronic toxicity studies are presented in table L-5 and discussed in the subsequent paragraphs.

**Table L-5. Subchronic and Chronic Toxicity Profile of Glyphosate (US EPA, 2006)**

| <b>US EPA Guideline No./<br/>Study Type</b>                           | <b>Results</b>                                                                                                                                                                                |
|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 870.3100<br>90-Day oral toxicity (Mouse)                              | NOAEL = 1500 mg/kg/day in males and females<br>LOAEL = 4500 mg/kg/day in males and females based on decreased body weight.                                                                    |
| 870.3100<br>90-Day oral toxicity (Range finding)                      | NOAEL = not established<br>LOAEL = 50 mg/kg/day in males and females based on possible increased phosphorus and potassium values.                                                             |
| 870.3150<br>90-Day oral toxicity (Rat) - AMPA - glyphosate metabolite | NOAEL = 400 mg/kg/day in males and females<br>LOAEL = 1200 mg/kg/day in males and females based on body weight loss and histopathological lesions of the urinary bladder.                     |
| 870.3200<br>21/28-Day dermal toxicity (Rabbit)                        | NOAEL = 1000 mg/kg/day in males and females<br>LOAEL = 5000 mg/kg/day based on slight erythema and edema on intact and abraded skin of both sexes, and decreased food consumption in females. |
| 870.3485<br>28-Day inhalation toxicity (rat)                          | NOAEL = 0.36 mg/L (highest dose tested; HDT)<br>LOAEL = not established based on 6 hours/day, 5 days/week for 4 weeks                                                                         |
| 870.4100b<br>Chronic toxicity (dog)                                   | NOAEL = 500 mg/kg/day in males and females (HDT)<br>LOAEL = not established.                                                                                                                  |

One of the studies included in table L-5 is a 90-day oral toxicity study in rats exposed to AMPA. As noted in the table and previously discussed, AMPA is a metabolite of glyphosate, and in soil and environmental water samples it is found more regularly than glyphosate. AMPA is considered slightly more toxic than glyphosate. However, while AMPA is a common environmental metabolite, only trace amounts of it are formed in mammals, with the remainder being excreted unchanged. For this reason, direct exposures to AMPA, as an endogenous metabolite in animals, are encompassed by the existing toxicity data on glyphosate. For further discussion on the occurrence of environmental concentrations of glyphosate or its metabolite AMPA, see the technical report: *Potential Impacts to Wildlife, Amphibians, Plants, and Ecosystems from Increased Glyphosate and Other Chemical Usage* (appendix N).

Other studies conducted at the time of the 1993 reregistration of glyphosate include two subchronic feeding studies in rodents that showed effects in the blood and pancreas. In the first 90-day feeding study, Sprague-Dawley rats were fed glyphosate for three months in doses equivalent to 0, 63, 317, or 1,267 mg/kg/day for males and 0, 84, 404, or 1,623 mg/kg/day for females. Males and females in all treated groups showed increased serum phosphorus and potassium. The mid-dose group had increased serum glucose. Likewise, the high-dose had increased serum glucose, blood urea nitrogen, and serum alkaline phosphatase and an increased occurrence of pancreatic lesions. US EPA determined that based on these results, the no observed effect level (NOEL) is <63 mg/kg/day for males and <84 mg/kg/day for females. However, these results were considered only possibly treatment related and the NOEL dose for each sex was not determined definitively (US EPA, 1993).

In the second subchronic feeding study, CD-1 mice were fed diets containing 0, 250, 500 or 2,500 mg/kg/day of glyphosate for 90 days. The risk assessment parameters were set based on decreases of body weight gains in the high-dose males and females of about 24% and 18%, respectively. Based on the observed decrease in body weight gain, the NOEL for both sexes is 500 mg/kg/day and the LOEL is 2,500 mg/kg/day (US EPA, 1993).

### *3.1.6 Effects on Nervous System*

There was no evidence of neurotoxicity in any of the toxicology studies conducted and there are no data requirements for neurotoxicity studies. Moreover, analysis of detailed literature on health outcomes of accidental and intentional gross over-exposures, such as suicides, to glyphosate or its commercial formulations also do not implicate it in neurotoxicity effects. The weight of evidence suggests that any neurological symptoms associated with glyphosate exposures were secondary to other toxic effects and cannot be attributed to it directly (USDA, 2003). Also based upon a weight of evidence considerations the conduct of a developmental neurotoxicity study with glyphosate to evaluate the potential for developmental neurotoxic effects was not required (US EPA 2006; USDA, 2003; US EPA1993).

Some of the relevant studies are discussed in the following paragraphs. Many of the other neurological studies conducted presented results that were not considered scientifically robust and, therefore, are not discussed in further detail in this section (USDA, 2003).

Glyphosate has been tested for neurotoxicity in rats after both acute and subchronic exposures, and has been tested for delayed neurotoxicity in hens (USDA, 2003). In an acute study, 10 male and 10 female rats were given doses of 50, 100, or 200 mg of glyphosate a.e./kg and were observed for 2 weeks. In a subchronic study, 12 female and 12 male rats were exposed to glyphosate in their diet at concentrations of 2,000, 8,000, or 20,000 ppm for 13 weeks. In both studies, glyphosate was negative for signs of neurotoxicity. In a third study, twenty hens were given a single gavage dose of glyphosate at 2,000 mg/kg; a slight decrease in brain AchE activity occurred, but there were no signs of delayed motor ataxia or neuropathology (USDA, 2003).

An additional subchronic study in rats and mice, performed by the National Toxicology Program (NTP, 1992), suggests that glyphosate may produce histological changes in the salivary glands in both organisms. While glyphosate may produce changes of the salivary gland by acting through an adrenergic pathway or by producing an adrenergic-mediated stimulation through some indirect mechanism, the mechanism causing this effect is not clearly understood and no signs of neurotoxicity were noted (USDA, 2003).

In an investigation of the effects of glyphosate on sensory mechanisms, 1 mM or 10 mM dose of glyphosate was applied to the tongue of anesthetized gerbils. As a result, their taste tester response (to table salt, sugar, and acids) decreased. Due to the possibility of outside variables affecting experimentation, these results were not classified clearly as a glyphosate-induced neurological effect (USDA, 2003).

### 3.1.7 Effects on Immune System

Glyphosate has been tested for effects on the immune system in humans and experimental animals, in both *in vivo* and *in vitro* studies. In an *in vivo* study performed by Blakley (1997), mice were exposed to glyphosate in their drinking water, at concentrations of 0, 0.35, 0.70, or 1.05 percent, for 26 days; their antibody immune response was evaluated using sheep red blood cell challenge. The study found that the response in exposed mice did not differ from that of the unexposed mice (controls). Additionally, an *in vitro* study using human immunocompetent cells also indicated that glyphosate at concentrations ranging from 0.01 to 10  $\mu$ moles had no effect on the immune system (Flaherty et al., 1991). Furthermore, there is also no evidence to suggest that glyphosate causes dermal sensitization or morphologic abnormalities, in experimental animals, which could implicate an effect on the immune system (USDA, 2003).

In studies performed on humans, there has been no confirmation that glyphosate directly causes photoirritation, photosensitization, or allergic responses (Williams et al, 2000; Jauhiainen et al., 1991; Maibach, 1986). In a 1986 study by Maibach, a group of volunteers were exposed to Roundup via direct dermal application and no significant responses were observed.

### 3.1.8 Effects of Endocrine Function

Of the specific tests conducted to determine potential effects of glyphosate on the endocrine system, none have reported any potential estrogen, androgen, and/or thyroid mediated toxicity resulting from exposure to glyphosate (US EPA, 2006; USDA, 2003).

Glyphosate was inactive as an estrogen receptor agonist in MCF-7 human breast cancer cells (Lin and Garry, 2000) and in yeast and trout hepatocyte assays (Petit et al., 1997). Additionally, in another study, the steroidogenic acute regulatory (StAR) protein, which mediates the rate-limiting step in the mitochondrial synthesis of steroid hormones, was not disrupted by glyphosate; therefore, glyphosate did not inhibit steroid synthesis in MA-10 mouse Leydig tumor cells. In a third test, glyphosate, with surfactant, was found to inhibit steroid synthesis. For all of these studies, it should be noted that they were conducted *in vitro*, and were used to assess whether a plausible biological mechanism for glyphosate to act as an endocrine disruptor exists (USDA, 2003).

### 3.1.9 Reproductive and Teratogenic Effects

Exposure to glyphosate has been evaluated for its effects on reproduction and ability to cause birth defects (teratogenic effects). Most of the literature indicates that glyphosate does not directly cause reproductive or teratogenic effects (US EPA, 2006; 1993; USDA, 2003). Four studies on the maternal, reproductive, and development toxicity of glyphosate were submitted for reregistration of glyphosate in 1993 (US EPA, 2006; 1993). The studies are discussed in the following paragraphs and the results are presented in table L-6.

In the first study, Charles River COBS CD rats were dosed with 0, 300, 1,000, or 3,500 mg/kg/day of glyphosate by gavage during gestation days six through 19. The high dose dams showed signs of diarrhea; decreased mean body weight; breathing rattles; inactivity; red matter around the nose, mouth, forelimbs, and dorsal head; decreases in total implantations per dam and

fetuses per dam; and mortality. Developmental effects were also only seen in the high-dose group and included increased number litters and fetuses with unossified sternebrae and decreased mean fetal body weights. Based on these results, the maternal and developmental toxicity NOAEL and LOAEL are 1,000 mg/kg/day and 3,500 mg/kg/day, respectively (US EPA, 2006; 1993; USDA, 2003).

In a second developmental and maternal toxicity study, Dutch Belted rabbits administered 0, 75, 175, or 350 mg/kg/day during gestation days six through 27 showed treatment-related findings at the highest dose only. These effects included diarrhea, nasal discharge, and death. There were no developmental effects observed, which could be attributable to the high maternal mortality level (62.5% at the highest dose). The NOAEL and LOAEL for maternal toxicity are 175 mg/kg/day and 350 mg/kg/day, respectively (US EPA, 2006; 1993; USDA, 2003).

In a three-generation reproduction study on male and female Sprague-Dawley rats administered 0, 3, 10, or 30 mg/kg/day of glyphosate continuously through diet, increased incidence of focal tubular dilation of the kidney was seen in the high-dose male third generation pups. Therefore, the NOEL for reproductive toxicity is  $\geq 30$  mg/kg/day. The developmental toxicity NOAEL and LOAEL are 10 mg/kg/day and 30 mg/kg/day, respectively (US EPA, 2006; 1993; USDA, 2003).

A second two-generation reproduction study showed treatment-related effects at the high dose when Sprague-Dawley rats were administered 0, 100, 500, or 1,500 mg/kg/day of glyphosate continuously through the diet. These effects included soft stools in the F<sub>0</sub> and F<sub>1</sub> generations, decreased food consumption and body weight gain in the F<sub>0</sub> and F<sub>1</sub> generations during the growth period, and decreased body weight gain in the F<sub>1</sub> and F<sub>2</sub> generations during the second and third week of lactation. Based on these effects, the reproductive and developmental NOELs are 500 mg/kg/day and the reproductive and development LOELs are 1,500 mg/kg/day (US EPA 2006; 1993).

**Table L-6. Reproductive and Teratogenic Toxicity Profile for Glyphosate (US EPA, 2006)**

| Study Type                                                         | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|--------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 870.3700a<br>Prenatal developmental in rodents (Rat)               | <b>Maternal</b> NOAEL = 1,000 mg/kg/day<br>LOAEL = 3,500 mg/kg/day based on inactivity, mortality, stomach hemorrhages and reduced body weight gain.<br><b>Developmental</b> NOAEL = 1,000 mg/kg/day<br>LOAEL = 3,500 mg/kg/day based on increased incidence in the number of fetuses and litters with unossified sternebrae and decreased fetal body weight.                                                                                                                                                                                                               |
| 870.3700b<br>Prenatal developmental in (Rabbit)                    | <b>Maternal</b> NOAEL = 175 mg/kg/day<br>LOAEL = 350 mg/kg/day based on mortality, diarrhea, soft stools, and nasal discharge.<br><b>Developmental</b> NOAEL = 350 mg/kg/day (HDT)<br>LOAEL = not established.                                                                                                                                                                                                                                                                                                                                                              |
| 870.3800<br>Reproduction and fertility effects, 3-generation (Rat) | <b>Parental/Systemic</b> NOAEL = 30 mg/kg/day (HDT)<br><b>Reproductive</b> NOAEL = 30 mg/kg/day (HDT)<br><b>Offspring</b> NOAEL = 10 mg/kg/day<br>LOAEL = 30 mg/kg/day based on focal dilation of the kidney in male F <sub>3b</sub> pups.                                                                                                                                                                                                                                                                                                                                  |
| 870.3800<br>Reproduction and fertility effects, 2-generation (Rat) | <b>Parental/Systemic</b> NOAEL = 500 mg/kg/day in males and females<br>LOAEL = 1,500 mg/kg/day in males and females based on soft stools, decreased body weight gain and food consumption. Focal dilation of the kidney observed at 30 mg/kg/day in the 3-generation study was not observed at any dose level in this study.<br><b>Reproductive</b> NOAEL ≥ 1,500 mg/kg/day (HDT) in males and females<br><b>Offspring</b> NOAEL = 500 mg/kg/day in males and females<br>LOAEL = 1,500 mg/kg/day in males and females based on decreased body weight gain during lactation. |

Additional studies conducted to evaluate the reproductive and teratogenic effects of glyphosate, include subchronic and chronic exposure studies, which attempted to examine the impacts of glyphosate exposure on morphology of reproductive organs, mammary glands, and endocrine glands (including the testis, ovary, pituitary, thyroid, adrenal, pancreas, parathyroid, and thymus). In both types no treatment-related effects on reproductive organs or endocrine glands were observed at or below the maximally tolerated dose of 20,000 ppm in the diet, in the chronic study (Stout and Ruecker, 1990) and 50,000 ppm in the subchronic study (NTP, 1992).

Furthermore, according to USDA (2003), two studies, by Yousef et al. (1996) and Schroeder and Hogan (1981), show conflicting results of glyphosate's effect on mating, fertility, and reproduction parameters (including libido level, ejaculate volume, sperm count, semen fructose level and osmolarity, and number of abnormal or dead sperm). Yousef et al. (1995) found that all of the effects seen in rabbits were statistically significant; however the study does not provide the actual doses used or specify the exact formulation. The study by Schroeder and Hogan (1981) suggests no treatment-related effects of glyphosate at doses of 3, 10, or 20 mg/kg body weight, although some changes in kidney morphology were observed at 30 mg/kg/day. The basis for inconsistency lies in the reporting and experimental design limitations and deficiencies in Yousef's study. Also, the use of gelatin capsules in Yousef et al. (1995) makes his study less comparable and relevant to potential human exposure (USDA, 2003).

In terms of effects in humans, several epidemiological studies have been conducted to assess the relationship between general, or overall, pesticide exposure, or assumed pesticide exposure, and reproductive health outcomes; however most have not characterized exposures to specific pesticides (Arbuckle and Sever, 1998). Of the few studies that have linked exposure to glyphosate to potential risks, no adverse reproductive effects were noted. For example, the Ontario Farm Health Study, three retrospective cohort studies (Arbuckle et al., 2001; Curtis et al., 1999; Savitz et al., 1997) collected data on the relationship between pregnancy outcomes and pesticide use among couples living on farms in Ontario. Risk of miscarriage, spontaneous abortions, and fecundity were all found to be unrelated to glyphosate formulation use and exposure (USDA, 2003).

### *3.1.10 Carcinogenicity and Mutagenicity*

The US EPA and the World Health Organization (WHO; 1994) have reviewed, in detail, information regarding the carcinogenicity and mutagenicity of glyphosate. In 1991, the US EPA classified glyphosate as a Group E carcinogen (evidence of non-carcinogenicity for humans). Likewise, based on three studies submitted (and discussed in the following paragraphs) for the reregistration of glyphosate in 1993, US EPA concluded that glyphosate is not carcinogenic at the levels tested (US EPA, 2006; 1993). The US EPA confirmed this decision again in their publication of tolerance for glyphosate in 2002 (US EPA, 2002).

In the first study considered during the reregistration of glyphosate in 1993, Sprague-Dawley rats were fed glyphosate at levels of 0, 3, 10, or 31 mg/kg/day in males and 0, 3, 11, or 34 mg/kg/day in females for 26 months. The high dose groups showed signs of increased incidence of thyroid C-cell carcinomas in females and interstitial cell testicular tumors, but the U.S. EPA determined that these neoplasms were not treatment-related, noted that the incidence of thyroid carcinomas was not statistically significant, and determined that the incidence of testicular tumors was within historical levels. Therefore, the US EPA determined that glyphosate was not considered carcinogenic in this study (US EPA, 1993).

A second carcinogenicity feeding study was also conducted using Sprague-Dawley rats fed diets containing 0, 89, 362, or 940 mg/kg/day in males and 0, 113, 456, or 1183 mg/kg/day in females of glyphosate. The low- and high-dose males and females showed an increase incidence of pancreatic islet cell adenomas and hepatocellular (liver) adenomas. The mid- and high-dose animals also showed an increased incidence of thyroid C-cell adenomas. However, the pancreatic islet cell adenomas were not associated with a statistically significant positive dose-related trend, a progression to carcinomas, or dose-related increase in pancreatic hyperplasia. Additionally, statistically significant increase in incidence of hepatocellular adenomas was not seen and the incidence was within historical range, there was no progression to carcinomas, and the incidence of hyperplasia was not compound-related. In terms of thyroid C-cell adenomas, there was no statistically significant dose-related trend in occurrence or a statistically significant increase in incidence, no progression to carcinomas, and no significant dose-related increase in hyperplasia. Therefore, glyphosate was not considered to be carcinogenic (US EPA, 1993)



Another carcinogenicity study involved an 18-month feeding study conducted with CD-1 mice using doses of glyphosate equivalent to 0, 150, 750, or 4500 mg/kg/day. The effects in the high-dose group included decreased body weight gain in both sexes, increased hepatocellular hypertrophy, hepatocellular necrosis and interstitial nephritis in males, increase incidence of proximal tubule epithelial basophilia and hypertrophy in females, and an increase incidence of renal tubular adenomas in males. Based the effects listed above, the NOAEL is 750 mg/kg/day for both sexes and the LOAEL is 4500 mg/kg/day for both sexes. However, it was determined by the US EPA and confirmed by other experts that the adenomas occurred spontaneously and that glyphosate is not considered carcinogenic based on the results of this study (US EPA, 2006; 1993).

In the US EPA (2002) assessment, US EPA addressed concerns about studies performed by Hardell and Erickson (1999a,b) which found that individuals in Sweden with a history of glyphosate exposure had an increased risk of developing non-Hodgkin lymphoma. A second study by Hardell and Erickson (199b) found this risk to be statistically significant. In response, the US EPA concluded that these studies did not establish a definitive link to cancer and their results were based on unverified recollection of exposure; as a result, the US EPA maintained its classification of glyphosate as a Group E carcinogen.

In terms of its mutagenicity, glyphosate has been shown to cause an increase in chromosomal aberration in a plant (*Allium sp.*) associated with cell abnormalities in spindle fiber (Rank et al. 1993), DNA adduct formation in mice (Reluso et al., 1998), and single strand DNA breaks in mice (Bolognesi et al., 1997). Reports on *in vitro* studies conducted by Vyse and Vigfusson (1979) and Vigfusson and Vyse (1980) indicate a significant increase in sister chromatid exchanges in human lymphocytes and conclude that glyphosate is a slight mutagen. Another positive assay was confirmed in a fruit fly study (Kaya et al., 2000; Kale et al., 1995) as well as in a study of lymphocyte cultures (Lioi et al., 1998a; Lioli et al., 1998b). Most of the remaining screening studies for mutagenicity, however, were negative.

For example, four mutagenicity studies were submitted for the reregistration of glyphosate in 1993. These studies included a gene mutation assay in an Ames Test on *Salmonella typhimurium* strains, a gene mutation assay in Chinese hamster ovary cells/hypoxanthine – guanine – phosphoribosyl transferase assay, a Structural Chromosomal Aberration Assay in male and female Sprague-Dawley rats, and a combined study employing a rec-assay using *B. subtilis* a reverse mutation assay using *E. coli* and *Salmonella typhimurium* strains. None of these studies showed a mutagenic or clastogenic response. As a result, the US EPA concluded that glyphosate is not a mutagen (USDA, 2003; US EPA, 2002; 1993).

#### 3.1.11 Irritation and Sensitization

According to EPA, glyphosate is classified as mildly irritating to the eyes (Category III) and slightly irritating to the skin (Category IV) based on data collected from skin and eye irritation studies during the registration process (US EPA 2006; 1993). Different formulations of glyphosate have different irritation patterns (e.g., the free acid of glyphosate is severely irritating to the eyes, but the IPA salt of the glyphosate is nonirritating to the skin and eyes) (USDA, 2003). Additionally, skin sensitization tests for glyphosate were all negative (US EPA, 2006; 1993).

### *3.1.12 Systemic Toxic Effects from Dermal Exposure*

System toxic effects from chronic dermal exposure are less damaging than those from chronic oral exposure, since glyphosate is poorly absorbed from the skin. Acute dermal exposure effects are similar to those of acute oral exposure effects (USDA, 2003). The US EPA classified glyphosate as a Category III for oral and dermal toxicity. The LD<sub>50</sub> value for the acute oral toxicity of glyphosate is >5,000 mg/kg (US EPA, 2006).

The US EPA RED for glyphosate (US EPA, 1993) gives more insight on the dermal toxicity of glyphosate. It cites a 1982 study (MRID 00098460) with rabbits in which glyphosate was applied to intact and abraded skin at doses of 10, 1,000, or 5,000 mg/kg/day, five days a week, for three weeks. The effects were minimal and included, slight irritation of the abraded skin, decreased food consumption, and decreased serum lactic dehydrogenase activity at 5,000 mg/kg. In a more recent study by Pinto (1996), dermal doses of 250, 500, or 1,000 mg/kg/day caused no effects on body weight, food consumption, hematology, clinical chemistry, or organ weights. There were also no signs of irritation or pathologic changes in tissue.

### *3.1.13 Inhalation Effects*

The US EPA did not require an acute inhalation study for technical grade glyphosate (US EPA, 2006; 1993) because of its low volatility rate. The acute inhalation LC<sub>50</sub> value of the isopropylamine salt glyphosate is >6.37 mg/L, which is equivalent to a finding of no mortality in any of the five rats of each sex exposed to this concentration for four hours (USDA, 2003). A study conducted by Jamison et al., (1986) exposed a group of human volunteers to glyphosate treated flax dust and untreated flax dust. The glyphosate treated dust consistently caused a decrease in respiratory function; however, this may have been due to a greater distribution of smaller dust particles, which are more easily inhaled, in the glyphosate treated dust.

### *3.1.14 Toxic Relevance of Surfactants in Glyphosate Formulations*

Various formulations of glyphosate contain POEA at a level of up to approximately 20 percent (200 g/L). Tallow contains a variety of fatty acids (e.g., oleic, palmitic, stearic, myristic, and linoleic acids), as well as smaller amounts of cholesterol, arachidonic, elaidic, and vaccenic acids. While surfactants are typically classified as “inert” components in herbicides, they are not toxicologically inert and in many cases they are found to be more toxic than the herbicide itself (USDA, 2003).

A study evaluating the toxicity of the POEA surfactant includes a series of teratology tests in rats using glyphosate (98.7% purity), POEA used in glyphosate formulations, and the phosphate ester neutralized POEA. Groups of pregnant female rats were dosed with glyphosate at 300, 1,000, or 3,500 mg/kg/day; POEA at 15, 100, or 300 mg/kg/day, or the neutralized POEA at 15, 50, or 150 mg/kg/day on days 6 through 19 of gestation. Results indicated that severe maternal poisoning occurred at the 3,500 mg/mg/day dose of glyphosate, in association with reduced fetal body weight and sternal ossification, as well as fetal death. At a dose of 300 mg/kg/day of POEA and

150 mg/kg/day of neutralized POEA maternal deaths were also reported. Another noteworthy result in dams included the fact that signs of mild clinical toxicity and decrease food consumption occurred at a dose of 100 mg/kg/day POEA surfactant. No fetotoxic effects were reported at any dose level. Based on these results, the NOAELs for glyphosate, POEA, and neutralized POEA were 1000 mg/kg/day, 15 mg/kg/day, and 50 mg/kg/day, respectively (USDA, 2003).

There has been some debate as to the acute toxicity of POEA and the determination of its LD<sub>50</sub> value, as compared to glyphosate; however, it is generally agreed that the acute toxicity of glyphosate formulations in humans (glyphosate and surfactant, LD<sub>50</sub> in rats 5400 mg/kg/day) is almost equivalent to that of glyphosate (LD<sub>50</sub> in rats 5600 mg/kg/day) (USDA, 2003). Additionally, based on drinking water studies on both glyphosate and Roundup (glyphosate with POEA), the surfactant does not affect the rapid elimination rate of glyphosate in mammals (NTP, 1992).

### *3.1.15 Toxic Relevance of Impurities in Glyphosate Formulations*

#### *3.1.15.1 N-nitrosoglyphosate (NNG)*

Technical grade glyphosate contains at least one impurity, N-nitrosoglyphosate (NNG). The US EPA determined that the NNG content in glyphosate was not toxicologically significant because more than 92% of the individual technical glyphosate samples tested contained less than 1.0 ppm NNG. There is general concern for the carcinogenic potential of nitroso compounds; however, it is hard to quantify (USDA, 2003; US EPA 1993).

#### *3.1.15.2 4-Dioxane*

1,4-Dioxane is an impurity in POEA, and the US EPA considers it to be a carcinogen (Class B2: Probable human carcinogen) and has derived a cancer potency factor (slope factor) of 0.011 mg/kg/day. 1,4-Dioxane is present in Roundup at a level of approximately 0.03% (Monsanto, 1999) or 300 mg/l (330 ppm). It has been demonstrated that dioxane does not present unique toxic effects; therefore, its toxicity (except its role as a carcinogen) is encompassed by the available toxicity data on glyphosate (USDA, 2003).

## **3.2 Exposure Assessment**

### *3.2.1 Overview*

As previously stated, there are five herbicide EUPs (end-use products) containing glyphosate that are recommended for use on a specific brand of GT alfalfa called Roundup Ready alfalfa. These products include: Roundup Original Max®, Roundup Weather Max®, and Roundup Ultra Max II®, Honcho® and Honcho Plus® (Greenbook, 2008; Monsanto, 2008). Each of these products contains between 41 and 49% glyphosate (Monsanto, 2007a; 2007b; 2007c; 2007d; 2004). Independent consideration of other ingredients in the EUPs is beyond the scope of this exposure assessment. For purposes of this analysis, exposure estimates to the chemical glyphosate are presented as opposed to exposure estimates to the EUPs. This is because toxicological data on

the EUPs, which are required to assess risk to workers, were not available at the time of the analysis.

### *3.2.2 Routes of Exposure*

The general public is not at a high risk of exposure to substantial levels of glyphosate under typical conditions (US EPA, 1993; USDA, 2003). Dermal and inhalation routes of exposure are not considered in this analysis because it is assumed that GT alfalfa will not be grown by members of the general public. Thus, it is assumed that the general public will not directly come in contact with or inhale herbicides recommended for use on GT alfalfa. It is, however, assumed that members of the general public may be exposed orally to these herbicides via consumption of foods that have been treated by herbicides containing glyphosate.

In the 1993 US EPA RED for glyphosate, the US EPA conducted a dietary risk assessment and determined that non-nursing infants under one year of age are at highest risk of adverse effects associated with glyphosate exposure (US EPA, 1993). The US EPA completed an additional risk assessment for glyphosate in 2006 to address its specific use on Indian mulberry and dried peas (US EPA). In this later assessment, the US EPA also found that infants under one year of age are at greatest risk. The results of these risk assessments are discussed in further detail in section 3.4.

Because oral exposure scenarios are feasible, this exposure analysis estimates potential glyphosate exposure associated with consumption of fruit and vegetables that have been treated with an herbicide containing glyphosate. It is not anticipated that alfalfa will be consumed in large quantities directly by humans; alfalfa sprouts are consumed generally in relatively small quantities. Because small quantities of alfalfa sprouts are consumed, potential glyphosate consumption was estimated by modeling contamination of other crops growing nearby alfalfa fields.

Consumption of crops treated with a glyphosate-based herbicide is rare because treated crops show signs of damage, making the contamination easily identifiable to the consumer. However, it cannot be assumed that consumption will never occur, thus, exposure scenarios evaluated in this analysis include adults' chronic and acute consumption of contaminated fruit and vegetation. Exposures of two additional sensitive subpopulations including the elderly and infants under one year of age are also estimated. Additional oral exposure scenarios might include consumption of contaminated water or fish, but analysis of these exposure pathways was not conducted for this assessment. Fish do not bioaccumulate glyphosate; in 2003, the USDA evaluated several water exposure scenarios, including consumption of contaminated surface water, and none were considered a risk to human health.

### *3.2.3 Application Rates*

Maximum single application rates of products containing glyphosate for GT crops range from 0.56 pounds of glyphosate a.e. per acre up to 3.75 pounds of glyphosate a.e. per acre (Monsanto, date unknown). Application rates were determined using specific product labels for each EUP

recommended for use on GT alfalfa (Monsanto, 2007a; 2007f; 2007c; 2007d; 2005b; 2005c; 2004). The maximum label single use rate for GT alfalfa is 1.55 pounds glyphosate a.e. per acre. Application rates on these products were presented in volume (i.e., quarts or ounces) of active ingredient per acre. These values were converted to mass (i.e., pounds) per acre by multiplying the application volume by the density of the EUP (See equations L-1 and L-2).

Equation L-1

$$\text{Density} = \text{Mass} / \text{Volume}$$

thus,

Equation L-2

$$\text{Mass} = \text{Density} * \text{Volume}$$

Density values were provided by material safety data sheets (MSDS) for each EUP. When product density was not available, the specific gravity of the EUP was used to calculate density. The specific gravity is the ratio of the product density to the density of water. It was assumed that the density of water is 1000 kg/m<sup>3</sup> (See equations L-3 and L-4).

Equation L-3

$$\text{Specific gravity} = \text{Product density} / \text{Water density}$$

thus,

Equation L-4

$$\text{Product density} = \text{Specific gravity} * \text{Water density}$$

Labels also provided application rates for the EUP as opposed to the chemical alone. Because this exposure analysis focuses on the chemical as opposed to the EUP, the percent a.e. (i.e., glyphosate) reported by the product label was considered in the exposure equation (See equation L-5). The percent of glyphosate in EUPs ranged from 41 and 49% (see table L-1).

Equation L-5

$$\text{Application rate of glyphosate} = \text{Application rate of EUP} * \text{Percent glyphosate in EUP}$$

Maximum application rates of the five EUP recommended for use on GT alfalfa are presented in table L-7. Please refer to appendix L-4 of this technical report for further explanation of application rate calculations.

**Table L-7. Maximum Application Rates of EUPs for Use on Glyphosate-Tolerant Alfalfa**

| Product               | Single Use Application Rate | Reference                     |
|-----------------------|-----------------------------|-------------------------------|
| Honcho®               | 2.0 lb a.e./acre            | Monsanto, 2007a; 2007e        |
| Honcho Plus®          | 2.0 lb a.e./acre            | Monsanto, 2007b; 2007f        |
| Roundup Original MAX® | 1.9 lb a.e./acre            | Monsanto, 2007c               |
| Roundup WeatherMAX®   | 1.9 lb a.e./acre            | Monsanto, 2007d; 2005a; 2005b |
| Roundup Ultra MAX II® | 1.9 lb a.e./acre            | Monsanto 2005c; 2004; 2003    |

### 3.2.4 General Public Exposure Scenarios

#### 3.2.4.1 Acute Consumption Scenario

Exposure scenarios for acute consumption were provided by USDA (2003) and acute exposure algorithms were provided by SERA (2006) in a supplemental calculations worksheet presented to USDA. In this scenario, an individual is exposed through consumption of contaminated vegetation or fruit after a single acute spray application of glyphosate. An acute oral dose ( $OD_{acute}$ ) of glyphosate may be estimated by multiplying the concentration of the chemical present on the contaminated vegetation or fruit ( $Conc$ ) by the amount of that vegetation or fruit consumed per day per unit body weight of the exposed individual ( $Amnt$ ) (See Equation L-6). The estimate of the concentration of the chemical present on the contaminated vegetation or fruit ( $Conc$ ) is calculated by multiplying the application rate ( $AR$ ), the residue rate ( $RR$ ), the drift proportion ( $Drift$ ), and the proportion of chemical remaining after washing ( $Prop$ ) (See equation L-7).

#### Equation L-6

$$OD_{acute} = Conc * Amnt$$

Where:

|              |   |                                                                      |
|--------------|---|----------------------------------------------------------------------|
| $OD_{acute}$ | = | estimated acute oral dose (mg/kg bw)                                 |
| $Conc$       | = | concentration on vegetation (mg/kg food item)                        |
| $Amnt$       | = | amount consumed per day per unit body weight (kg food/kg BW per day) |

#### Equation L-7

$$Conc = AR * RR * Drift * Prop$$

Where:

|         |   |                                               |
|---------|---|-----------------------------------------------|
| $Conc$  | = | concentration on vegetation (mg/kg food item) |
| $AR$    | = | application rate (lbs/acre)                   |
| $RR$    | = | residue rates (mg/kg food per lb/acre)        |
| $Drift$ | = | drift proportion (unitless)                   |
| $Prop$  | = | proportion remaining after washing (unitless) |

The amounts of fruit or vegetables consumed by individuals (*Amnt*) are based on the estimates from the US EPA's *Exposure Factor's Handbook* (US EPA, 1997). Data are based on US EPA's analysis of the USDA's (1991) nationwide survey called the Consumption of Food Intake by Individuals (CSFII) from 1989 to 1991. Data are in kilograms of fruit or vegetables consumed per kilogram of body weight of the individual per day (US EPA, 1997). Data are already normalized to the body weights of the exposed individuals. Amounts of fruits and vegetables consumed by adults aged 20 to 39 years, elderly individuals aged 70 years and older, and infants under one year were collected. For each age category, the mean consumption rate is presented as the central estimate of consumption. Also for each age category, the 25<sup>th</sup> percentile of the distribution of consumption rates for the entire population of the age category evaluated in the CSFII is presented as the lower estimate, and the 100<sup>th</sup> percentile of the distribution is presented as the upper estimate of consumption. Consumption rates for fruits and vegetables by age category are presented in table L-8 and table L-9 respectively.

**Table L-8. Amount of Fruit Consumed by Age Category (in kg of fruit per kg of body weight per day) (USEPA, 1997)**

| Age Group         | Mean<br>(Central Estimate) | 25 <sup>th</sup> Percentile<br>(Lower Estimate) | 100 <sup>th</sup> Percentile<br>(Upper Estimate) |
|-------------------|----------------------------|-------------------------------------------------|--------------------------------------------------|
| Adult (20-39 yrs) | 1.88E-03                   | 0                                               | 4.16E-02                                         |
| Elderly (70+ yrs) | 2.98E-03                   | 8.90E-04                                        | 1.50E-02                                         |
| Infants (<1 yr)   | 1.49E-02                   | 0                                               | 2.11E-01                                         |

**Table L-9. Amount of Vegetables Consumed by Age Category (in kg of fruit per kg of body weight per day) (USEPA, 1997)**

| Age Group         | Mean<br>(Central Estimate) | 25 <sup>th</sup> Percentile<br>(Lower Estimate) | 100 <sup>th</sup> Percentile<br>(Upper Estimate) |
|-------------------|----------------------------|-------------------------------------------------|--------------------------------------------------|
| Adult (20-39 yrs) | 3.53E-03                   | 2.06E-03                                        | 1.71E-02                                         |
| Elderly (70+ yrs) | 4.07E-03                   | 2.47E-03                                        | 1.89E-02                                         |
| Infants (<1 yr)   | 6.80E-03                   | 0                                               | 4.50E-02                                         |

An application rate (*AR*) of 2.0 pounds a.e. per acre was used because it is the more conservative of the single use application rates for the five EUPs recommended for use on GT alfalfa (See table L-7). This rate is consistent with the labeled maximum single use rate of 1.55 a.e. pounds glyphosate per acre for application on GT alfalfa.

Residue rates (*RR*) were based on an empirical relationship between application rate and concentration on food developed by Fletcher et al. (1994). Fletcher et al. used the Kenaga nomogram, a device developed by EPA to predict maximum potential pesticide residue levels. Fletcher et al. conducted a review to determine if the residue levels predicted by the nomogram are comparable to values reported in the literature. The authors concluded that the Kenaga nomogram predicts values for residue rates that are comparable to values reported in the literature. According to Fletcher et al., the estimated values range from 7 mg/kg food per lb/acre to 15 mg/kg food per lb/acre for fruit and from 45 mg/kg food per lb/acre to 135 mg/kg food per lb/acre for vegetation.

It was assumed that both the drift proportion (*Drift*) and the proportion of chemical remaining on the fruit or vegetation after washing (*Prop*) are equal to one. The drift proportion or spray drift of a pesticide is defined by US EPA as the physical movement of a pesticide or herbicide

through the air at the time of application to a site that is not intended for application (US EPA, 2008). A drift proportion of one assumes that the same amount of pesticide is applied to target and non-target crops. In this case, the herbicide target is GT alfalfa. It is unlikely that non-target fruit or vegetation would have the same level of contamination as the target plant since they are likely to grow in different fields. Thus, a drift proportion of one is a highly conservative estimate. The proportion of the chemical remaining on the fruit or vegetation is likely to be reduced after washing, thus one is also a highly conservative estimate.

Central, lower, and upper bound exposure estimates from ingestion of fruit and vegetables were calculated for the acute oral consumption exposure scenarios for adults, the elderly, and infants. Results are presented in tables L-10 and L-11. Please refer to the calculations worksheet submitted with this report for further explanation of exposure estimate calculations.

**Table L-10. Exposure Estimates for Acute Consumption of Fruit by Age Category (in mg/kg body weight per day)**

| Age Category      | Central Estimate | Lower Estimate | Upper Estimate | Worksheet |
|-------------------|------------------|----------------|----------------|-----------|
| Adult (20-39 yrs) | 2.63E-02         | 0              | 1.25E+00       | 1         |
| Elderly (70+ yrs) | 4.17E-02         | 1.25E-02       | 4.50E-01       | 2         |
| Infants (<1 yr)   | 2.09E-01         | 0              | 6.32E+00       | 3         |

**Table L-11. Exposure Estimates for Acute Consumption of Vegetables by Age Category (in mg/kg body weight per day)**

| Age Category      | Central Estimate | Lower Estimate | Upper Estimate | Worksheet |
|-------------------|------------------|----------------|----------------|-----------|
| Adult (20-39 yrs) | 3.18E-01         | 1.85E-01       | 4.61E+00       | 4         |
| Elderly (70+ yrs) | 3.66E-01         | 2.22E-01       | 5.11E+00       | 5         |
| Infants (<1 yr)   | 6.12E-01         | 0              | 1.21E+01       | 6         |

#### 3.2.4.2 Chronic Consumption Scenario

Exposure scenarios for chronic consumption scenario were provided by USDA (2003) and chronic exposure algorithms were provided by SERA (2006) in a supplemental calculations worksheet presented to USDA. In this scenario, the contaminated fruit or vegetation is exposed to glyphosate for a defined period of exposure ( $ED$ ). The general public's consumed dose of glyphosate ( $OD_{chronic}$ ) may be estimated by multiplying the time-weighted average concentration of consumed vegetation ( $C_{TWA\ CON}$ ) by the amount of vegetation or fruit consumed per day per unit body weight (See equation L-8). The  $C_{TWA\ CON}$  is calculated by multiplying the time-weighted average concentration on food over the exposure duration ( $Con_{TWA}$ ) by the proportion of the chemical remaining after the food item is washed ( $Prop$ ) (See equation L-9). The time-weighted average concentration on food over the exposure duration ( $Con_{TWA}$ ) is estimated in equation L-10 (De Sapia, 1976). The concentration at a specific time ( $Conc_{ED}$ ) can be calculated based on the initial concentration on food ( $C_0$ ), assuming a first-order decrease in concentrations in contaminated food (See equation L-11).  $C_0$  is estimated by multiplying the application rate by the residue rate ( $RR$ ) and the proportion of anticipated spray drift (See equation L-12). The decay coefficient ( $k$ ) is estimated by dividing the natural log of 2 ( $Ln(2)$ ) by the half-life of the chemical on the food item ( $t_{50}$ ) (See equation L-13).



### Equation L-8

$$OD_{chronic} = C_{TWA\ CON} * Amnt$$

Where:

|                |   |                                                                                          |
|----------------|---|------------------------------------------------------------------------------------------|
| $OD_{chronic}$ | = | estimated chronic oral dose (mg/kg bw)                                                   |
| $C_{TWA\ CON}$ | = | time-weighted average concentration on consumed food item over exposure duration (mg/kg) |
| $Amnt$         | = | amount consumed per day per kilogram of body weight (kg food item/kg BW per day)         |

### Equation L-9

$$C_{TWA\ CON} = Con_{TWA} * Prop$$

Where:

|                |   |                                                                                               |
|----------------|---|-----------------------------------------------------------------------------------------------|
| $C_{TWA\ CON}$ | = | time-weighted average concentration on consumed food item over exposure duration (mg/kg food) |
| $Con_{TWA}$    | = | time-weighted average concentration on food over exposure duration (mg/kg food)               |
| $Prop$         | = | proportion remaining after food item is washed (unitless)                                     |

### Equation L-10

$$Con_{TWA} = C_0 \times (1 - e^{-k \cdot ED}) \div (k * ED)$$

Where:

|             |   |                                                                                 |
|-------------|---|---------------------------------------------------------------------------------|
| $Con_{TWA}$ | = | time-weighted average concentration on food over exposure duration (mg/kg food) |
| $C_0$       | = | initial concentration on vegetation (mg/kg food)                                |
| $k$         | = | decay coefficient (per day)                                                     |
| $ED$        | = | time (days)                                                                     |

### Equation L-11

$$Conc_{ED} = C_0 * e^{-k \cdot ED}$$

Where:

|             |   |                                                       |
|-------------|---|-------------------------------------------------------|
| $Conc_{ED}$ | = | concentration on food at a specific time (mg/kg food) |
| $C_0$       | = | initial concentration on vegetation (mg/kg food)      |
| $k$         | = | decay coefficient (per day)                           |
| $ED$        | = | time (days)                                           |

### Equation L-12

$$C_0 = AR * Drift * RR$$

Where:

|       |   |                                                 |
|-------|---|-------------------------------------------------|
| $C_0$ | = | initial concentration on food item (mg/kg food) |
| AR    | = | application rate (lbs/acre)                     |
| Drift | = | spray drift (unitless)                          |
| RR    | = | residue rate (mg/kg food per lb/acre)           |

### Equation L-13

$$k = \ln(2) / t_{50}$$

Where:

|          |   |                             |
|----------|---|-----------------------------|
| k        | = | decay coefficient (per day) |
| $\ln(2)$ | = | natural log of 2 (unitless) |
| $t_{50}$ | = | half-life of food (days)    |

For the chronic oral exposure scenarios, a number of variables are comparable to variables incorporated in the equations used to estimate acute exposure. Values for the amount of fruit and vegetables consumed (*Amnt*) are the same as the values used for the acute oral exposure scenarios. Consumption rates for each age category (adults aged 20-39 years, elderly individuals aged 70+ years, and infants under 1 year) were taken from EPA's *Exposure Factors Handbook* (USEPA, 1997). The proportion of the chemical remaining after a food item is washed (*Prop*) is also assumed to be one. The same application rate (AR) of 2 pounds of glyphosate a.i per acre was also used and the same residue rates (RR) for fruits and vegetables from Fletcher et al. (1994) were assumed for the chronic exposure scenario and the acute exposure scenario. The same spray drift (*Drift*) assumption of one was also assumed for the chronic scenario.

Several additional default values were required for the chronic exposure scenarios that were not required for the acute exposure scenario. An exposure duration (*ED*) of 90 days was assumed based on USDA's assumption that a harvesting season will last approximately three months (USDA, 2003). Thus, it is assumed that an individual could be exposed for 90 consecutive days during this season. Calculation of the decay coefficient (*k*) required a half life of the chemical on food. Siltanen et al. (1981) used the dissipation on the vegetation to estimate the half-life of glyphosate on fruits and vegetation. The study reported a half-life of 46 days which is the value assumed in this analysis.

Central, lower, and upper bound chronic exposure estimates from ingestion of fruits and vegetables were calculated for adults, the elderly, and infants. Results are presented in tables L-12 and L-13. Please refer to the calculations worksheet submitted with this report for further explanation of exposure estimate calculations.

**Table L-12. Exposure Estimates for Chronic Consumption of Fruit by Age Category(in mg/kg body weight per day)**

| <b>Age Category</b> | <b>Central Estimate</b> | <b>Lower Estimate</b> | <b>Upper Estimate</b> | <b>Worksheet</b> |
|---------------------|-------------------------|-----------------------|-----------------------|------------------|
| Adult (20-39 yrs)   | 1.44E-02                | 0                     | 6.83E-01              | 7                |
| Elderly (70+ yrs)   | 2.29E-02                | 6.82E-03              | 2.46E-01              | 8                |
| Infants (<1 yr)     | 1.14E-01                | 0                     | 3.46E+00              | 9                |

**Table L-13. Exposure Estimates for Chronic Consumption of Vegetables by Age Category (in mg/kg body weight per day)**

| <b>Age Category</b> | <b>Central Estimate</b> | <b>Lower Estimate</b> | <b>Upper Estimate</b> | <b>Worksheet</b> |
|---------------------|-------------------------|-----------------------|-----------------------|------------------|
| Adult (20-39 yrs)   | 1.74E-01                | 1.01E-01              | 2.52E+00              | 10               |
| Elderly (70+ yrs)   | 2.00E-01                | 1.22E-01              | 2.80E+00              | 11               |
| Infants (<1 yr)     | 3.35E-01                | 0                     | 6.65E+00              | 12               |

### 3.3 Dose-presonse assessment

#### 3.3.1 Overview

An RfD is defined as a level of exposure that will not result in any adverse effects in any individual. The RfD value for glyphosate proposed by the U.S. EPA Office of Pesticide Programs is 2 mg/kg/day, and is based on a teratogenicity study in rabbits in which there were no observed effects in offspring at any dose level, and maternal toxicity was noted at 350 mg/kg/day with a NOAEL of 175 mg/kg/day (Rodwell et al., 1980b). The RfD of 2 mg/kg/day was derived by dividing the NOAEL by an uncertainty factor of 100 – 10 for sensitive individuals and 10 for species-to-species extrapolation – and rounding the result to one significant figure (US EPA, 2006; 2002; 1993).

#### 3.3.2 Existing Guidelines

The current section of this risk assessment attempts to take into account the two, US EPA Office of Pesticide Programs (US EPA OPP) proposed, chronic reference doses (RfDs) for glyphosate and the WHO's comparable proposed ADI (acceptable daily intake) in its analysis. As discussed in the previous paragraph, the RfD of 2 mg/kg/day was derived from a teratogenicity study in rabbits and was first derived in the 1993 RED document for glyphosate (US EPA, 1993). The US EPA has also derived an RfD for glyphosate of 0.1 mg/kg/day (US EPA, 1990). This RfD was originally derived by the US EPA's Integrated Information System (IRIS) workgroup and is still posted on IRIS. This value is based on a dietary 3-generation reproduction study by Schroeder and Hogan (1981), in which rats were exposed to glyphosate in their diet and no adverse effects were observed. The NOAEL was 10 mg/kg/day and an uncertainty factor of 100 was used.

The ADI proposed by WHO (1994) is based on a life-time feeding study in rats, as opposed to a reproductive toxicity study. A study by Lankas and Hogan (1981) supplied male and female rats a daily dose (0, 3.1, 10.3, or 31.5 mg/kg/day in males; 0, 3.4, 11.3, or 34.0 mg/kg/day in females) of glyphosate in their diet for 26 months. No effects were observed in any of the animals at any of the dose levels; therefore, WHO used a NOAEL of 31.5 mg/kg/day and an uncertainty factor of 100 to derive the ADI.

US EPA's Office of Drinking Water (US EPA ODW) proposed a 10-day health advisory for glyphosate of 17.5 mg/L, based on the NOAEL of 175 mg/kg/day, and a longer-term health advisory of 1 mg/L, based on the U.S. EPA RfD of 0.1 mg/kg/day. The US EPA ODW also derived a short-term RfD of 2 mg/kg/day, which is identical to the chronic RfD proposed by US EPA OPP.

### 3.3.3 *Dose-Response and Dose-Severity Relationships*

A threshold and non-threshold multistage model was used to estimate the LD<sub>50</sub> in humans. Both models approximated the LD<sub>50</sub> to be 3,000 mg/kg/day, similar to the range of 2000 to 6000 mg/kg reported in experimental mammals. Additionally, the threshold version of the multistage model was also used to yield an estimate of the threshold dose of 445 mg/kg for systemic toxic effects. Below this dose, it is assumed that no individual in the population will respond (USDA, 2003).

In addition, dose severity relationships were analyzed for experimental mammals and humans. The available animal data were characterized using four standard severity levels: NOEL (no observed effect level), NOAEL (no observed adverse effect level), AEL (adverse effect level), and FEL (frank effect level). Furthermore, three different groups of end points were determined: general systemic toxic effects, reproductive or developmental effects, and acute LD<sub>50</sub> values. Although the exposure periods for these studies ranged from one day to greater than two years, glyphosate is rapidly excreted from the body; therefore, duration of exposure is not an important parameter in assessing the toxicity of glyphosate (USDA, 2003).

The data for experimental animals was further analyzed using categorical regression analysis in the next step of assessing the dose-severity relationships, which correlates categorical responses with factors that may influence the response. Results of the categorical regression indicate that the probabilities of an adverse effect at the RfD of 0.1 mg/kg/day is 0.0005, at 1 mg/kg/day is 0.003, and at a dose of 10 mg/kg/day is 0.12. From these results, it was inferred that an RfD of 2 mg/kg is protective. It was further determined that the probability of a frank toxic effect (a sufficiently severe effect that can be observed in the whole organism without the use of invasive methods) at the RfD of 0.1 mg/kg/day is 0.00005 and at the RfD of 2 mg/kg/day increases to 0.0006 (USDA, 2003).

The consistency between the categorical analysis in experimental animals and the dose-response analysis using the multistage model for humans is relatively good. At 445 mg/kg, the estimated threshold of human lethality, the probability of observing a frank toxic effects is approximately 0.04. At this dose in the non-threshold version of the multi-stage model, the probability is 0.02. At the estimated human LD<sub>50</sub> of approximately 3000 mg/kg, the probability of observing an adverse or frank effect, as determined by a categorical regression using two categories, is 0.7.

For glyphosate, the data suggests that humans are no more sensitive than experimental animals. Subsequently, this suggests that the current and proposed RfDs may be overly protective by a factor of 10 or greater.

### 3.3.4 *Susceptible Populations*

On the basis of developmental studies in rats and rabbits and reproductive findings in rats, glyphosate exhibited no evidence of increased qualitative and quantitative susceptibility. Additionally, an acute RfD was not established for any population subgroup or the general population, including infants and children, based on the absence of an appropriate toxicological endpoint attributable to a single exposure (dose), including maternal toxicity in developmental toxicity studies (US EPA, 2006).

### 3.3.5 *RfD Values Used in Risk Assessment of Glyphosate*

The database on glyphosate is large, complex, and open to many potential interpretations. For example, according to a 1986 determination by the Joint Food and Agricultural Organization of the United Nation (FAO)/World Health Organization (WHO) on Pesticides Residues (JMPR), an Allowable Daily Intake (ADI) of glyphosate is 0.3 mg/kg *per se*. This was based on a 26-month feeding study in rats with a resulting NOEL of >31 mg/kg/day and an uncertainty factor of 100. However, the US EPA determined a NOAEL of 175 mg/kg/day and an uncertainty factor of 100, because maternal mortality was observed at the highest dose group. As a result, in 1992, the US EPA's Office of Pesticide Program Reference Dose Peer Review Committee recommended that the reference dose for glyphosate be set at 2 mg/kg/day (USDA, 2006) for longer-term exposures. The US EPA's Office of Drinking Water also recommended a value of 2 mg/kg/day for short-term exposures. As a result, the same RfD is used for both short- and long-term exposures; however, due to a lack of significant dose-response data for glyphosate, this approach was deemed appropriate (USDA, 2006; US EPA 2002; 1993). Glyphosate endpoints for this risk assessment are summarized in table L-14 below.

**Table L-14. Summary of Toxicological Doses and Endpoints for Chemical for Use in Human Health Risk Assessments (US EPA, 2006)**

| <b>Exposure Scenario</b>                                                                                              | <b>Dose Used in Risk Assessment, UF</b>                                                                                     | <b>Special FQPA SF* and Level of Concern for Risk Assessment</b>                 | <b>Study and Toxicological Effects</b>                                                                                                                                                                                        |
|-----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chronic Dietary (all populations)                                                                                     | NOAEL= 175 mg/kg/day<br>UF = 100<br><b>Chronic RfD</b> = 1.75 mg/kg/day = 2.0 mg/kg/day (rounded to one significant figure) | FQPA SF = 1X<br><b>cPAD</b> = $\frac{cRfD}{FQPA\ SF}$<br><b>= 1.75 mg/kg/day</b> | Developmental Toxicity Study - rabbit<br>LOAEL = 350 mg/kg/day based on diarrhea, nasal discharge and death in maternal animals                                                                                               |
| Short-, and Intermediate-Term Incidental, Oral (Residential)                                                          | NOAEL = 175 mg/kg/day                                                                                                       | LOC for MOE = 100                                                                | Developmental Toxicity Study - rabbit<br>LOAEL = 350 mg/kg/day based on diarrhea, nasal discharge and death in maternal animals                                                                                               |
| Short-, Intermediate- and Long-Term Dermal (1 - 30 days, 1-6 months, 6 months – lifetime) (Occupational/Residential)  | None                                                                                                                        | None                                                                             | Based on the systemic NOAEL of 1,000 mg/kg/day in the 21 day dermal toxicity study in rabbits, and the lack of concern for developmental and reproductive effects, the quantification of dermal risks is not required.        |
| Short-, Intermediate- and Long-Term Inhalation (1-30 days, 1- 6 months, 6 months-lifetime) (Occupational/Residential) | None                                                                                                                        | None                                                                             | Based on the systemic toxicity NOAEL of 0.36 mg/L (HDT) in the 28-day inhalation toxicity study in rats, and the physical characteristics of the technical (wetcake), the quantification of inhalation risks is not required. |
| Cancer (oral, dermal, inhalation)                                                                                     | <b>Classification:</b> Group E; no evidence of carcinogenicity; risk assessment not required                                |                                                                                  |                                                                                                                                                                                                                               |

### 3.3.6 Other Chemicals

For the purpose this risk assessment, the discussion on “other chemical usage” will be limited to describing the herbicides that glyphosate will be replacing and will be qualitative in nature. In order to thoroughly assess glyphosate’s toxicity as compared to “other chemicals” it would be necessary to do a complete risk assessment on each “other chemical.”

Glyphosate is more environmentally and toxicologically benign than many of the herbicides that it replaces (Cerdeira and Duke, 2006). Peterson and Hulting (2004) compared the ecological risks of glyphosate used in GT wheat with 15 other herbicides used in spring wheat in the northern U.S. Great Plains (Mn, ND, SD, WY, and MT). The herbicides were as follows: 2,4-D, bromoxynil, clodinafop, clopyralid, dicamba, fenoxaprop, flucarbazone, MCPA, metasulfuron, thifensulfuron, tralkoxydim, triallate, triasulfuron, tribenuron, and trifluralin. The ecological risks for the 15 herbicides relative to glyphosate were highly variable, with glyphosate having

less relative risk to non-target terrestrial and aquatic plant life and groundwater than most other active ingredients. The study predicted that glyphosate use in GT crops will be less toxic to terrestrial and aquatic wildlife than several of the herbicides which they replace (Peterson and Hulting, 2004).

The other major ecological concern from glyphosate usage in GT crops is the development of glyphosate resistant weeds. Weeds can develop resistance to herbicides for the following reasons: frequent exposure to a particular herbicide, the spread of naturally resistant weed seeds, and the outcrossing of herbicide-tolerant genes from genetically altered plants to weedy relatives. In the event of glyphosate resistant weeds the management practices suggested are use the following less resistant-prone herbicides recommended for use: paraquat/diquat, MSMA, phenoxy herbicide (e.g., 2,4-D, MCPA, trichlopyr, dicamba), tubulin inhibitors (e.g., benefin, fluchloralin, pendimethalin, ethanlfluralin, trifluralin), triazine (amitrole, atrazine, cyanazine, simazine, trietazine, metribuzin) and/or rare protox herbicides (acifluorfen). These herbicides are more toxic and persistent exerting a greater environmental impact; however, weed management is plant specific. In some cases of multiple herbicide resistance weed management practices are deep tillage (Peterson and Hulting, 2004).

In terms of human health, a qualitative assessment was conducted by comparing oral RfDs for these “other chemicals” (if available) to the proposed oral RfD for glyphosate. Based on the available acute and chronic oral RfDs for the majority of the “other chemicals”, glyphosate’s RfD is higher, therefore, making it more toxicologically benign, compared to the “other chemicals”. The RfDs for the “other chemicals” are presented in table L-15. For further information and references to these RfD values, please see appendix L-5 of this technical report.

**Table L-15. Summary Table of RfDs for “Other Chemicals”**

| <b>Chemical Name</b>              | <b>RfD (oral)</b>                                                                                                                                                                                       |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2,4-D                             | Acute dietary (Females 13-49 years of age): 0.025 mg/kg/day<br>Acute dietary (General population including infants and children): 0.067 mg/kg/day<br>Chronic dietary (All populations): 0.005 mg/kg/day |
| Acifluorfen                       | Chronic: 0.013 mg/kg/day                                                                                                                                                                                |
| Amitrole                          | Not established                                                                                                                                                                                         |
| Atrazine                          | Acute Dietary: 0.1 mg/kg/day<br>Intermediate and Chronic: 0.018 mg/kg/day                                                                                                                               |
| Benefin                           | Chronic: 0.3 mg/kg/day                                                                                                                                                                                  |
| Bromoxynil                        | Chronic: 0.015 mg/kg/day (                                                                                                                                                                              |
| Clodinafop (clodinafop-propargyl) | Acute dietary (females 13-50 years of age): 0.05 mg/kg/day<br>Acute dietary (general population including infants and children): 0.25 mg/kg/day<br>Chronic dietary (all populations): 0.0003 mg/kg/day  |
| Clopyralid                        | Chronic: 0.5 mg/kg/day                                                                                                                                                                                  |
| Cyanazine                         | Not available (NA)                                                                                                                                                                                      |
| Dicamba                           | Acute dietary (All populations): 1.0 mg/kg/day<br>Chronic dietary (All populations): 0.45 mg/kg/day                                                                                                     |

| Chemical Name                             | RfD (oral)                                                                                                                                                      |
|-------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Diquat (cation)                           | Chronic: 0.005 mg/kg/day                                                                                                                                        |
| Ethalfuralin                              | Chronic: 0.04 mg/kg/day                                                                                                                                         |
| Fenoxaprop<br>(fenoxaprop-ethyl)          | Chronic: 0.0025 mg/kg/day                                                                                                                                       |
| Flucarbazono<br>(flucarbazono-sodium)     | Acute: 3.0 mg/kg/day<br>Chronic: 0.36 mg/kg/day                                                                                                                 |
| Fluchloralin                              | NA                                                                                                                                                              |
| MCPA                                      | Acute (General population): 0.05 mg/kg/day<br>Acute (Females 13-50 years old): 0.04 mg/kg/day<br>Chronic: 0.0044 mg/kg/day                                      |
| Metribuzin                                | Chronic dietary: 0.013 mg/kg/day                                                                                                                                |
| Metsulfuron<br>(metsulfuron methyl)       | Chronic: 0.3 mg/kg/day                                                                                                                                          |
| MSMA                                      | Acute: 0.1 mg/kg/day<br>Chronic: 0.03 mg/kg/day                                                                                                                 |
| Paraquat (cation)                         | Chronic: 0.0045 mg/kg/day                                                                                                                                       |
| Pendimethalin                             | Chronic: 0.10 mg/kg.day                                                                                                                                         |
| Simazine                                  | Acute dietary (females 13-49 years of age): 0.3 mg/kg/day<br>Chronic dietary (all populations): 0.018 mg/kg/day                                                 |
| Thifensulfuron<br>(thifensulfuron methyl) | Acute dietary (Females 13-50 years of age): 1.59 mg/kg/day<br>Chronic dietary (All populations): 0.20 mg/kg/day                                                 |
| Tralkoxydim                               | Acute: 0.3 mg/kg/day<br>Chronic: 0.005 mg/kg/day                                                                                                                |
| Triallate                                 | Acute (General population including infants and children): 0.60 mg/kg/day<br>Acute (Females 15-30 years): 0.05 mg/kg/day<br>Chronic non-cancer: 0.025 mg/kg/day |
| Triasulfuron                              | Chronic: 0.01mg/kg/day                                                                                                                                          |
| Tribenuron<br>(tribenuron methyl)         | Chronic: 0.008 mg/kg/day<br>Acute: 0.20 mg/kg/day                                                                                                               |
| Trichlopyr                                | Chronic: 0.05 mg/kg/day                                                                                                                                         |
| Trietazine                                | NA                                                                                                                                                              |
| Trifluralin                               | Chronic: 0.024 mg/kg/day                                                                                                                                        |



## 3.4 Risk Characterization

### 3.4.1 Overview

As discussed in section 3.2, the general public may be exposed to herbicides used on GT alfalfa if they consume crops that were grown near GT alfalfa fields. However, in section 3.1, it was demonstrated that the US EPA considers glyphosate to be of low acute toxicity by oral, dermal, and ocular routes of exposure, since all studies are classified as Toxicity Category III or IV. Furthermore, an acute inhalation study was waived by the US EPA because glyphosate is a non-volatile solid and the studies conducted on the end-use product formulation are considered sufficient. In terms of subchronic and chronic toxicity, one of the more consistent effects of exposure to glyphosate is loss of body weight. This observed weight loss may be consistent with experimental data indicating glyphosate's mechanism of action as an uncoupler of oxidative phosphorylation (see section 3.1.2). Other general and non-specific signs of toxicity from subchronic and chronic exposure to glyphosate include changes in liver weight, blood chemistry (may suggests mild liver toxicity), liver pathology, and in pituitary weight (USDA, 2003). Glyphosate is not a carcinogen, however, and has been classified by the US EPA as a Group E carcinogen (evidence of non-carcinogenicity for humans) (US EPA, 2006; 1993).

### 3.4.2 Risk Characterization

To determine if any population subgroup is at risk of adverse effects associated with glyphosate, estimated exposure doses are compared with a health benchmark specific to glyphosate. As discussed in section 3.3, the recommended oral RfD for acute and chronic exposure scenarios for glyphosate is 2 mg/kg of body weight per day. This means that individuals with oral exposure doses equal to or less than 2 mg/kg of body weight per day should not be at risk of adverse effects associated with exposure to glyphosate. The risk metric used to determine if individuals are at risk of adverse effects is called the hazard quotient (HQ). The hazard quotient is the ratio of the estimated exposure dose to the chemical-specific health benchmark (e.g., RfD) (See equation 3.4.2). If the HQ is estimated to be less than 1, no adverse effects are expected as a result of exposure to the chemical of concern. If the HQ is greater than 1, adverse health effects are possible. However, an HQ exceeding 1 does not indicate that adverse effects are certain to occur. Since glyphosate is considered a Group E carcinogen (i.e., signifies non-carcinogenicity in humans) (US EPA, 1993), an analysis of cancer risk was not conducted.

Equation L-14

$$HQ = \frac{Exposure}{RfD}$$

Where:

|          |   |                                            |
|----------|---|--------------------------------------------|
| HQ       | = | Hazard quotient (unitless)                 |
| Exposure | = | Estimated exposure dose (mg/kg BW per day) |
| RfD      | = | Reference dose (mg/kg BW per day)          |

### 3.4.2.1 Risk Characterization for Acute Oral Exposure

Acute exposure estimates for adults (20-39 years), the elderly (70+ years), and infants (under 1 year in age) exposed to glyphosate-contaminated fruits and vegetables were presented in section 3.2. Results are summarized in table L-16 and in worksheet 13 in the calculations spreadsheet submitted with this report. Also, please refer to the calculations worksheet submitted with this report for further explanation of exposure estimate calculations.

**Table L-16. Acute Exposure Estimates by Age Group and Scenario (in mg/kg BW per day)**

| Scenario  | Age Group | Central Estimate | Lower Estimate | Upper Estimate | Worksheet |
|-----------|-----------|------------------|----------------|----------------|-----------|
| Fruit     | Adults    | 2.63E-02         | 0.00E+00       | 1.25E+00       | 1         |
| Fruit     | Elderly   | 4.17E-02         | 1.25E-02       | 4.50E-01       | 2         |
| Fruit     | Infants   | 2.09E-01         | 0.00E+00       | 6.32E+00       | 3         |
| Vegetable | Adults    | 3.18E-01         | 1.85E-01       | 4.61E+00       | 4         |
| Vegetable | Elderly   | 3.66E-01         | 2.22E-01       | 5.11E+00       | 5         |
| Vegetable | Infants   | 6.12E-01         | 0.00E+00       | 1.21E+01       | 6         |

Acute exposure estimates were compared to the acute oral RfD of 2 mg/kg of body weight per day. Results are presented in table L-17. HQs above 1 are presented in bold type. Please refer to the calculations worksheet submitted with this report for further explanation of hazard quotient calculations.

**Table L-17. HQs by Age Group and Scenario**

| Scenario  | Age Group | Central Estimate (in mg/kg BW per day) | Lower Estimate (in mg/kg BW per day) | Upper Estimate (in mg/kg BW per day) | RfD (in mg/kg BW per day) | Worksheet |
|-----------|-----------|----------------------------------------|--------------------------------------|--------------------------------------|---------------------------|-----------|
| Fruit     | Adults    | 0.01                                   | 0.00                                 | 0.62                                 | 2                         | 14        |
| Fruit     | Elderly   | 0.02                                   | 0.01                                 | 0.23                                 | 2                         |           |
| Fruit     | Infants   | 0.10                                   | 0.09                                 | <b>3.16</b>                          | 2                         |           |
| Vegetable | Adults    | 0.16                                   | 0.09                                 | <b>2.30</b>                          | 2                         |           |
| Vegetable | Elderly   | 0.18                                   | 0.11                                 | <b>2.55</b>                          | 2                         |           |
| Vegetable | Infants   | 0.31                                   | 0.00                                 | <b>6.07</b>                          | 2                         |           |

### 3.4.2.2 Risk Characterization for Chronic Oral Exposure

Chronic exposure estimates for adults (20-39 years), the elderly (70+ years), and infants (under 1 year) exposed to glyphosate-contaminated fruits and vegetables were presented in section 3.2. Results are summarized in table L-18 and in worksheet 13 in the calculations spreadsheet submitted with this report. Also, please refer to the calculations worksheet submitted with this report for further explanation of exposure estimate calculations.

**Table L-18. Chronic Exposure Estimates by Age Group and Scenario  
(in mg/kg BW per day)**

| Scenario  | Age Group | Central Estimate | Lower Estimate | Upper Estimate | Worksheet |
|-----------|-----------|------------------|----------------|----------------|-----------|
| Fruit     | Adults    | 1.44E-02         | 0.00E+00       | 6.83E-01       | 7         |
| Fruit     | Elderly   | 2.29E-02         | 6.82E-03       | 2.46E-01       | 8         |
| Fruit     | Infants   | 1.14E-01         | 0.00E+00       | 3.46E+00       | 9         |
| Vegetable | Adults    | 1.74E-01         | 1.01E-01       | 2.52E+00       | 10        |
| Vegetable | Elderly   | 2.00E-01         | 1.22E-01       | 2.80E+00       | 11        |
| Vegetable | Infants   | 3.35E-01         | 0.00E+00       | 6.65E+00       | 12        |

Chronic oral exposure estimates were compared to the chronic oral RfD of 2 mg/kg of body weight per day. Results are presented in table L-19. HQs above 1 are presented in bold type. Please refer to the calculations worksheet submitted with this report for further explanation of hazard quotient calculations.

**Table L-19. HQs by Age Group and Scenario**

| Scenario  | Age Group | Central Estimate<br>(in mg/kg<br>BW per<br>day) | Lower Estimate<br>(in mg/kg<br>BW per<br>day) | Upper Estimate<br>(in mg/kg<br>BW per<br>day) | RfD<br>(in mg/kg<br>BW per<br>day) | Worksheet |
|-----------|-----------|-------------------------------------------------|-----------------------------------------------|-----------------------------------------------|------------------------------------|-----------|
| Fruit     | Adults    | 0.01                                            | 0.00                                          | 0.34                                          | 2                                  | 14        |
| Fruit     | Elderly   | 0.01                                            | 0.00                                          | 0.12                                          | 2                                  |           |
| Fruit     | Infants   | 0.06                                            | 0.00                                          | <b>1.73</b>                                   | 2                                  |           |
| Vegetable | Adults    | 0.09                                            | 0.05                                          | <b>1.26</b>                                   | 2                                  |           |
| Vegetable | Elderly   | 0.10                                            | 0.06                                          | <b>1.40</b>                                   | 2                                  |           |
| Vegetable | Infants   | 0.17                                            | 0.00                                          | <b>3.32</b>                                   | 2                                  |           |

### 3.4.3 Discussion

EPA's (1993) RED for glyphosate included a dietary risk assessment in which it was determined that non-nursing infants were at highest risk of potential adverse effects associated with glyphosate exposure. EPA used tolerance level residues to estimate the Theoretical Maximum Residue Contribution (TMRC) for the overall U.S. population and 22 population subgroups. The TMRC for the U.S. population from food uses of glyphosate was 0.025 mg/kg/day (or 1.2% of the 2 mg/kg/day reference dose). Non-nursing infants less than one year old had a TMRC of 0.058 mg/kg/day (or 2.9% of the reference dose). This analysis was designed as a worst case scenario and assumptions most likely result in an extremely protective estimate of exposure and risk. However, there was little commodity-specific consumption data at the time of the analysis, which may result in a less protective estimate. In its 2006 risk assessment for specific uses of glyphosate on Indian mulberry and dried peas, EPA used a proprietary dietary exposure and risk assessment model, DEEM-FCID™ to complete the dietary analysis for the general public. EPA only conducted a chronic dietary analysis and found that the highest exposed group, also infants under one year of age, was only exposed at 7% of the health benchmark used in the analysis. The results suggested that even the highest exposed group is not at risk of adverse effects (EPA, 2006).

The present analysis considers the possibility that any type of fruit or vegetable could be contaminated by glyphosate. As explained in section 3.2, central, upper, and lower estimates of

consumption rates were used to estimate exposure and risk for adults, infants, and the elderly. It is anticipated that the results of this analysis are highly conservative for several reasons. First, the upper bound exposure and risk estimates are based on fruit and vegetable consumption rates characteristic of the 100<sup>th</sup> percentile of the population. In addition, in assuming a spray drift of one for all scenarios, this analysis assumes that fruits and vegetables will have the same residue of glyphosate as the GT alfalfa will. Application rates are specific to herbicides used to treat GT alfalfa fields, which is not meant for human consumption, as opposed to rates specific to fruits and vegetables. Acute and chronic scenarios assume that fruits and vegetables growing in nearby fields will be contaminated at the same level; however this is a highly conservative and in most cases unlikely scenario.

### 3.5 Summary of Findings

The use of currently registered pesticide products containing glyphosate in accordance with the labeling will not pose unreasonable risks or adverse effects to humans or the environment. It is a violation of federal law for any person to apply a registered pesticide in a manner inconsistent with its label. In general, the herbicidal activity of glyphosate is due primarily to a metabolic pathway that does not occur in humans or other animals, and, thus, this mechanism of action is not directly relevant to the human health risk assessment. The US EPA considers glyphosate to be of low acute toxicity by oral, dermal, and ocular routes of exposure, since all studies are classified as Toxicity Category III or IV. Furthermore, an acute inhalation study was waived by the US EPA because glyphosate is a non-volatile solid and the studies conducted on the end-use product formulation are considered sufficient.

Acute oral exposure estimates from fruit ingestion for adults ranged from zero to 1.25E+00 mg/kg body weight per day. For elderly people, acute oral exposure estimates from fruit ingestion ranged from 1.25E-02 to 4.5E-01 mg/kg body weight per day. For infants, acute oral exposure estimates from fruit ingestion ranged from zero to 6.32E+00 mg/kg bodyweight per day.

Acute oral exposure estimates from vegetable ingestion for adults ranged from 1.85E-01 to 4.61E+00 mg/kg body weight per day. For elderly people, acute oral exposure estimates from vegetable ingestion ranged from 2.22E-01 to 5.11E+00 mg/kg body weight per day. For infants, acute oral exposure estimates from vegetable ingestion ranged from zero to 1.21E+01 mg/kg body weight per day.

Central and lower hazard quotient (HQ) estimates were all under 1, suggesting that the majority of the population is not at risk of adverse health effects associated with acute exposure to glyphosate. Based on upper estimates of exposure, however, infants consuming fruit and all age groups consuming vegetables may be at risk of adverse effects associated with acute exposure to glyphosate. The age group at highest risk is infants under one year of age, which is consistent with US EPA's findings (US EPA, 2006; 1993). The upper estimate HQ for infants with acute exposure to fruit was approximately 3. The upper estimate HQs for all age groups with acute exposure to vegetables ranged from approximately 2 to 6. These results are all over 1, suggesting the potential for adverse health effects associated with glyphosate. It should be noted,

though, that the upper estimates of risk are based on highly conservative fruit and vegetable intake rates; thus it is anticipated that only a very small number of individuals will have this magnitude of exposure and therefore be at this level of risk.

In terms of subchronic and chronic toxicity, one of the more consistent effects of exposure to glyphosate is loss of body weight. This observed weight loss may be consistent with experimental data indicating glyphosate's mechanism of action as an uncoupler of oxidative phosphorylation (see section 3.1.2). Other general and non-specific signs of toxicity from subchronic and chronic exposure to glyphosate include changes in liver weight, blood chemistry (may suggest mild liver toxicity), liver pathology, and in pituitary weight (USDA, 2003). Glyphosate is not a carcinogen, however, and has been classified by the US EPA as a Group E carcinogen (evidence of non-carcinogenicity for humans) (US EPA, 2006; 1993).

Chronic oral exposure estimates from fruit ingestion for adults ranged from zero to  $6.83\text{E-}01$  mg/kg body weight per day. For elderly people, chronic oral exposure estimates from fruit ingestion ranged from  $6.82\text{E-}03$  to  $2.46\text{E-}01$  mg/kg body weight per day. For infants, chronic oral exposure estimates from fruit ingestion ranged from 0 to  $3.46\text{E+}00$  mg/kg body weight per day.

Chronic oral exposure estimates from vegetable ingestion for adults ranged from  $1.01\text{E-}01$  to  $2.52\text{E+}00$  mg/kg body weight per day. For elderly people, chronic oral exposure estimates from vegetable ingestion ranged from  $1.22\text{E-}01$  to  $2.80\text{E+}00$  mg/kg body weight per day. For infants, chronic oral exposure estimates from vegetable ingestion ranged from 0 to  $6.65\text{E+}00$  mg/kg body weight per day.

Central and lower hazard quotient (HQ) estimates were all under 1, suggesting that the majority of the population is not at risk of adverse health effects associated with acute exposure to glyphosate. Based on upper estimates of exposure, however, infants consuming fruit and all age groups consuming vegetables may be at risk of adverse effects associated with chronic exposure to glyphosate. The age group at highest risk is infants under one year of age, which is consistent with US EPA's findings (1993, 2006). The upper estimate HQ for infants with chronic exposure to fruit was approximately 2. The upper estimate HQs for all age groups with chronic exposure to vegetables ranged from approximately 1 to 3. These results are all greater than or equal to one, suggesting the potential for adverse health effects associated with glyphosate. It should be noted, though, that the upper estimates of risk are based on highly conservative fruit and vegetable intake rates; thus it is anticipated that only a very small number of individuals will have this magnitude of exposure and, therefore, be at this level of risk.

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## **Appendix L-2. Literature Search**

### **1.0 Literature Search Strategy**

#### **1.1 Purpose**

Primary sources of data were obtained from the following three documents: the United States Environmental Protection Agency (US EPA) 1993 Reregistration Eligibility Decision (RED) document on glyphosate (US EPA, 1993); the U.S. EPA's Glyphosate Human Health Risk Assessment for Proposed Use on Indian Mulberry and Amended Use on Pea, Dry (US EPA, 2006); and the USDA, Forest Service 2003 human health and ecological risk assessment on glyphosate (USDA, 2003). The purpose of this literature search, therefore, was to locate additional references about the health and safety risks from increased glyphosate and other chemical usage on humans (exclusive of field workers). Several DIALOG databases were searched, and Google, and Google Scholar search engines supplemented the DIALOG search. References were selected from the extensive list of literature based on requesting the abstracts and determining if the open literature data were not included in the three primary documents listed below or provided contrary or controversial information to these documents.

The following DIALOG databases will be included in the search:

|                                                 |                                |
|-------------------------------------------------|--------------------------------|
| File 5: BIOSIS                                  | File 6: NTIS                   |
| File 34: SciSearch                              | File 41: Pollution Abstracts   |
| File 40: Enviroline                             | File 72: EMBASE                |
| File 76: Environmental Sciences                 | File 79: Aqualine              |
| File 98: General Science Abstracts              | File 117: Water Resources      |
| Abstracts                                       | File 144: PASCAL               |
| File 154: MEDLINE                               | File 156: ToxFile              |
| File 245: WATERNET™                             | File 250: CAB Abstracts        |
| File 266: Federal Research In Progress (FEDRIP) | File 399: CA SEARCH®: Chemical |
| File 5: BIOSIS                                  | File 6: NTIS                   |
| File 34: SciSearch                              | File 41: Pollution Abstracts   |

Descriptions of these files are available at <http://library.dialog.com/bluesheets/>.

#### **1.2 Scope of Search**

The search will focus on references published after 1990. A reference list with abstracts will be screened for relevance. English language only publications will be retrieved.

### 1.3 Strategy Overview

A list of search parameters is listed below.

### 1.4 Synonyms

- Glyphosate
- Glyphosate, isopropylamine salt
- Glyphosate, sodium salt
- Glyphosate, potassium
- Glyphosate, ammonium
- Glyphosate, sulfosate
- *N*-(phosphonomethyl) glycine
- Roundup®
- Roundup Ultra®
- Honcho®

### 1.5 Keywords

- |                          |                    |
|--------------------------|--------------------|
| • Acute                  | • Incidental       |
| • Alfalfa                | • Ingest*          |
| • Allowable daily intake | • Inhal*           |
| • Cancer*                | • Inhibition       |
| • Carcino*               | • Irritation       |
| • Chronic                | • Leach*           |
| • Crop                   | • Metabo*          |
| • Degradation            | • Mutagen*         |
| • Derma*                 | • Neuro*           |
| • Developmental          | • Non-target crops |
| • Dietary risk           | • Persistence      |
| • Dose                   | • Reproducti*      |
| • Emission               | • Residue          |
| • Endpoint               | • Risk             |
| • Environmental Health   | • Sensitization    |
| • Embryo                 | • Spray drift      |
| • Environmental impacts  | • Subchronic       |
| • Exposure(s)            | • Terato*          |
| • Eye                    | • Tolerance        |
| • Fertility              | • Toxic*           |
| • Health effect(s)       | • Usage patterns   |

- Human health risk

## 1.6 Submission of Citations for Approval

Using reference management software, pooled information obtained from the various bibliographic databases will be screened to remove duplicates. Additionally, ICF will review the list prior to submission and eliminate any irrelevant citations. Information provided to USDA will include the following (when available):

Title. Publication Year.

## 1.7 Literature Search Results:

### TITLES FROM VARIOUS COMBINATIONS OF THE SEARCH SETS

22/6/3 (Item 3 from file: 154)

14946077 PMID: 12507058

An analysis of \*glyphosate\* data from the California Environmental Protection Agency Pesticide Illness Surveillance Program.

\*2002\*

22/6/20 (Item 20 from file: 154)

14535687 PMID: 11890463

Current methods for assessing \*safety\* of genetically modified crops as exemplified by data on \*Roundup\* Ready soybeans.

Jan-Feb \*2002\*

22/6/21 (Item 21 from file: 154)

16416941 PMID: 15929894

Differential effects of \*glyphosate\* and \*roundup\* on \*human\* placental cells and aromatase.

Jun \*2005\*

22/6/27 (Item 27 from file: 50)

0008562363 CAB Accession Number: 20043013531

The effect of spray particle size and distribution on drift and efficacy of herbicides.

Publication Year: 2004

22/6/28 (Item 28 from file: 154)

14263603 PMID: 11564623

An exploratory analysis of the effect of pesticide \*exposure\* on the risk of spontaneous abortion in an Ontario farm population.

Aug \*2001\*

22/6/32 (Item 32 from file: 73)

0081488433 EMBASE No: 2006551723

The farm family \*exposure\* study: Acquavella et al. respond [3]

November 1, 2006

22/6/33 (Item 33 from file: 73)  
0080877664 EMBASE No: 2005522322  
Farm Family \*Exposure\* Study: Methods and recruitment practices for a  
biomonitoring study of pesticide \*exposure\*  
November 1, 2005

22/6/34 (Item 34 from file: 73)  
0081234988 EMBASE No: 2006297170  
Gliomas and farm pesticide \*exposure\* in men: The upper midwest health  
study  
December 1, 2004

22/6/35 (Item 35 from file: 162)  
0005035481 CAB Accession Number: 20053018188  
\*Glyphosate\*.  
Publication Year: 2004

22/6/37 (Item 37 from file: 154)  
16233423 PMID: 15694458  
A glyphosate-based pesticide impinges on transcription.  
Feb 15 \*2005\*

22/6/38 (Item 38 from file: 154)  
16165018 PMID: 15862083  
\*Glyphosate\* \*poisoning\*.  
\*2004\*

22/6/39 (Item 39 from file: 73)  
0080634337 EMBASE No: 2005278629  
\*Glyphosate\* results revisited (multiple letters) [2]  
June 1, 2005

22/6/42 (Item 42 from file: 154)  
15338586 PMID: 12937207  
Integrative assessment of multiple pesticides as risk factors for  
non-Hodgkin's lymphoma among men.  
Sep \*2003\*

22/6/43 (Item 43 from file: 73)  
0081540797 EMBASE No: 2006604398  
In utero pesticide \*exposure\* and childhood morbidity  
January 1, 2007

22/6/44 (Item 44 from file: 76)  
0001821739 IP ACCESSION NO: 6653001  
Mechanism of \*toxicity\* of commercial \*glyphosate\* formulatons: How  
important is the surfactant?  
PUBLICATION DATE: \*2005\*

22/6/45 (Item 45 from file: 73)  
0080120735 EMBASE No: 2004304381  
Non-Hodgkin's lymphoma among asthmatics \*exposed\* to pesticides  
August 20, 2004



22/6/49 (Item 49 from file: 73)  
0080171096 EMBASE No: 2004353558  
Patterns of pesticide use and their determinants among wives of farmer  
pesticide applicators in the agricultural health study  
August 1, 2004

22/6/50 (Item 50 from file: 162)  
0005222326 CAB Accession Number: 20073099434  
Pesticide contamination inside farm and nonfarm homes.  
Publication Year: 2005

22/6/51 (Item 51 from file: 73)  
0081560810 EMBASE No: 2006624680  
Pesticides and adult respiratory outcomes in the agricultural health study  
ISSUE TITLE: Living in a Chemical World: Framing the Future in Light of the  
Past  
September 1, 2006

22/6/52 (Item 52 from file: 73)  
0082048526 EMBASE No: 2007489590  
Pesticide \*dose\* estimates for children of Iowa farmers and non-farmers  
November 1, 2007

22/6/56 (Item 56 from file: 154)  
26616354 PMID: 18320729  
Pesticide-related \*dermatitis\* in Saku district, Japan, 1975-2000.  
Jan-Mar \*2008\*

22/6/59 (Item 59 from file: 73)  
0080634359 EMBASE No: 2005278651  
\*Roundup\* revelation. Weed killer adjuvants may boost \*toxicity\*  
June 1, 2005

22/6/61 (Item 61 from file: 73)  
0081488432 EMBASE No: 2006551722  
Suggested corrections to the farm family \*exposure\* study [2]  
November 1, 2006

22/6/62 (Item 62 from file: 10)  
4632422 43919222 Holding Library: AGL  
Time- and \*Dose\*-Dependent Effects of \*Roundup\* on \*Human\* Embryonic and  
Placental Cells  
\*2007\*  
URL: <http://dx.doi.org/10.1007/s00244-006-0154-8>

22/6/64 (Item 64 from file: 10)  
4638864 43876156 Holding Library: AGL  
\*Toxicity\* assessment of the main pesticides used in Costa Rica  
\*2007\*  
URL: <http://dx.doi.org/10.1016/j.agee.2006.05.010>

28/6/3 (Item 3 from file: 154)  
26532387 PMID: 18358975  
\*Acute\* pancreatitis caused by severe \*glyphosate\*-surfactant oral  
\*intoxication\*.  
Mar \*2008\*

28/6/5 (Item 5 from file: 55)

18548217 BIOSIS NO.: 200510242717  
Agricultural pesticide-related \*poison\* in Italy: Cases reported to the  
\*Poisoning\* Control Center of Milan in 2000-2001  
\*2004\*

28/6/8 (Item 8 from file: 154)  
25632929 PMID: 17984146  
Alteration of estrogen-regulated gene expression in \*human\* cells induced  
by the agricultural and horticultural herbicide \*glyphosate\*.  
Sep \*2007\*

28/6/14 (Item 14 from file: 73)  
0081251566 EMBASE No: 2006313832  
Analysis of 8000 hospital admissions for \*acute\* \*poisoning\* in a rural  
area of Sri Lanka  
May 1, 2006

28/6/20 (Item 20 from file: 55)  
18056718 BIOSIS NO.: 200400427507  
Avoiding the penalties of \*spray\* \*drift\* with a practical look at  
\*glyphosate\*  
\*2004\*

28/6/30 (Item 30 from file: 154)  
16614216 PMID: 16190155  
Biomonitoring for \*farm\* \*families\* in the \*farm\* \*family\*  
\*exposure\* study.  
\*2005\*

28/6/33 (Item 33 from file: 154)  
14660317 PMID: 12060842  
Birth defects, season of conception, and sex of \*children\* born to  
pesticide applicators living in the Red River Valley of Minnesota, USA.  
Jun \*2002\*

28/6/45 (Item 45 from file: 154)  
13704636 PMID: 10958131  
Clinical presentations and prognostic factors of a \*glyphosate\*  
-surfactant herbicide \*intoxication\*: a review of 131 cases.  
Aug \*2000\*

28/6/46 (Item 46 from file: 55)  
0019973330 BIOSIS NO.: 200800020269  
Clinical outcomes after suicidal \*ingestion\* of \*glyphosate\* surfactant  
herbicide: Severity of \*intoxication\* according to amount \*ingested\*  
\*2007\*

28/6/48 (Item 48 from file: 154)  
15525131 PMID: 14705857  
Comment on "An analysis of \*glyphosate\* data from the California  
Environmental Protection Agency Pesticide Illness Surveillance Program".  
\*2003\*

28/6/50 (Item 50 from file: 10)  
4371758 43771446 Holding Library: AGL

Comparative effects of the \*Roundup\* and \*glyphosate\* on mitochondrial oxidative phosphorylation  
\*2005\*

28/6/51 (Item 51 from file: 73)  
0081478551 EMBASE No: 2006541781  
Comparative \*genotoxicity\* of the herbicides \*Roundup\*, Stomp and Reglone in plant and mammalian test systems  
November 1, 2006

28/6/54 (Item 54 from file: 154)  
16715180 PMID: 16315092  
A comparative risk assessment of genetically engineered, \*mutagenic\*, and conventional wheat production systems.  
Dec \*2005\*

28/6/59 (Item 59 from file: 55)  
17952638 BIOSIS NO.: 200400323402  
Comparison of the effect of \*Roundup\* Ultra 360 SL pesticide and its active compound \*glyphosate\* on \*human\* erythrocytes  
\*2004\*

28/6/74 (Item 74 from file: 55)  
0019750321 BIOSIS NO.: 200700410062  
Cysteine turnover in \*human\* cell lines is influenced by \*glyphosate\*  
\*2007\*

28/6/78 (Item 78 from file: 154)  
25632485 PMID: 17882442  
Defense against \*dermal\* \*exposures\* is only \*skin\* deep: significantly increased penetration through slightly damaged \*skin\*.  
Nov \*2007\*

28/6/79 (Item 79 from file: 55)  
0019648010 BIOSIS NO.: 200700307751  
Differential effects of \*glyphosate\* and \*roundup\* in gene expression of \*human\* peripheral blood mononuclear cells: Implications for hematological \*carcinogenesis\*.  
\*2007\*

28/6/80 (Item 80 from file: 156)  
4011073 NLM Doc No: 15929894  
Differential effects of \*glyphosate\* and \*roundup\* on \*human\* placental cells and aromatase.  
Jun \*2005\*

28/6/87 (Item 87 from file: 154)  
15857617 PMID: 15240034  
Determination of \*glyphosate\* in biological fluids by 1H and 31P NMR spectroscopy.  
Jul 16 \*2004\*

28/6/88 (Item 88 from file: 154)  
15169562 PMID: 12731658  
Determination of the herbicide \*glyphosate\* and its \*metabolite\* in biological specimens by gas chromatography-mass spectrometry. A case of \*poisoning\* by \*roundup\* herbicide.  
Apr \*2003\*

28/6/91 (Item 91 from file: 73)  
0082318049 EMBASE No: 2008142852  
\*Dietary\* \*exposure\* to pesticide residues in Yaounde: The Cameroonian  
total diet study  
April 1, 2008

28/6/92 (Item 92 from file: 154)  
13858726 PMID: 11139167  
Development of California Public Health Goals (PHGs) for chemicals in  
drinking water.  
Sep-Oct \*2000\*

28/6/107 (Item 107 from file: 10)  
3899354 22437401 Holding Library: AGL  
Influence of paraquat, \*glyphosate\*, and cadmium on the activity of some  
serum enzymes and protein electrophoretic behavior (in vitro)  
\*2001\*

28/6/108 (Item 108 from file: 55)  
16070131 BIOSIS NO.: 200100241970  
Effect of pesticides and CdCl<sub>2</sub> on serum enzyme and protein electrophoretic  
behaviour (in vitro)  
\*2000\*

28/6/109 (Item 109 from file: 162)  
0004952937 CAB Accession Number: 20033205456  
The effects of refining consumer \*exposure\* assessments of \*glyphosate\*.  
Book Title: The BCPC International Congress: Crop Science and  
Technology, Volumes 1 and 2. Proceedings of an international congress held  
at the SECC, Glasgow, Scotland, UK, 10-12 November 2003  
Publication Year: 2003

28/6/110 (Item 110 from file: 10)  
4211069 43658629 Holding Library: AGL  
Effects of refining predicted \*chronic\* \*dietary\* intakes of pesticide  
residues: a case study using \*glyphosate\*  
\*2004\*

28/6/119 (Item 119 from file: 154)  
16176902 PMID: 17134388  
Environmental and human health impacts of growing genetically modified  
herbicide-tolerant sugar beet: a life-cycle assessment.  
Jul \*2004\*

28/6/124 (Item 124 from file: 154)  
17063768 PMID: 16749554  
Can early hemodialysis affect the outcome of the \*ingestion\* of  
\*glyphosate\* herbicide?  
\*2006\*

28/6/126 (Item 126 from file: 154)  
26532351 PMID: 18358936  
The early prognostic factors of \*glyphosate\*-surfactant \*intoxication\*.  
Mar \*2008\*

28/6/127 (Item 127 from file: 73)  
0078416702 EMBASE No: 2001022513  
Erratum: Rapid lethal \*intoxication\* caused by the herbicide \*glyphosate\*  
-trimesium (touchdown) (\*Human\* & Experimental \*Toxicology\* vol. 18(12)  
(2000) (735-737))  
December 1, 2000

28/6/129 (Item 129 from file: 55)  
0019787949 BIOSIS NO.: 200700447690  
Evaluation of DNA damage in an Ecuadorian population \*exposed\* to  
\*glyphosate\*  
\*2007\*

28/6/131 (Item 131 from file: 156)  
3686287 NLM Doc No: 11564623  
An exploratory analysis of the effect of pesticide \*exposure\* on the risk  
of spontaneous abortion in an Ontario farm population.  
Aug \*2001\*

28/6/132 (Item 132 from file: 154)  
16811634 PMID: 16357597  
\*Exposure\* misclassification in studies of agricultural pesticides:  
insights from biomonitoring.  
Jan \*2006\*

28/6/135 (Item 135 from file: 154)  
14733906 PMID: 12148884  
\*Exposure\* to pesticides as risk factor for non-Hodgkin's lymphoma and  
hairy cell leukemia: pooled analysis of two Swedish case-control studies.  
May \*2002\*

28/6/140 (Item 140 from file: 55)  
17061934 BIOSIS NO.: 200300020653  
\*Farm\* \*family\* \*exposure\* study: Biomonitoring results for \*glyphosate\*.  
\*2002\*

28/6/142 (Item 142 from file: 55)  
17543919 BIOSIS NO.: 200300498947  
Farm \*exposure\* to pesticides and glioma in women.  
\*2003\*

28/6/150 (Item 150 from file: 154)  
15655427 PMID: 14998747  
\*Glyphosate\* biomonitoring for \*farmers\* and their families: results from  
the \*Farm\* \*Family\* \*Exposure\* Study.  
Mar \*2004\*

28/6/151 (Item 151 from file: 154)  
15806818 PMID: 15182708  
\*Glyphosate\*-based pesticides affect cell cycle regulation.  
Apr \*2004\*

28/6/154 (Item 154 from file: 154)  
15847227 PMID: 15228468  
Glyphosate herbicide formulation: a potentially lethal ingestion.  
Jun \*2004\*

28/6/155 (Item 155 from file: 55)  
19155868 BIOSIS NO.: 200600501263  
\*Glyphosate\*-induced antioxidant imbalance in HaCaT: The protective effect  
of vitamins C and E  
\*2006\*

28/6/157 (Item 157 from file: 156)  
3973750 NLM Doc No: 15862083  
Glyphosate \*poisoning\*.  
\*2004\*

28/6/158 (Item 158 from file: 73)  
0079472981 EMBASE No: 2003178348  
\*Glyphosate\* \*poisoning\* - A rare case of herbicide \*poisoning\*  
July 1, 2002

28/6/160 (Item 160 from file: 10)  
4823604 44034732 Holding Library: AGL  
\*Glyphosate\*-resistant crops: adoption, use and future considerations  
\*2008\*  
URL: <http://dx.doi.org/10.1002/ps.1501>

28/6/162 (Item 162 from file: 55)  
18724863 BIOSIS NO.: 200600070258  
\*Glyphosate\* surfactant herbicide-induced \*acute\* renal failure  
\*2005\*

28/6/164 (Item 164 from file: 73)  
0080873358 EMBASE No: 2005518013  
GMO: \*Human\* \*health\* \*risk\* assessment  
August 1, 2005

28/6/169 (Item 169 from file: 10)  
4795875 44017629 Holding Library: AGL  
\*Genotoxic\* Potential of \*Glyphosate\* Formulations: Mode-of-Action  
Investigations  
\*2008\*  
URL: <http://dx.doi.org/10.1021/jf072581i>

28/6/170 (Item 170 from file: 154)  
26379341 PMID: 18084044  
A gene-shuffled \*glyphosate\* acetyltransferase protein from *Bacillus*  
licheniformis (GAT4601) shows no evidence of allergenicity or \*toxicity\*.  
Apr \*2008\*

28/6/175 (Item 175 from file: 10)  
4823622 44034750 Holding Library: AGL  
Herbicides, \*glyphosate\* resistance and \*acute\* mammalian \*toxicity\*:  
simulating an environmental effect of \*glyphosate\*-resistant weeds in the  
USA  
\*2008\*  
URL: <http://dx.doi.org/10.1002/ps.1497>

28/6/180 (Item 180 from file: 73)

0078408708        EMBASE No: 2001014519  
 Impact of pesticides use on \*human\* health in Mexico: A review  
 December 1, 2000

28/6/181        (Item 181 from file: 10)  
 3979215 23250194 Holding Library: AGL  
 Implications of \*glyphosate\* \*toxicology\* and \*human\* biomonitoring data  
 for epidemiologic research  
 \*2001\*

28/6/186        (Item 186 from file: 73)  
 0081657997        EMBASE No: 2007091481  
 Inferring past pesticide \*exposures\*: A matrix of individual active  
 ingredients in \*home\* and garden pesticides used in past decades  
 February 1, 2007

28/6/190        (Item 190 from file: 156)  
 3850884 NLM Doc No: 12937207  
 Integrative assessment of multiple pesticides as risk factors for  
 non-Hodgkin's lymphoma among men.  
 Sep \*2003\*

28/6/193        (Item 193 from file: 55)  
 0019466064 BIOSIS NO.: 200700125805  
 In utero pesticide \*exposure\* and childhood morbidity  
 \*2007\*

28/6/194        (Item 194 from file: 154)  
 13655777 PMID: 10933758  
 In vitro studies of cellular and molecular developmental \*toxicity\* of  
 adjuvants, herbicides, and fungicides commonly used in Red River Valley,  
 Minnesota.  
 Jul 28 \*2000\*

28/6/195        (Item 195 from file: 55)  
 18581240 BIOSIS NO.: 200510275740  
 In vitro evaluation of \*glyphosate\*-induced DNA damage in fibrosarcoma  
 cells HT1080 and Chinese hamster ovary (CHO) cells.  
 \*2004\*

28/6/196        (Item 196 from file: 154)  
 14266614 PMID: 11569770  
 Investigation of the herbicide \*glyphosate\* and the plant growth  
 regulators chlormequat and mepiquat in cereals produced in Denmark.  
 Oct \*2001\*

28/6/206        (Item 206 from file: 55)  
 19253044 BIOSIS NO.: 200600598439  
 Molecular and cellular effects of \*glyphosate\* on \*human\* lymphocytes:  
 Implications for non-Hodgkin's lymphoma.  
 \*2006\*

28/6/212        (Item 212 from file: 55)  
 17262052 BIOSIS NO.: 200300220771  
 Non-specific alteration of steroidogenesis in MA-10 Leydig cells by supra-  
 physiological concentrations of the surfactant in \*Roundup\*(R) herbicide.  
 \*2003\*

28/6/213 (Item 213 from file: 156)  
190707 NLM Doc No: DART/TER/4001875 Sec. Source ID: DART/TER/4001875  
Neural Tube Defects And Maternal Residential Proximity To Agricultural  
Pesticide Applications.  
\*2004\*

28/6/226 (Item 226 from file: 40)  
00640398 ENVIROLINE NUMBER: 03-07730  
Organophosphorus Pesticide \*Exposure\* of Urban and Suburban Preschool  
\*Children\* with Organic and Conventional Diets  
Mar 03

28/6/227 (Item 227 from file: 154)  
16224136 PMID: 15683179  
Oral bioavailability of \*glyphosate\*: studies using two intestinal cell  
lines.  
Jan \*2005\*

28/6/228 (Item 228 from file: 154)  
26643404 PMID: 18442254  
Oxidative damage mediated by herbicides on yeast cells.  
May 28 \*2008\*

28/6/235 (Item 235 from file: 154)  
14119755 PMID: 11391760  
Parkinsonism after glycine-derivate \*exposure\*.  
May \*2001\*

28/6/238 (Item 238 from file: 154)  
17095239 PMID: 16787817  
Parenteral \*glyphosate\*-surfactant herbicide \*intoxication\*.  
Jul \*2006\*

28/6/246 (Item 246 from file: 154)  
16487576 PMID: 16020099  
Pesticide contamination inside farm and nonfarm \*homes\*.  
Jul \*2005\*

28/6/247 (Item 247 from file: 154)  
25071148 PMID: 17659274  
Pesticide \*dose\* estimates for \*children\* of Iowa \*farmers\* and non-  
\*farmers\*.  
Nov \*2007\*

28/6/249 (Item 249 from file: 73)  
0080532622 EMBASE No: 2005176821  
Pesticides and \*human\* health: Why public health officials should support  
a ban on non-essential residential use  
March 1, 2005

28/6/253 (Item 253 from file: 73)  
0080107139 EMBASE No: 2004291195  
Pesticide \*intoxications\* in the Centre of Portugal: Three years analysis  
July 16, 2004



28/6/254 (Item 254 from file: 154)  
14961841 PMID: 12549246  
Pesticide use and practices in an Iowa \*farm\* \*family\* pesticide  
\*exposure\* study.  
Nov \*2002\*

28/6/255 (Item 255 from file: 73)  
0082286261 EMBASE No: 2008100152  
Pesticides and prostate \*cancer\*: A review of epidemiologic studies with  
specific agricultural \*exposure\* information  
April 1, 2008

28/6/257 (Item 257 from file: 154)  
25284275 PMID: 17976274  
Pesticide regulation, utilization, and retailers' selling practices in  
Trinidad and Tobago, West Indies: current situation and needed changes.  
Aug \*2007\*

28/6/259 (Item 259 from file: 154)  
14540961 PMID: 11896679  
Pesticide \*Roundup\* provokes cell division dysfunction at the level of  
CDK1/cyclin B activation.  
Mar \*2002\*

28/6/263 (Item 263 from file: 154)  
26291470 PMID: 18371753  
Quantitative determination of \*glyphosate\* in \*human\* serum by 1H NMR  
spectroscopy.  
Jan 15 \*2008\*

28/6/266 (Item 266 from file: 55)  
16849926 BIOSIS NO.: 200200443437  
A quantitative approach for estimating \*exposure\* to pesticides in the  
agricultural health study  
\*2002\*

28/6/277 (Item 277 from file: 154)  
25260805 PMID: 17915625  
\*Roundup\* \*intoxication\* and a rationale for treatment.  
Sep \*2007\*

28/6/284 (Item 284 from file: 154)  
13617796 PMID: 10854122  
\*Safety\* evaluation and risk assessment of the herbicide \*Roundup\* and  
its active ingredient, \*glyphosate\*, for \*humans\*.  
Apr \*2000\*

28/6/288 (Item 288 from file: 154)  
26557440 PMID: 18407393  
\*Skin\* decontamination of \*glyphosate\* from \*human\* \*skin\* in vitro.  
Jun \*2008\*

28/6/289 (Item 289 from file: 154)  
15959003 PMID: 15362602  
\*Skin\* \*toxicity\* from \*glyphosate\*-surfactant formulation.  
\*2004\*

28/6/295 (Item 295 from file: 73)  
0078595998 EMBASE No: 2001202299  
The surveillance of agrichemical spraydrift incidents in New Zealand 1999-  
2000  
June 29, 2001

28/6/311 (Item 311 from file: 144)  
15662712 PASCAL No.: 02-0368723  
The \*toxicology\* of herbicides  
\*2001\*

28/6/312 (Item 312 from file: 73)  
0080836676 EMBASE No: 2005481309  
\*Toxicity\* tests: "inert" and active ingredients (multiple letters) [5]  
October 1, 2005

28/6/313 (Item 313 from file: 55)  
0019458363 BIOSIS NO.: 200700118104  
\*Toxicity\* assessment of the main pesticides used in Costa Rica  
\*2007\*

28/6/317 (Item 317 from file: 154)  
17473895 PMID: 16984946  
Urinary pesticide concentrations among \*children\*, mothers and fathers  
living in farm and non-farm households in iowa.  
Jan \*2007\*

## Appendix L-3. Summary of Toxicology Studies

**Table L-20. Summary of Toxicology Studies Included in USDA (2003) and US EPA (1993) Reports**

| Study Type                                   | Species                   | Dose Range                                                                                                                                              | Result                                                                                                                                                                                                                                             | Primary Author(s) <sup>a</sup>                                                                                                              |
|----------------------------------------------|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Acute Toxicity</i>                        |                           |                                                                                                                                                         |                                                                                                                                                                                                                                                    |                                                                                                                                             |
| Acute Dermal                                 | Rabbit                    | Not provided                                                                                                                                            | > 2 g/kg (Category III)                                                                                                                                                                                                                            | Birch et al., 1970 (MRID 00067039)                                                                                                          |
| Acute Oral                                   | Rat                       | Not provided                                                                                                                                            | > 4,320 mg/kg (Category III)                                                                                                                                                                                                                       | Birch et al., 1970 (MRID 00067039)                                                                                                          |
| Eye Irritation                               | Not provided              | Not provided                                                                                                                                            | Mild irritation, clears in 7 days (Category III)                                                                                                                                                                                                   | Blaszczak, 1988c (MRID 41400603)                                                                                                            |
| Dermal Irritation                            | Not provided              | Not provided                                                                                                                                            | Slight irritation (Category IV)                                                                                                                                                                                                                    | Blaszczak, 1988d (MRID 41400604)                                                                                                            |
| Skin Sensitization                           | Not provided              | Not provided                                                                                                                                            | Negative                                                                                                                                                                                                                                           | Auletta et al., 1983a (MRID 00137137), Auletta et al., 1983b (MRID 00137138), Maibach, 1982 (MRID 0013139), and Franz, 1983 (MRID 00137140) |
| <i>Subchronic Toxicity</i>                   |                           |                                                                                                                                                         |                                                                                                                                                                                                                                                    |                                                                                                                                             |
| 90-Day Feeding                               | CD-1 Mice                 | 0, 250, 500, or 2,500 mg/kg/day                                                                                                                         | NOEL: 500 mg/kg (both sexes)<br>LOEL: 2,500 mg/kg (both sexes)<br>Systemic toxicity<br><br>Based on body weight gains                                                                                                                              | Street et al., 1980 (MRID 00036803)                                                                                                         |
| 13-Week Feeding                              | Mice                      | 3,125, 6,250, 12,500, 25,000 or 50,000 ppm (Males: 507, 1,065, 2,273, 4,776 or 10,780 mg/kg/day; Females: 753, 1,411, 2,707, 5,846 or 11,977 mg/kg/day) | Decreased body weight at two highest dose levels in both sexes, increased relative heart, kidney, liver, lung, thymus, and testis weight for males, salivary gland lesions, no effects on food consumption, sperm motility or estrous cycle length | NCI, 1992                                                                                                                                   |
| 21-Day Dermal                                | New Zealand White Rabbits | 10, 1,000, or 5,000 mg/kg/day                                                                                                                           | NOEL: 1,000 mg/kg/day (both sexes)<br>LOEL: 5,000 mg/kg/day (both sexes)<br><br>Based on erythema, edema, food consumption, and serum changes                                                                                                      | Johnson et al., 1982 (MRID 00098460)                                                                                                        |
| 6-Weeks, gelatin capsule administered orally | New Zealand Rabbits, male | 1/10 <sup>th</sup> or 1/100 <sup>th</sup> of the LD <sub>50</sub>                                                                                       | Decreased body weight, libido, ejaculate volume, sperm concentrations, semen initial fructose and semen osmolarity, increases in abnormal and dead                                                                                                 | Yousef et al., 1995                                                                                                                         |

| Study Type                                                                                                                    | Species             | Dose Range                                                                                                                                               | Result                                                                                                                                                                                                                                                                                                                | Primary Author(s) <sup>a</sup>                                                  |
|-------------------------------------------------------------------------------------------------------------------------------|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| 90-Day Feeding                                                                                                                | Sprague-Dawley Rats | 0, 1,000, 5,000, or 20,000 ppm                                                                                                                           | sperm<br>NOEL: < 1,000 ppm (both sexes)<br>Systemic toxicity<br><br>Based on serum changes and pancreatic lesions                                                                                                                                                                                                     | Stout and Johnson, 1987 (MRID 40559401) and Lankas et al., 1981 (MRID 00093879) |
| 13-Week Feeding                                                                                                               | Rat                 | 3,125, 6,250, 12,500, 25,000, or 50,000 ppm<br>(Males: 205, 410, 811, 1,678, or 3,393 mg/kg/day<br>Females: 213, 421, 844, 1,690, or 3,393 or mg/kg/day) | Decreased body weight in males (20%) and females (5%) at the highest dose level, mild liver toxicity in both sexes at all time points, 20% decrease in sperm counts at two higher doses, longer estrous cycle at the highest dose, frequency of salivary gland lesions increases with dose level.                     | NCI, 1992                                                                       |
| <i>Chronic Toxicity</i>                                                                                                       |                     |                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                       |                                                                                 |
| One-Year Feeding                                                                                                              | Beagle Dogs         | 0, 20, 100, or 500 mg/kg/day                                                                                                                             | NOEL: ≥ 500 mg/kg/day<br>Systemic toxicity                                                                                                                                                                                                                                                                            | Reyna, 1985 (MRID 00153374)                                                     |
| 24-Month Feeding<br><br>*U.S. EPA 1995[FR July 7, Vol 60, No. 130] indicates that the exposure duration was 18 months, not 24 | CD Mice             | 1,000, 5,000, or 30,000 ppm<br>(Males: 111-250, 519-1,264 or 3,465-7,220 mg/kg/day<br>Females: 129-288, 690-1,322, or 4,232-9,859 mg/kg/day)             | NOAEL: 5,000 ppm (750 mg/kg/day)<br><br>Based on non-neoplastic chronic effects, body weights, histopathological changes and chronic interstitial necrosis, proximal tubule epithelial cell basophilia and hypertrophy of the kidneys                                                                                 | U.S. EPA, 1986                                                                  |
| 2-Year Feeding (Carcinogenicity)                                                                                              | Sprague-Dawley Rats | 0, 2,000, 8,000, or 20,000 ppm<br>(Males: 0, 89, 362, or 940 mg/kg/day<br>Females: 0, 113, 457 or 1,183 mg/kg/day)                                       | NOEL: 8,000 ppm (both sexes),<br>Males: 362 mg/kg/day,<br>Females: 457 mg/kg/day<br>LOEL: 20,000 ppm (both sexes),<br>Males: 940 mg/kg/day,<br>Females: 1,183 mg/kg/day<br>Systemic toxicity<br><br>Based on body weight, cataracts and lens abnormalities, urinary pH, liver weight, liver weight/brain weight ratio | Stout and Ruecker, 1990 (MRID 41643801)                                         |
| 26-Month Feeding                                                                                                              | Sprague-Dawley Rats | 0, 30, 100, or 300 ppm<br>(Males: 0, 3, 10 or 31 mg/kg/day<br>Females: 0, 3, 11, or 34 mg/kg/day)                                                        | NOEL: ≥ 300 ppm (both sexes);<br>Males: 31 mg/kg/day, Females: 34 mg/kg/day<br>Systemic toxicity<br><br>Based on toxic signs, mortality, body weights, food consumption, hematology, clinical chemistry, urinalysis, organ weights and organ/tissue pathology                                                         | Lankas et al., 1981 (MRID 00093879)                                             |
| <i>Carcinogenicity</i>                                                                                                        |                     |                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                       |                                                                                 |
| 18-Month Feeding                                                                                                              | CD-1 Mice           | 0, 150, 750, or                                                                                                                                          | NOEL: 750 mg/kg/day                                                                                                                                                                                                                                                                                                   | Knezevich and                                                                   |

| Study Type                                            | Species                              | Dose Range                                                                                           | Result                                                                                                                                                                                              | Primary Author(s) <sup>a</sup>                                  |
|-------------------------------------------------------|--------------------------------------|------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|
|                                                       |                                      | 4,500 mg/kg/day                                                                                      | LOEL: 4,500 mg/kg/day<br><br>Not carcinogenic based on body weight, hepatocellular hypertrophy or necrosis, interstitial nephritis, proximal tubule epithelial basophilia and hypertrophy, adenomas | Hogan, 1983 (MRID 00130406) and McConnell, 1985 (MRID 00150564) |
| 2-Year Feeding (Chronic)                              | Sprague-Dawley Rats                  | Males: 0, 89, 362, or 940 mg/kg/day<br>Females: 0, 113, 457 or 1183 mg/kg/day                        | Not carcinogenic based on incidences of adenomas                                                                                                                                                    | MRID 41648301                                                   |
| 24-Month Feeding                                      | Sprague Dawley Rats                  | 2,000, 8,000, or 20,000 ppm (Males: 89, 362 or 940 mg/kg/day<br>Females: 45, 113 or 1,183 mg/kg/day) | NOAEL: 8,000 ppm<br><br>Based on body weight, cataracts and lens abnormalities, urinary tract pH, liver weight and inflammation of gastric mucosa                                                   | Stout and Ruecker, 1990                                         |
| 26-Month Feeding (Chronic)                            | Sprague-Dawley Rats                  | Males: 0, 3, 10, or 31 mg/kg/day<br>Females: 0, 3, 11 or 34 mg/kg/day                                | Not carcinogenic based on incidences of carcinomas and tumors                                                                                                                                       | Lankas et al., 1981 (MRID 00093879)                             |
| <i>Developmental Toxicity</i>                         |                                      |                                                                                                      |                                                                                                                                                                                                     |                                                                 |
| Gavage on days 6-27 of gestation                      | Dutch Belted Rabbits, pregnant       | 0, 75, 175, or 350 mg/kg/day                                                                         | NOEL: $\geq$ 175 mg/kg/day                                                                                                                                                                          | Rodwell et al., 1980b (MRID 00046363)                           |
| Gavage on days 6-19 of gestation                      | Charles River COBS CD Rats, pregnant | 0, 300, 1,000, or 3,500 mg/kg/day                                                                    | NOEL: 1,000 mg/kg/day<br>LOEL: 3,500 mg/kg/day<br><br>Based on number of litters and fetuses with uossified sternbrae and fetal body weights                                                        | Rodwell et al., 1980a (MRID 00046362)                           |
| Continuously in diet for two successive generations   | Sprague-Dawley Rats                  | 0, 100, 500, or 1,500 mg/kg/day                                                                      | NOEL: 500 mg/kg/day<br>LOEL: 1,500 mg/kg/day<br><br>Based on soft stools, food consumption, and body weight                                                                                         | Reyna, 1990 (MRID 41621501)                                     |
| Continuously in diet for three successive generations | Sprague-Dawley Rats                  | 0, 3, 10, or 30 mg/kg/day                                                                            | NOEL: 10 mg/kg/day<br>LOEL: 30 mg/kg/day<br><br>Based on focal tubular dilation of kidney                                                                                                           | Street, 1982 (MRID 00105995)                                    |
| <i>Maternal Toxicity</i>                              |                                      |                                                                                                      |                                                                                                                                                                                                     |                                                                 |
| Gavage on days 8-20 of gestation                      | New Zealand Rabbits                  | 0, 100, 175, or 300 mg/kg/day                                                                        | Maternal toxicity: 175 and 300 mg/kg/day<br>Fetal toxicity: 300 mg/kg/day<br><br>Based on diarrhea, fecal output, food intake, body weight and ossification                                         | Moxon, 1996b                                                    |
| Gavage on days 6-27 of gestation                      | Dutch Belted Rabbits, pregnant       | 0, 75, 175, or 350 mg/kg/day                                                                         | NOEL: 175 mg/kg/day<br>LOEL: 350 mg/kg/day<br><br>Based on diarrhea, nasal discharge, and death                                                                                                     | Rodwell et al., 1980b (MRID 00046363)                           |
| Gavage                                                | CD Rats                              | 0, 300, 1,000, or                                                                                    | NOAEL: 1,000 mg/kg/day                                                                                                                                                                              | Rodwell et al.,                                                 |

| Study Type                                                           | Species                              | Dose Range                                     | Result                                                                                                                                                                                                                           | Primary Author(s) <sup>a</sup>                      |
|----------------------------------------------------------------------|--------------------------------------|------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|
|                                                                      |                                      | 3,500 mg/kg/day                                | (fetotoxicity and maternal toxicity), 3,500 mg/kg/day (teratogenicity)<br><br>Based on breathing, activity, diarrhea, stomach hemorrhages, weight gain, physical appearance, mortality and ossification of sternebrae in fetuses | 1980a; Cited as Monsanto Co., 1980 in U.S. EPA 1986 |
| Gavage on days 6-19 of gestation                                     | CD Rats, pregnant                    | 0, 300, 1,000, or 3,500 mg/kg/day (98.7% pure) | NOEL: 1,000 mg/kg/day<br>Maternal and developmental toxicity<br><br>Based on weight gain, mortality, and fetal weights, viability and ossification of sternebrae                                                                 | Farmer et al., 2000b                                |
| POEA by gavage on days 6-15 of gestation                             | CD Rats, pregnant                    | 0, 15, 100, or 300 mg/kg/day                   | NOEL: 15 mg/kg/day<br><br>Based on food consumption, body weight gain                                                                                                                                                            | Farmer et al., 2000b                                |
| Phosphate ester neutralized POEA by gavage on days 6-15 of gestation | CD Rats, pregnant                    | 0, 15, 50, or 150 mg/kg/day                    | NOEL: 50 mg/kg/day<br><br>Based on mortality, food consumption, body weight gain                                                                                                                                                 | Farmer et al., 2000b                                |
| Gavage on days 6-19 of gestation                                     | Charles River COBS CD Rats, pregnant | 0, 300, 1,000, or 3,500 mg/kg/day              | NOEL: 1,000 mg/kg/day<br>LOEL: 3,500 mg/kg/day<br><br>Based on diarrhea, body weight, breathing, activity patterns, red matter around the mouth, total implantations/dam, inviable fetuses/dam, and deaths                       | Rodwell et al., 1980 (MRID 00046362)                |
| Gavage on days 7-16 of gestation                                     | Wistar Rats                          | 0, 250, 500, or 1,000 mg/kg/day                | No signs of maternal or developmental toxicity                                                                                                                                                                                   | Moxon, 1996a                                        |
| <i>Reproductive Toxicity</i>                                         |                                      |                                                |                                                                                                                                                                                                                                  |                                                     |
| 60-Day Feeding                                                       | Charles River CD Rats                | 0, 3, 10, or 30 mg/kg/day                      | No effects on rat survival, body weight, consumption, mating, pregnancy, fertility and gestation length observed                                                                                                                 | Schroeder and Hogan, 1981                           |
| 2-Generation Feeding                                                 | Sprague-Dawley Rats                  | 0, 100, 500, or 1,500 mg/kg/day                | NOEL: 1,500 mg/kg/day (reproductive); 500 mg/kg/day (systemic)<br>LOEL: 1,500 mg/kg/day (systemic)<br><br>Based on soft stools, food consumption, and body weight                                                                | Reyna, 1990 (MRID 41621501)                         |
| 3-Generation Feeding                                                 | Sprague-Dawley Rats                  | 0, 3, 10, or 30 mg/kg/day                      | NOEL: $\geq$ 30 mg/kg/day<br>Systemic and reproductive toxicity<br><br>Based on focal tubular dilation of kidney                                                                                                                 | Street, 1982 (MRID 00105995)                        |
| 3-Generation Feeding                                                 | CD Rats                              | 0, 3, 10, or 30 mg/kg/day                      | No effects on any reproductive parameters                                                                                                                                                                                        | Farmer et al., 2000a                                |

| Study Type                                                                                                                        | Species                                                                                                         | Dose Range                                    | Result                                                                                                                                                 | Primary Author(s) <sup>a</sup>                         |
|-----------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|
| Feeding                                                                                                                           | CD Rats                                                                                                         | 0, 2,000, 10,000, or 30,000 ppm (97.7 % pure) | NOAEL: 10,000 ppm (740 mg/kg/day) Systemic and reproductive toxicity<br>LOAEL: 30,000 ppm (2268 mg/kg/day)<br><br>Based on body weight and litter size | Farmer et al., 2000a                                   |
| <i>Mutagenicity</i>                                                                                                               |                                                                                                                 |                                               |                                                                                                                                                        |                                                        |
| Allium anaphase-telophase assay, glyphosate                                                                                       | Allium                                                                                                          | 1,440 or 2,880 µg/L                           | No effect                                                                                                                                              | Rank et al., 1993                                      |
| Allium anaphase-telophase assay, Roundup                                                                                          | Allium                                                                                                          | 1,440 or 2,880 µg/L                           | Statistically significant increase in chromosome aberrations                                                                                           | Rank et al., 1993                                      |
| <i>In vitro</i> lymphocyte cultures, glyphosate                                                                                   | Bovine                                                                                                          | 17-70 µM                                      | Statistically significant increase of structural aberrations, sister chromatid exchanges, and G6PD activity                                            | Lioi et al., 1998a                                     |
| Rec-assay, with and without metabolic activation                                                                                  | <i>B. subtilis</i> H17 (rec+) and M45 (rec-)                                                                    | Not provided                                  | No effect, based on increases in mutations                                                                                                             | Shirasu et al., 1978 (MRID 00078619)                   |
| Gene mutation assay in a Hypoxanthine – Guanine – Phosphoribosyl Transferase (HGPRT) assay, with and without metabolic activation | Chinese hamster ovary (CHO) cells                                                                               | Not provided                                  | No mutagenic response observed up to limit of cytotoxicity                                                                                             | Li et al., 1983a (MRID 00132681)                       |
| Sex-linked recessive lethal (SLRL), Roundup                                                                                       | Drosophila larvae                                                                                               | 1 ppm                                         | High frequency of lethals in laraval spermatocytes and in spermatogonia                                                                                | Kale et al., 1995                                      |
| Sex-linked recessive lethal (SLRL), Pondmaster                                                                                    | Drosophila larvae                                                                                               | 0.1 ppm                                       | High frequency of lethals in laraval spermatocytes and in spermatogonia                                                                                | Kale et al., 1995                                      |
| Reverse mutation assays, with and without metabolic activation                                                                    | <i>E. coli</i> WP2 <i>hcr</i> and <i>Salmonella typhimurium</i> strains TA98, TA100, TA1535, TA1537, and TA1538 | Not provided                                  | No effect, based on increases in mutations                                                                                                             | Shirasu et al., 1978 (MRID 00078619)                   |
| <i>In vitro</i> lymphocyte cultures, glyphosate                                                                                   | Human                                                                                                           | 5.0, 8.5, 17.0, or 51.0 µM                    | Dose-related increase in the percent of aberrant cells and an increase of SCE/cell                                                                     | Lioi et al., 1998b                                     |
| SCE in human lymphocytes <i>in vitro</i> , Roundup                                                                                | Human                                                                                                           | 0.25, 2.5, or 25 mg/mL                        | Statistically significant increase (p<0.001) in SCE at 0.25 and 2.5 mg/mL; no lymphocyte growth at highest dose                                        | Vyse and Vigfusson, 1979; and Vigfusson and Vyse, 1980 |
| Bone marrow micronucleus assay, Roundup                                                                                           | Mice                                                                                                            | 133 or 200 mg/kg                              | No clastogenicity                                                                                                                                      | Rank et al., 1993                                      |
| Erythrocyte                                                                                                                       | Mice                                                                                                            | 0.5 mL (two                                   | No MN induction                                                                                                                                        | Grisolia, 2002                                         |

| Study Type                                                                        | Species                                                                 | Dose Range                                            | Result                                                                                                                                                      | Primary Author(s) <sup>a</sup>                                               |
|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| micronuclei (MN) assay, Roundup                                                   |                                                                         | injections in 24 hours)                               |                                                                                                                                                             |                                                                              |
| Structural Chromosomal Aberration Assay                                           | Sprague-Dawley Rats                                                     | 1 g/kg (single i.p. dose)                             | No significant effects, based on clastogenic (chromosome-damaging) effect in the bone marrow cells                                                          | Li et al., 1983b (MRID 00132683)                                             |
| Gene mutation assay in an Ames Test, with and without metabolic activation        | <i>Salmonella typhimurium</i> , strains TA98, TA100, TA1535, and TA1537 | Not provided                                          | No response, based on increases in reverse mutations                                                                                                        | Kier et al., 1978 (MRID 00078620)                                            |
| Plate incorporation assay, presence or absence of Aroclor induced S9 mix, Roundup | <i>Salmonella typhimurium</i>                                           | 360, 720, 1,081, or 1,440 µg/plate                    | Slight but significant number of revertants at 360 µg/plate for TA98 (w/o S9) and at 720 µg/plate for TA100 (w/ S9)                                         | Rank et al., 1993                                                            |
| Alkaline SCG assay (24-hour exposure), Roundup                                    | Tadpole ( <i>Rana catesbeiana</i> )                                     | 1.69, 6.75, or 27 mg/L                                | Significant increases in DNA damage at 6.75 mg/L (p<0.05) and 27 mg/L (p<0.001), compared with controls, no significant increase in DNA damage at 1.69 mg/L | Clements et al., 1997                                                        |
| Erythrocyte micronuclei (MN) assay, Roundup                                       | <i>Tilapia rendalli</i>                                                 | 50, 100, or 200 mg/kg                                 | Statistically significant induction of MN frequencies at all doses                                                                                          | Grisolia, 2002                                                               |
| Frequency of micronucleated cells, glyphosate                                     | <i>Vicia faba</i>                                                       | 35, 70, 105, 140, 350, 700, 1,050, or 1,400 µg/g soil | No genotoxicity                                                                                                                                             | De Marco et al., 1992                                                        |
| <i>Metabolism</i>                                                                 |                                                                         |                                                       |                                                                                                                                                             |                                                                              |
| Radiolabeled <sup>14</sup> C-glyphosate administered orally                       | Sprague-Dawley Rats                                                     | 10 mg/kg, single or repeated                          | No significant change in metabolism, distribution or excretion, based on absorption and excretion rates                                                     | Ridley and Mirly, 1981 (MRID 40767101) and Howe et al., 1988 (MRID 40767102) |
| Radiolabeled <sup>14</sup> C-glyphosate injected                                  | Sprague-Dawley Rats                                                     | 1,150 mg/kg (single i.p. dose)                        | Rapidly eliminated from bone marrow and plasma, based on radioactivity measurements                                                                         | Ridley et al., 1983 (MRID 00132685)                                          |

<sup>a</sup> All of the study summaries were derived from USDA (2003) and US EPA (1993). The original primary author citations are included for the purpose of reference. In order to obtain the full citation for these studies, please refer to USDA (2003) and US EPA (1993).



## Appendix L-4.

## Application Rates for Herbicides Recommended for Use on Glyphosate-Tolerant Alfalfa

**Table L-21. Honcho®**

| Final Max AR = Max AR*Percent AI*Product Density*Mass Conversion*Volume Conversion |             |                |                 |
|------------------------------------------------------------------------------------|-------------|----------------|-----------------|
| Single Application                                                                 |             |                |                 |
| Parameter                                                                          | Value       | Units          | Reference       |
| Max AR                                                                             | 2           | quarts ae/acre | Monsanto, 2007b |
| Percent AI                                                                         | 0.41        | unitless       | Monsanto, 2007b |
| Density                                                                            | 1.1655      | g/cm3          | Monsanto, 2007a |
| Mass conversion                                                                    | 0.002204623 | lb/g           | Constant        |
| Volume conversion                                                                  | 946.352946  | cm3/quart      | Constant        |
| Final AR                                                                           | 1.993946622 | lb AI/acre     | Equation        |

**Table L-22. Honcho Plus®**

| Final Max AR = Max AR*Percent AI*Product Density*Mass Conversion*Volume Conversion |             |                |                 |
|------------------------------------------------------------------------------------|-------------|----------------|-----------------|
| Single Application                                                                 |             |                |                 |
| Parameter                                                                          | Value       | Units          | Reference       |
| Max AR                                                                             | 2           | quarts ae/acre | Monsanto, 2007d |
| Percent AI                                                                         | 0.41        | unitless       | Monsanto, 2007d |
| Density                                                                            | 1.1655      | g/cm3          | Monsanto, 2007c |
| Mass conversion                                                                    | 0.002204623 | lb/g           | Constant        |
| Volume conversion                                                                  | 946.352946  | cm3/quart      | Constant        |
| Final AR                                                                           | 1.993946622 | lb AI/acre     | Equation        |

Note: The density value came from the product MSDS. There appears to be a typo on this sheet. It was assumed that the density and specific gravity values would be comparable and that the density of Honcho Plus would be comparable to the density of a similar product, Honcho.

**Table L-23. Roundup Original Max®**

| Final Max AR = Max AR*Percent AI*Product Density*Mass Conversion*Volume Conversion |             |            |                 |
|------------------------------------------------------------------------------------|-------------|------------|-----------------|
| Single Application                                                                 |             |            |                 |
| Parameter                                                                          | Value       | Units      | Reference       |
| Max AR                                                                             | 44          | oz ae/acre | Monsanto, 2007e |
| Percent AI                                                                         | 0.487       | unitless   | Monsanto, 2007e |
| Density                                                                            | 1360        | kg/m3      | Monsanto, 2006  |
| Mass conversion                                                                    | 2.204622622 | lb/kg      | Constant        |
| Volume conversion                                                                  | 2.95735E-05 | m3/oz      | Constant        |
| Final AR                                                                           | 1.900019095 | lb AI/acre | Equation        |
| Specific gravity = Product density/Water density                                   |             |            |                 |
| Parameter                                                                          | Value       | Units      | Reference       |
| Specific gravity                                                                   | 1.36        | unitless   | Monsanto, 2006  |
| Water density                                                                      | 1000        | kg/m3      | Constant        |
| Product density                                                                    | 1360        | kg/m3      | Equation        |

Note: Density was not provided on label or MSDS sheet. Density was calculated using the provided specific gravity value of 1.36 using the equation  $\text{Density} = \text{Mass}/\text{Volume}$ .

**Table L-24. Roundup Ultra MaxII®**

| <b>Final Max AR = Max AR*Percent AI*Product Density*Mass Conversion*Volume Conversion</b> |              |              |                                 |
|-------------------------------------------------------------------------------------------|--------------|--------------|---------------------------------|
| <b>Single Application</b>                                                                 |              |              |                                 |
| <b>Parameter</b>                                                                          | <b>Value</b> | <b>Units</b> | <b>Reference</b>                |
| Max AR                                                                                    | 44           | oz ae/acre   | Monsanto, 2004; Monsanto, 2005c |
| Percent AI                                                                                | 0.488        | unitless     | Monsanto, 2004                  |
| Density                                                                                   | 1360         | kg/m3        | Equation                        |
| Mass conversion                                                                           | 2.204622622  | lb/kg        | Constant                        |
| Volume conversion                                                                         | 2.95735E-05  | m3/oz        | Constant                        |
| Final AR                                                                                  | 1.903920572  | lb AI/acre   | Equation                        |
| <b>Specific gravity = Product density/Water density</b>                                   |              |              |                                 |
| <b>Parameter</b>                                                                          | <b>Value</b> | <b>Units</b> | <b>Reference</b>                |
| Specific gravity                                                                          | 1.36         | unitless     | Monsanto, 2003                  |
| Density of water                                                                          | 1000         | kg/m3        | Constant                        |
| Density of product                                                                        | 1360         | kg/m3        | Equation                        |

Note: Density was not provided on label or MSDS sheet. Density was calculated using the provided specific gravity value of 1.36 using the equation  $\text{Density} = \text{Mass}/\text{Volume}$ .

**Table L-25. Roundup Weather Max®**

| <b>Final Max AR = Max AR*Percent AI*Product Density*Mass Conversion*Volume Conversion</b> |              |              |                                  |
|-------------------------------------------------------------------------------------------|--------------|--------------|----------------------------------|
| <b>Single Application</b>                                                                 |              |              |                                  |
| <b>Parameter</b>                                                                          | <b>Value</b> | <b>Units</b> | <b>Reference</b>                 |
| Max AR                                                                                    | 44           | oz ae/acre   | Monsanto, 2007f; Monsanto, 2005b |
| Percent AI                                                                                | 0.488        | unitless     | Monsanto, 2007f                  |
| Density                                                                                   | 1360         | kg/m3        | Monsanto, 2005a                  |
| Mass conversion                                                                           | 2.204622622  | lb/kg        | Constant                         |
| Volume conversion                                                                         | 2.95735E-05  | m3/oz        | Constant                         |
| Final AR                                                                                  | 1.903920572  | lb AI/acre   | Equation                         |
| <b>Specific gravity = Product density/Water density</b>                                   |              |              |                                  |
| <b>Parameter</b>                                                                          | <b>Value</b> | <b>Units</b> | <b>Reference</b>                 |
| Specific gravity                                                                          | 1.36         | unitless     | Monsanto, 2005a                  |
| Density of water                                                                          | 1000         | kg/m3        | Constant                         |
| Density of product                                                                        | 1360         | kg/m3        | Equation                         |

Note: Density was not provided on label or MSDS sheet. Density was calculated using the provided specific gravity value of 1.36 using the equation  $\text{Density} = \text{Mass}/\text{Volume}$ .

## Appendix L-5. Reference Doses for “Other Chemicals”

**Table L-26. Summary Table of RfDs for “Other Chemicals”**

| <b>Chemical Name</b> | <b>Reference Dose (Oral)</b>                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Reference</b>                                                                                                                                           |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2,4-D                | Acute dietary (Females 13-49 years of age): 0.025 mg/kg/day<br>Acute dietary (General population including infants and children): 0.067 mg/kg/day<br>Chronic dietary (All populations): 0.005 mg/kg/day                                                                                                                                                                                                                                 | EPA RED, 2005:<br><a href="http://www.epa.gov/oppsrrd1/REDs/24d_red.pdf">http://www.epa.gov/oppsrrd1/REDs/24d_red.pdf</a>                                  |
| Acifluorfen          | 0.013 mg/kg/day (based on a 2-generation reproduction rat study)                                                                                                                                                                                                                                                                                                                                                                        | EPA IRIS, 1987:<br><a href="http://www.epa.gov/ncea/iris/subst/0192.htm">http://www.epa.gov/ncea/iris/subst/0192.htm</a>                                   |
| Amitrole             | Not established                                                                                                                                                                                                                                                                                                                                                                                                                         | EPA RED, 1996:<br><a href="http://www.epa.gov/oppsrrd1/REDs/0095red.pdf">http://www.epa.gov/oppsrrd1/REDs/0095red.pdf</a>                                  |
| Atrazine             | Acute Dietary: 0.1 mg/kg/day (based on a developmental toxicity study in rat & rabbit)<br>Intermediate and Chronic: 0.018 mg/kg/day (based on a six-month LH surge study in rat)                                                                                                                                                                                                                                                        | EPA RED, 2006:<br><a href="http://www.epa.gov/oppsrrd1/REDs/atrazine_combined_docs.pdf">http://www.epa.gov/oppsrrd1/REDs/atrazine_combined_docs.pdf</a>    |
| Benefin              | 0.3 mg/kg/day (based on a dog chronic oral bioassay)                                                                                                                                                                                                                                                                                                                                                                                    | EPA IRIS, 1987:<br><a href="http://www.epa.gov/ncea/iris/subst/0133.htm">http://www.epa.gov/ncea/iris/subst/0133.htm</a>                                   |
| Bromoxynil           | 0.015 mg/kg/day (based on 12-month-chronic oral toxicity study in dogs using bromoxynil phenol)                                                                                                                                                                                                                                                                                                                                         | EPA RED, 1998:<br><a href="http://www.epa.gov/oppsrrd1/REDs/2070red.pdf">http://www.epa.gov/oppsrrd1/REDs/2070red.pdf</a>                                  |
| Clodinafop           | For clodinafop-propargyl: Acute dietary (females 13-50 years of age): 0.05 mg/kg/day (based on a developmental toxicity study in rats)<br>For clodinafop-propargyl: Acute dietary (general population including infants and children): 0.25 mg/kg/day (based on a developmental toxicity study in rabbits)<br>For clodinafop-propargyl: Chronic dietary (all populations): 0.0003 mg/kg/day (based on a chronic toxicity study in rats) | EPA Pesticide Fact Sheet, 2000:<br><a href="http://www.epa.gov/oppr001/factsheets/clodinafop.pdf">http://www.epa.gov/oppr001/factsheets/clodinafop.pdf</a> |
| Clopyralid           | Chronic: 0.5 mg/kg/day (based on a 2-year rat feeding study)                                                                                                                                                                                                                                                                                                                                                                            | Federal Register, 1997: <a href="http://www.epa.gov/EPA-PEST/1997/March/Day-12/p5875.htm">http://www.epa.gov/EPA-PEST/1997/March/Day-12/p5875.htm</a>      |
| Cyanazine            | Not available (NA)                                                                                                                                                                                                                                                                                                                                                                                                                      | NA                                                                                                                                                         |

| <b>Chemical Name</b> | <b>Reference Dose (Oral)</b>                                                                                                                                                                                                                                                                        | <b>Reference</b>                                                                                                                                                           |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Dicamba              | Acute dietary (All populations): 1.0 mg/kg/day (based on acute neurotoxicity in rats)<br>Chronic dietary (All populations): 0.45 mg/kg/day (based on multi-generation reproduction study in rats)                                                                                                   | EPA RED, 2006:<br><a href="http://www.epa.gov/oppsrrd1/REDs/dicamba_red.pdf">http://www.epa.gov/oppsrrd1/REDs/dicamba_red.pdf</a>                                          |
| Diquat               | Diquat cation: Chronic: 0.005 mg/kg/day (based on chronic toxicity study in dogs)                                                                                                                                                                                                                   | EPA RED, 1995:<br><a href="http://www.epa.gov/oppsrrd1/REDs/0288.pdf">http://www.epa.gov/oppsrrd1/REDs/0288.pdf</a>                                                        |
| Ethalfuralin         | 0.04 mg/kg/day (based on a one-year oral dog study)                                                                                                                                                                                                                                                 | EPA RED, 1995:<br><a href="http://www.epa.gov/oppsrrd1/REDs/2260.pdf">http://www.epa.gov/oppsrrd1/REDs/2260.pdf</a>                                                        |
| Fenoxaprop           | For fenoxaprop-ethyl: Chronic: 0.0025 mg/kg/day (based on a 2-generation rat reproductive study)                                                                                                                                                                                                    | Federal Register, 1998: <a href="http://www.epa.gov/EPA-PEST/1998/April/Day-22/p10395.htm">http://www.epa.gov/EPA-PEST/1998/April/Day-22/p10395.htm</a>                    |
| Flucarbazone         | For flucarbazone-sodium: Acute: 3.0 mg/kg/day (based on a developmental toxicity study in rabbits)<br>For flucarbazone-sodium: Chronic: 0.36 mg/kg/day (based on a one-year dog feeding study)                                                                                                      | EPA Pesticide Fact Sheet, 2000:<br><a href="http://www.epa.gov/opprd001/factsheets/flucarbazone.pdf">http://www.epa.gov/opprd001/factsheets/flucarbazone.pdf</a>           |
| Fluchloralin         | NA                                                                                                                                                                                                                                                                                                  | NA                                                                                                                                                                         |
| MCPA                 | Acute (General population): 0.05 mg/kg/day (based on a rat developmental study with MCPA DMAS)<br>Acute (Females 13-50 years old): 0.04 mg/kg/day (based on a rat developmental study with MCPA 2-EHE)<br>Chronic: 0.0044 mg/kg/day (based on a chronic toxicity and carcinogenicity study in rats) | EPA RED, 2004:<br><a href="http://www.epa.gov/oppsrrd1/REDs/mcpa_red.pdf">http://www.epa.gov/oppsrrd1/REDs/mcpa_red.pdf</a>                                                |
| Metribuzin           | Chronic dietary: 0.013 mg/kg/day (based on a two-year feeding study)                                                                                                                                                                                                                                | EPA RED, 1997:<br><a href="http://www.epa.gov/oppsrrd1/REDs/0181red.pdf">http://www.epa.gov/oppsrrd1/REDs/0181red.pdf</a>                                                  |
| Metsulfuron          | For metsulfuron methyl: 0.3 mg/kg/day (based on a 2-year rat study)                                                                                                                                                                                                                                 | Federal Register, 1998:<br><a href="http://www.epa.gov/fedrgstr/EPA-PEST/1998/March/Day-19/p7141.htm">http://www.epa.gov/fedrgstr/EPA-PEST/1998/March/Day-19/p7141.htm</a> |

| Chemical Name  | Reference Dose (Oral)                                                                                                                                                                                                                                                                                               | Reference                                                                                                                                                       |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MSMA           | For all MMAs: Acute: 0.1 mg/kg/day (based on a chronic toxicity dog study)<br>For all MMAs: Chronic: 0.03 mg/kg/day (based on a chronic toxicity rat study)                                                                                                                                                         | EPA RED, 2006:<br><a href="http://www.epa.gov/oppsrrd1/REDs/organic_arsenicals_red.pdf">http://www.epa.gov/oppsrrd1/REDs/organic_arsenicals_red.pdf</a>         |
| Paraquat       | Paraquat cation: Chronic: 0.0045 mg/kg/day (based on 1-year dog feeding study)                                                                                                                                                                                                                                      | EPA RED, 1997:<br><a href="http://www.epa.gov/oppsrrd1/REDs/0179.pdf">http://www.epa.gov/oppsrrd1/REDs/0179.pdf</a>                                             |
| Pendimethalin  | Chronic: 0.10 mg/kg.day                                                                                                                                                                                                                                                                                             | EPA RED, 1997:<br><a href="http://www.epa.gov/oppsrrd1/REDs/0187red.pdf">http://www.epa.gov/oppsrrd1/REDs/0187red.pdf</a>                                       |
| Simazine       | Acute dietary (females 13-49 years of age): 0.3 mg/kg/day (based on a developmental study in rats)<br>Chronic dietary (all populations): 0.018 mg/kg/day (based on a 6-month LH surge study in rat with atrazine)                                                                                                   | EPA RED, 2006:<br><a href="http://www.epa.gov/oppsrrd1/REDs/simazine_red.pdf">http://www.epa.gov/oppsrrd1/REDs/simazine_red.pdf</a>                             |
| Thifensulfuron | For thifensulfuron methyl: Acute dietary (Females 13-50 years of age): 1.59 mg/kg/day (based on a developmental oral toxicity study in rats)<br>For thifensulfuron methyl: Chronic dietary (All populations): 0.20 mg/kg/day (based on a combined chronic/carcinogenicity oral toxicity study in rats)              | Federal Register, 2004: <a href="http://www.epa.gov/EPA-PEST/2004/September/Day-17/p20983.htm">http://www.epa.gov/EPA-PEST/2004/September/Day-17/p20983.htm</a> |
| Tralkoxydim    | Acute: 0.3 mg/kg/day (based on a rat developmental study)<br>Chronic: 0.005 mg/kg/day (based on a chronic toxicity study in dogs)                                                                                                                                                                                   | Federal Register, 2005: <a href="http://www.epa.gov/EPA-PEST/2005/June/Day-22/p12076.htm">http://www.epa.gov/EPA-PEST/2005/June/Day-22/p12076.htm</a>           |
| Triallate      | Acute (General population including infants and children): 0.60 mg/kg/day (based on an acute neurotoxicity study)<br>Acute (Females 15-30 years): 0.05 mg/kg/day (based on a developmental study in rats)<br>Chronic non-cancer: 0.025 mg/kg/day (based on a 2-year chronic toxicity/carcinogenicity study in rats) | EPA RED, 2000:<br><a href="http://www.epa.gov/oppsrrd1/REDs/2695.pdf">http://www.epa.gov/oppsrrd1/REDs/2695.pdf</a>                                             |

| <b>Chemical Name</b> | <b>Reference Dose (Oral)</b>                                                                                                                                                        | <b>Reference</b>                                                                                                                                                           |
|----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Triasulfuron         | 0.01mg/kg/day (based on a 2-year mouse feeding/carcinogenicity study)                                                                                                               | EPA IRIS, 1991:<br><a href="http://www.epa.gov/ncea/iris/subst/0510.htm">http://www.epa.gov/ncea/iris/subst/0510.htm</a>                                                   |
| Tribenuron           | For tribenuron methyl: Chronic: 0.008 mg/kg/day (based on a 1-year dog feeding study)<br>For tribenuron methyl: Acute: 0.20 mg/kg/day (based on rabbit and rat development studies) | Federal Register, 2004:<br><a href="http://www.epa.gov/fedrgstr/EPA-PEST/2004/July/Day-07/p15208.htm">http://www.epa.gov/fedrgstr/EPA-PEST/2004/July/Day-07/p15208.htm</a> |
| Trichlopyr           | 0.05 mg/kg/day (based on a 2-generation reproduction study in rats)                                                                                                                 | EPA RED, 1997:<br><a href="http://www.epa.gov/oppsrrd1/REDs/2710red.pdf">http://www.epa.gov/oppsrrd1/REDs/2710red.pdf</a>                                                  |
| Trietazine           | NA                                                                                                                                                                                  | NA                                                                                                                                                                         |
| Trifluralin          | Chronic: 0.024 mg/kg/day (based on a one-year feeding study in dogs)                                                                                                                | EPA RED, 2004:<br><a href="http://www.epa.gov/oppsrrd1/REDs/0179.pdf">http://www.epa.gov/oppsrrd1/REDs/0179.pdf</a>                                                        |

## **Appendix M. Health and Safety Risks for Field Workers**

# Health and Safety Risks for Field Workers

## Executive Summary

In an effort to assess the potential health and safety risks from increased glyphosate usage on field workers due to the proposed deregulation of glyphosate-tolerant alfalfa by the U.S. Department of Agriculture (USDA) in 2005, an occupational health risk assessment was conducted for glyphosate usage on glyphosate-tolerant alfalfa. Conservative hazard estimates suggest that workers are not at risk of adverse health effects associated with acute or chronic dermal exposure to glyphosate. More details on the toxicity and risk of glyphosate are discussed in this technical report.

Glyphosate is a broad spectrum herbicide. It is a systemic, post-emergence herbicide widely used on both agricultural commodities and non-agriculture sites. Glyphosate absorbs directly through plant leaves and spreads rapidly throughout the plant. The use of surfactants enables greater leaf penetration. Glyphosate's mode of action is as a potent and specific inhibitor of the enzyme 5-enolpyruvylshikimate 3-phosphate synthase. This enzyme is located in the shikimate pathway and is essential for the biosynthesis of aromatic amino acids and other aromatic compounds in algae, higher plants, bacteria, fungi, and apicomplexan parasites. The shikimate pathway is absent in mammals.

Glyphosate is among the most widely used pesticides by volume in the United States. While additional glyphosate products may be used, five products are recommended for use on glyphosate-tolerant alfalfa. The five herbicides are Monsanto products and include: Honcho®, Honcho Plus®, Roundup Original MAX®, Roundup WeatherMAX®, and Roundup Ultra MAX II®. Glyphosate products can be formulated to have different concentrations of glyphosate acid per gallon of product. To improve handling, performance, and concentration, the glyphosate acid is formulated as a salt compound. The term acid equivalent (a.e.) refers to the weight of the glyphosate acid, which is herbicidally active, while the term active ingredient (a.i.) is the weight of the glyphosate acid plus the salt.

The U.S. Environmental Protection Agency (EPA) and the states (usually that state's agriculture office) register or license pesticides for use in the United States. EPA receives its authority to register pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Glyphosate was registered for use as an herbicide within the United States through EPA. EPA's toxicological database on glyphosate is considered adequate and complete (US EPA, 1993; 2006). Based on these data, glyphosate is considered to be a toxicologically low-risk herbicide (Cerdeira and Duke, 2006). According to the Reregistration Eligibility Decision (RED) document for glyphosate (US EPA, 1993), glyphosate is of relatively low oral and dermal acute toxicity. For this reason, glyphosate has been assigned to Toxicity Categories III and IV for these effects (i.e., Toxicity Category I indicates the highest degree of acute toxicity, and Category IV the lowest). An acute inhalation study was waived by EPA because glyphosate is a non-volatile solid and the studies conducted on the end-use product formulation are considered



sufficient. With regard to subchronic and chronic toxicity, one of the more consistent effects of exposure to glyphosate is loss of body weight. This observed weight loss may be consistent with experimental data indicating glyphosate's mechanism of action. Other general and non-specific signs of toxicity from subchronic and chronic exposure to glyphosate include changes in liver weight, blood chemistry (may suggest mild liver toxicity), liver pathology, and pituitary weight (USDA, 2003). Glyphosate is not considered a carcinogen; it has been classified by EPA as a Group E carcinogen (evidence of non-carcinogenicity for humans) (US EPA, 1993; 2006).

There are two types of worker exposure scenarios assessed in this report. The first are general worker scenarios in which workers have chronic dermal exposure to glyphosate via one of three typical pesticide application methods: directed foliar, broadcast foliar, or aerial. Chronic dermal exposure estimates ranged from 0.9 ppb (i.e.,  $\mu\text{g/kg}$ ) to 160 ppb for directed foliar application, from 1.32 ppb to 302 ppb for broadcast foliar application, and from 0.48 ppb to 160 ppb for aerial application.

Central, lower, and upper bound chronic dermal hazard quotient (HQ) estimates were all under 1, suggesting that workers exposed to herbicides recommended for use on glyphosate-tolerant alfalfa via directed foliar, broadcast foliar, or aerial application methods are not at risk of adverse effects associated with chronic dermal exposure to glyphosate. HQs ranged from 0 to 0.8 for directed foliar application, from 0.001 to 0.15 for broadcast foliar application and from 0 to 0.08 for aerial application. The most exposed workers were those using a broadcast foliar application method. The upper bound HQ was 0.15, approximately 8% of the chronic dermal reference dose (RfD) of 2 mg/kg/day.

In addition to general worker scenarios, accidental exposure scenarios are also assessed in this report. Accidental exposure scenarios result in workers' acute exposure to glyphosate. There are two accidental exposure scenarios assessed in this report, including an accidental spill on the worker's hands or an accidental spill on the worker's legs. Acute dermal exposure estimates from a spill on the worker's hands ranged from 4.44 ppb to 50.5 ppb. Acute dermal exposure estimates from a spill on the worker's legs ranged from 10.9 to 124 ppb.

Central, upper, and lower bound HQs were all under 1, suggesting that workers who accidentally spill herbicides recommended for use on glyphosate-tolerant alfalfa on hands or legs are not at risk of adverse effects associated with acute dermal exposure to glyphosate. HQs for a spill on the hands ranged from 0.002 to 0.025. HQs for a spill on the legs ranged from 0.005 to 0.062. The most exposed workers were those who spilled glyphosate on the legs. The upper bound HQ was 0.06, approximately 3% of the acute dermal RfD of 2 mg/kg/day.

## 1.0 Introduction

In June 2005, the U.S. Department of Agriculture (USDA) approved the use of Roundup Ready® alfalfa, the only commercially available genetically engineered (GE) alfalfa on the market. Roundup Ready® alfalfa is resistant to the herbicide glyphosate. This means that it is able to survive applications of glyphosate, the active ingredient (a.i.) in the Monsanto Company's trademark herbicide, Roundup®. Monsanto produced this glyphosate-tolerant (GT) alfalfa in partnership with the largest alfalfa seed company, Forage Genetics International (FGI). The transgene responsible for glyphosate tolerance was first introduced in soybeans in 1996 and has since been commercialized in several other crops (e.g., corn, canola, and cotton). In order to determine health and safety risks to field workers in contact with GT alfalfa, an occupational risk assessment must consider the toxicology and exposure potential associated with herbicides containing glyphosate that may be used on the crop. In addition, the assessment should consider risks associated with the gene product and the conventional crop (i.e., alfalfa).

### 1.1 Herbicides

There are several herbicide products containing glyphosate that are recommended for use on GT alfalfa. These products include: Roundup Original Max®, Roundup Weather Max®, and Roundup Ultra Max II® (Monsanto, 2008). According to Greenbook, an online database that partners with chemical manufacturers such as Monsanto to provide information about agricultural products, Honcho® and Honcho Plus® are also recommended for use on GT alfalfa (Greenbook, 2008). Each of these products contains between 41 and 48% glyphosate (Monsanto, 2004; 2007b; 2007d; 2007f; 2007e). Consideration of other ingredients in the end use products (EUPs) is beyond the scope of this exposure assessment. For purposes of this analysis, exposure estimates of glyphosate are presented as opposed to exposure estimates of the EUPs because toxicological data required to assess risk were not available for the EUPs at the time of this analysis.

Glyphosate use increased more than six-fold between 1992 and 2002, to become the most used herbicide in the United States. In 1997, it was listed on the Agency of Toxic Substances and Disease Registry's (ATSDR) 100 most frequently released substances (ATSDR, 1997). A controversy exists over whether glyphosate usage has increased as a result of GT crops. A few studies have claimed that the volume of herbicide use is greater due to GT crops (Benbrook, 2001; 2003; 2004). On the other hand, others, such as Heimlich et al. (2000) have indicated there has not been a significant increase in the amount of glyphosate usage since emergence of GT crops. Heimlich et al. (2000) noted that using glyphosate has resulted in the replacement of herbicides that are at least three times as toxic and persist almost twice as long as glyphosate. For example, in cotton and soybean fields for the most part, several herbicides were replaced by glyphosate (million pounds reduction): bentazon (-4.4), disodium methanearsenate (DSMA; -0.8), fluometuron (-4.5), imazethapyr (-1.0), metribuzin (-1.5), methylarsonic acid sodium salt (MSMA) (-1.7), paraquat (-2.9), pendimethalin (-14.0), sethoxydim (-1.1), and trifluralin (-13.0). Furthermore, prior to 2002, metolachlor, which accounted for 67 million pounds of herbicide used in 1997, was voluntarily withdrawn from the market prior to 2002. Glyphosate was adopted on many soybean acres that were previously treated with metolachlor. Cyanazine,

which accounted for 20 million pounds of herbicide used in 1997, was also voluntarily withdrawn from the market prior to 2002 and replaced by glyphosate for use on cotton and corn. In addition to glyphosate, corn producers replaced cyanazine with the herbicides mesotrione, rimsulfuron, and simazine (Gianessi and Reigner, 2006).

Additionally, Trewavas and Leaver (2001) conducted an analysis which revealed that 3.27 million kg of other herbicides have been replaced with 2.45 million kg of glyphosate in soybean fields in the United States. Carpenter and Gianessi (2003) concluded that the introduction of GT soybeans has resulted in a decrease in the total volume of herbicides used. Gianessi (2005) estimates that averaged over all GT crops, GT technology has reduced herbicide use by 17 million kg/year in the United States. However, Gianessi's (2005) calculations indicate that if GT sugar beets were adopted, reduction in herbicide use would not be as great as for combined GT crops, because the herbicides used now in non-transgenic sugar beets are mainly low use rate compounds in the United States.

Biomonitoring studies confirm that agricultural workers who apply glyphosate to crops internalize some of the chemical (Curwin et al., 2007; Mandel et al., 2005). EPA (1993) determined in its RED for glyphosate that the chemical may be classified as either a Category III (i.e., slightly toxic; slightly irritating) or Category IV (i.e., practically non-toxic; not an irritant) toxicant. Toxicity and occupational exposure data exist for glyphosate, and the remainder of this occupational assessment utilizes these data to estimate exposure and risk to field workers.

## 1.2 Gene Product

The expressed gene product in GT alfalfa is a protein, 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), derived from a soil bacterium, *Agrobacterium* sp. CP4 strain, thus called CP4 EPSPS. The protein is a single polypeptide that is 455 amino acids long and structurally and functionally similar to the native plant EPSPS enzymes. The herbicide glyphosate inhibits an essential step in aromatic amine synthesis in plants. The CP4 EPSPS protein is not inhibited by the herbicide glyphosate; thus any plant with the protein is resistant to glyphosate application.

The U.S. Food and Drug Administration (FDA), the lead U.S. regulatory agency for review of the food and feed safety of GE crops, completed a voluntary consultation with FGI and Monsanto in 2004 regarding the safety of GT alfalfa (US FDA, 2004b). The FDA (2004b) made the following assertions: the soil bacterium used to create GT alfalfa is not a known allergen or pathogen; the CP4 EPSPS gene and protein lack structural similarities to any allergen; the CP4 EPSPS protein is only a small portion of alfalfa; and while acute toxicity in mice was observed, allergenic responses associated with GT crops have not been reported by farm workers or members of the general population since the commercialization of these crops in 1996. FDA (2004b) did not review studies on dermal or inhalation toxicity of the CP4 EPSPS gene or protein, nor were any available at the time of this analysis.

## 1.3 Conventional Crop

Conventional alfalfa has been used for animal feed for decades. Alfalfa is also consumed by humans (e.g., sprouts, dietary supplements, and herbal teas). Pollen from alfalfa may be a minor

contributor to some respiratory allergic diseases such as asthma, but the risk to human health is minimal. In addition, alfalfa sprouts have been the source of several foodborne outbreaks due to bacterial contamination (US FDA, 1999). Epidemiological investigations suggest that seeds are the likely source in most, if not all, sprout-associated illness outbreaks. Seeds grown for sprouts have more stringent restrictions for chemical applications during growing since the chemicals must be evaluated as food residues. FDA considers GT alfalfa not materially different from conventional alfalfa; therefore it is permitted for human consumption (US FDA, 2004a). However, Monsanto does not allow GT alfalfa to be planted for sprouts (Hubbard, 2008).

#### 1.4 Methodology

The toxicological literature suggests that exposure to the herbicide glyphosate is of greater health concern than is exposure to the gene product or alfalfa itself. Thus, the remainder of this analysis focuses on the chemical and physical properties of glyphosate and the toxicological data on glyphosate. These data, in combination with data specific to the occupational scenarios, are used to conduct an occupational risk assessment for workers exposed to glyphosate. The result of the assessment is an estimate of potential risks associated with occupational exposures to glyphosate due to increased use of glyphosate and deregulation of GT alfalfa.

To support the occupational assessment, literature searches of glyphosate toxicity and exposure were conducted in the open literature using the literature search strategy presented in appendix M-2 of this technical report. This occupational assessment is not a comprehensive summary of all of the available information and does not cite all of the available literature. As USDA (2003) determined, an all inclusive and detailed review of all of the available literature would tend to obscure rather than inform. Therefore, this document relies on the information that is likely to impact the risk assessment. Primary sources of data were obtained from the following three documents: EPA's (1993) RED on glyphosate, EPA's (2006) Glyphosate Human Health Risk Assessment for Proposed Use on Indian Mulberry and Amended Use on Pea, Dry, and USDA's (2003) human health and ecological risk assessment on glyphosate.

Additionally, for the exposure assessment, the application rate of glyphosate on GT alfalfa was determined by collecting the use rates on GT alfalfa from labels of the five products recommended for use on GT alfalfa mentioned previously. It can be expected that other formulations for glyphosate herbicide could and may be used on GT alfalfa. However, this analysis focuses only on the products recommended for use on GT alfalfa.

## 2.0 Overview of Glyphosate

### 2.1 Glyphosate

Glyphosate is a systemic, post-emergence herbicide widely used on both agricultural commodities (food uses) and non-agriculture sites. Glyphosate salts serve as the source of the active ingredient *N*-(phosphonomethyl)glycine. Several salts of glyphosate with different counter cations are currently marketed. Each salt has a different “glyphosate equivalent”, which is defined as the ratio of the molecular weight of *N*-(phosphonomethyl)-glycine to the molecular weight of the salt. While GT alfalfa could tolerate other herbicides formulated with glyphosate, there are five glyphosate herbicides recommended for use on GT alfalfa. These end use products (EUPs) are presented in table M-1.

**Table M-1. End Use Products Approved for Use on Glyphosate-Tolerant Alfalfa**

| Product Name          | % Salt | Glyphosate salt CAS No.           | US EPA PC Code | Surfactant                                           | Manufacture     |
|-----------------------|--------|-----------------------------------|----------------|------------------------------------------------------|-----------------|
| Honcho®               | 41     | Isopropylamine<br>CAS: 38641-94-0 | 103601         | Alkyl Tallow<br>Ethoxylated Amines<br>CAS 61791-26-2 | Monsanto, 2007b |
| Honcho Plus®          | 41     | Isopropylamine<br>CAS: 38641-94-0 | 103601         | Trade Secret                                         | Monsanto, 2007d |
| Roundup Original MAX® | 48.7   | Potassium<br>CAS: 70901-12-1      | 103613         | Trade Secret                                         | Monsanto, 2007e |
| Roundup WeatherMAX®   | 48.8   | Potassium<br>CAS: 70901-12-1      | 103613         | Trade Secret                                         | Monsanto, 2007f |
| Roundup Ultra MAX II® | 48.8   | Potassium<br>CAS: 70901-12-1      | 103613         | Trade Secret                                         | Monsanto, 2004  |

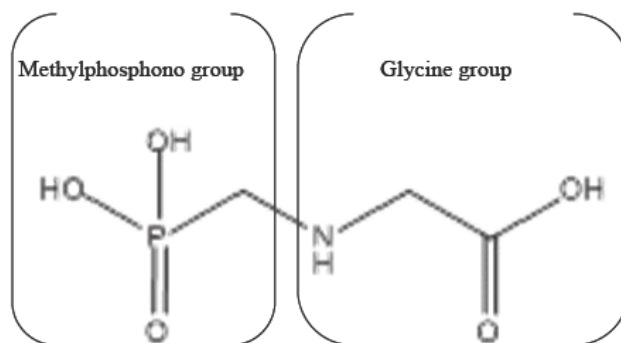
The Honcho® and Honcho Plus® products contain 41% of the isopropylamine (IPA) salt of glyphosate, equivalent to 3 pounds of glyphosate acid equivalent per gallon or 356 grams of a.e. per liter.<sup>47</sup> The product is to be applied as over-the-top (spot treatment; broadcast ground application) for pre-plant, preemergence, and post-emergence uses. The maximum total application rate is 7.98 pounds of glyphosate a.i. per acre per year or 2.6 gallons of product per acre, and the single use maximum application rate is 1.99 pounds of glyphosate a.i. per acre (rounded to 2 pounds of glyphosate a.i. per acre; 1.55 pounds of glyphosate a.e.). Further information regarding application rates is available in section 3.2.2 and in appendix M-4 of this technical report. The minimum reapplication interval is 7 days.

The Roundup Ready Original MAX®, Roundup WeatherMAX®, and Roundup Ultra MAX II® products contain 48.8% of the phosphate salt of glyphosate, equivalent to 4.5 pounds of glyphosate a.e. per gallon or 540 grams per liter. The product is to be applied as over-the-top (spot treatment; broadcast ground application) for pre-plant, preemergence, and post-emergence uses. The maximum total application rate is 7.32 glyphosate pounds a.i. per acre per year or 2.4 gallons of product per acre. The single use maximum application rate is 1.90 pounds of glyphosate a.i. per acre. Further information regarding application rates is available in section 3.2.2 and in appendix M-4 of this technical report. The minimum reapplication interval is 7 days.

<sup>47</sup> In this technical report, the term a.e. refers to the acid equivalent or weight of the glyphosate acid, which is herbicidally active. The term a.i. is the weight of the glyphosate acid plus the salt.

### 2.1.1 Structure and Nomenclature

Glyphosate is a substituted glycine, the simplest amino acid. The glyphosate molecule has a methylphosphono group bonded to the nitrogen atom of the amino group of glycine, as denoted in figure M-1 below.



**Figure M-1: Glyphosate molecular structure**

Glyphosate's structure and nomenclature are presented in table M-2 below.

**Table M-2. Glyphosate Structure and Nomenclature**

| Property                                               | Value                                           | Source             |
|--------------------------------------------------------|-------------------------------------------------|--------------------|
| Common Name                                            | Glyphosate                                      | US EPA, 2006; 1993 |
| International Union of Pure and Applied Chemistry Name | <i>N</i> -(phosphonomethyl)glycine              | US EPA, 2006; 1993 |
| Chemical Abstract Registry Number                      | 1071-83-6                                       | US EPA, 1993       |
| Empirical Formula                                      | C <sub>3</sub> H <sub>8</sub> NO <sub>5</sub> P | US EPA, 2006       |
| Smiles notation                                        | OC(=O)CNCP(O)(O)=O                              | EPI Suite          |
| PC Code                                                | 417300                                          | US EPA, 1993       |

### 2.1.2 Physical and Chemical Properties

Physical and chemical properties of glyphosate are in table M-3 below.

**Table M-3. Physical and Chemical Properties of Glyphosate**

| Property                                                                          | Value                                                                                                                     | Source       |
|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|--------------|
| Molecular Weight g                                                                | 169.07                                                                                                                    | USDA, 2003   |
| Density at 25°C                                                                   | 1.7                                                                                                                       | US EPA, 1993 |
| Solubility in water at 25°C                                                       | 12,000 mg/L                                                                                                               | US EPA, 1993 |
| pKa                                                                               | 0.8 first phosphonic acid<br>2.3 carboxylate<br>6.0 second phosphonic acid<br>11.0 amine                                  |              |
| Vapor Pressure at 25°C, Pa                                                        | $1.3 \times 10^{-7}$                                                                                                      | US EPA, 1993 |
| Henry's Law Constant (Pa m <sup>3</sup> /mol)                                     | $2.1 \times 10^{-9}$                                                                                                      | US EPA, 1993 |
| Log Kow                                                                           | -3                                                                                                                        | US EPA, 1993 |
| Hydrolysis                                                                        | Stable ≥30 days at pH 3, 6, and 9 at 5 and 35°C                                                                           | US EPA, 1993 |
| Photolysis                                                                        | Does not absorb light energy pH 5, 7, and 9                                                                               | US EPA, 1993 |
| Metabolism in soil, half life                                                     | 1.85 – 2.06 day                                                                                                           | US EPA, 1993 |
| Metabolism water-sediment system, half life                                       | Aerobic: 7 days<br>Anaerobic: 8.1 – 199 days                                                                              | US EPA, 1993 |
| Soil Mobility, K <sub>ads</sub> , Freundlich                                      | 9.4 – 700 mL/g                                                                                                            | US EPA, 1993 |
| Soil water partition coefficient K <sub>d</sub> (adsorption)                      | 62 Drummer silty clay loam<br>90 Ray silt<br>70 Spinks sandy loam<br>22 Lintonia sandy loam<br>175 Cattail swamp sediment | US EPA, 1993 |
| Soil adsorption K <sub>oc</sub>                                                   | 2100 (500 – 2600) (L/kg)<br>2600 – 4900 (L/kg)<br>8 to >500,000 (L/kg)<br>54 (L/kg)                                       | USDA, 2003   |
| Metabolite                                                                        | aminomethyl phosphonic acid (AMPA)                                                                                        | US EPA, 1993 |
| Field dissipation (application rate: 7.95 lb ae/acre, 10.7 lb ai/acre), half life | 13.9 days (median)<br>2.6 days in Texas<br>140.6 days Iowa                                                                | US EPA, 1993 |
| Aquatic field dissipation, half life                                              | 7.5 days and 120 days                                                                                                     | US EPA, 1993 |
| Bioaccumulation in fish                                                           | 0.38X edible tissue<br>0.63X nonedible tissue<br>0.52X whole fish                                                         | US EPA, 1993 |

## 2.2 Summary of Findings

Glyphosate is a systemic, post-emergence herbicide widely used on both agricultural commodities (food uses) and non-agriculture sites. Glyphosate salts serve as the source of the a.i. *N*-(phosphonomethyl)glycine. Several salts of glyphosate with different counter cations are currently marketed. At ambient temperatures, glyphosate is a white crystalline substance that is not volatile with high water solubility. In the crystalline form, glyphosate has both positive and negative regions of charge. These dipolar ion species are sometimes referred to as a zwitterion. In aqueous solutions, the hydrogen atoms of the carboxylic acid (COOH) and phosphate (PO<sub>2</sub>H<sub>2</sub>) groups may be associated or dissociated depending on the pH of the solution. These dipolar ion species are the regions expected to bond to carbon-containing molecules in the soil. Glyphosate is in a liquid form for herbicide formulations; generally, the composition of the herbicide is considered trade secret. One formulation of glyphosate, Honcho®, has a tallow amine surfactant (Monsanto, 2007b). This and other surfactants are added to the herbicide formulations to increase leaf penetration.



## 3.0 Occupational Risk Assessment

This occupational risk assessment focuses on risks associated with exposure to herbicides recommended for use on GT alfalfa, all of which contain the active ingredient glyphosate. The risk assessment is presented in four sections, including a hazard identification section in which toxicological data on glyphosate are reviewed and summarized, an exposure assessment section in which worker exposure estimates are presented, a dose-response assessment section in which health benchmarks for glyphosate are reviewed and recommended for different exposure scenarios, and finally a risk characterization section in which worker exposure estimates are compared to health benchmarks to determine the potential for adverse health effects associated with occupational exposures to glyphosate.

### 3.1 Hazard Identification

#### 3.1.1 Overview

According to EPA, the existing toxicity database for glyphosate is complete and without data gaps. There is high confidence in the quality of the existing studies and the reliability of the toxicity endpoints identified for use in risk assessments (US EPA, 1993; 2006). In general, the herbicidal activity of glyphosate is due primarily to a metabolic pathway that does not occur in humans or other animals. Thus, this mechanism of action is not directly relevant to the occupational health risk assessment. However, there remains some uncertainty regarding glyphosate's mechanism of action in humans or experimental animals. Nonetheless, EPA considers glyphosate to be of low acute toxicity by oral, dermal, and ocular routes of exposure, since all studies are classified as Toxicity Category III or IV. Furthermore, an acute inhalation study was waived by EPA because glyphosate is a non-volatile solid and the studies conducted on the end-use product formulation are considered sufficient (US EPA, 1993; 2006).

Glyphosate's toxicity database and its mechanism of action are discussed in greater detail in the following sections. Additionally, a summary table of the toxicology studies included in the USDA (2003) and EPA (1993) documents is included in appendix M-3 of this technical report.

#### 3.1.2 Mechanisms of Action

In plants, glyphosate is a potent and specific inhibitor of the enzyme 5-enolpyruvylshikimate 3-phosphate synthase (EPSPS) in plants. EPSPS is the sixth enzyme on the shikimate pathway and it is essential for the biosynthesis of aromatic amino acids and other aromatic compounds in algae, higher plants, bacteria, fungi, and apicomplexan parasites. However, this metabolic pathway does not exist in humans or other animals (USDA, 2003; US EPA 1993).

While its mechanism of action in plants is well understood, not much is known about glyphosate's ability to cause toxic effects in humans or experimental animals. Corrosive effects on the gastric mucosa, as well as other tissues, are a consistent response following acute oral exposure to high doses of glyphosate or polyethoxylated tallow amine (POEA), a surfactant included in some glyphosate formulations. However, it is speculated that the biochemical pathway leading to mucosal effects differs for each glyphosate and POEA. At present, there are

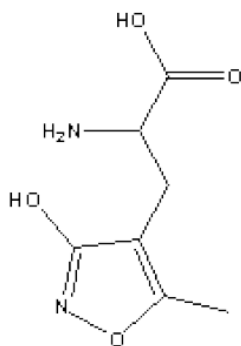
two proposed biochemical mechanisms of action in humans for glyphosate: uncoupling of oxidative phosphorylation, and inhibition of hepatic mixed function oxidases (USDA, 2003).

Oxidative phosphorylation is a process where nutrients are oxidized to yield metabolic energy which is then transferred to high-energy phosphate bonds and stored. Glyphosate appears to be an uncoupler of oxidative phosphorylation, based on the results of a series of experiments using rat liver mitochondria that was exposed to glyphosate (USDA, 2003). When glyphosate uncouples this process, the result is a loss of energy and eventually death. Symptoms such as increased heart and respiratory rate, labored breathing, profuse sweating, fever, metabolic acidosis, and weight loss may occur in response to the uncoupling of oxidative phosphorylation. Uncoupling of this process has been seen after experimental animals were given intraperitoneal doses as low as 15 mg/kg. However, it has not been determined if interrupting this process plays a major role in acute exposures (USDA, 2003).

Inhibition of hepatic mixed-function oxidases may also account for some of the toxic effects observed following glyphosate exposure. Hepatic mixed-function enzymes are comprised of various isozymes of cytochrome P-450, which is involved in the metabolism of a variety of endogenous compounds as well as xenobiotics. In a study by Hietanen et al. (1983), a decrease in hepatic mixed-function oxidase activity was observed in rats after a 500 mg/kg/day dose of glyphosate for four days followed by doses of 300 mg/kg/day for six days. While this decrease in hepatic mixed-function oxidase activity is only indicative of cytochrome P-450 inhibition, it has been suggested that this effect may be due to glyphosate's inhibition of cytochrome P-450, since glyphosate has caused inhibition in plants (USDA, 2003).

### 3.1.3 *Kinetics and Metabolism*

The residue of concern for risk assessment purposes is glyphosate *per se*. Glyphosate's only known metabolite, aminomethylphosphonate (AMPA; see figure M-2), is not included in either the tolerance expression or the risk assessment (US EPA, 2006). While AMPA is a common environmental metabolite, only trace amounts of it are formed in mammals and the remainder is excreted unchanged. For this reason, direct exposures to AMPA, as an endogenous metabolite in animals, are encompassed by the existing toxicity data on glyphosate.



**Figure M-2: Chemical structure of AMPA**

Since glyphosate is eliminated rapidly from the body and shows a lack of degradation into toxic metabolites, dose levels expressed in mg/kg/day display analogous effects over broad periods of exposure (USDA, 2003). For the general public, the majority of exposures to glyphosate are via the oral and dermal route. Select results from both oral and dermal absorption studies are discussed below.

According to experimental studies, glyphosate is not completely absorbed following oral administration. Much of the reviewed literature has revealed that only about 30% of glyphosate is absorbed from the gastrointestinal tract after oral exposure (USDA, 2003). One metabolism study available at the time of the 1993 reregistration of glyphosate involved a single or repeated dose of radiolabeled  $^{14}\text{C}$ -glyphosate administered orally to Sprague-Dawley rats. Of this dose, 30-36% was absorbed. Less than 0.27% was eliminated as  $\text{CO}_2$ , 97.5% was excreted in the urine and feces as the parent compound, and 0.4-0.7% was excreted in the urine and feces as AMPA. Repeated dosing did not change the metabolism significantly (US EPA, 1993).

Furthermore, studies conducted by Davies (1996e), indicate that the majority of unabsorbed glyphosate remains in the gastrointestinal tract, while the absorbed glyphosate is widely distributed throughout the body. The highest concentrations of glyphosate are found in the bone relative to other tissues, although glyphosate does not concentrate significantly or persist in any tissue (US EPA, 1993). A second metabolism study available at the time of the 1993 reregistration of glyphosate involved dosing Sprague-Dawley rats with a single 1150 mg/kg intraperitoneal injection of radiolabeled  $^{14}\text{C}$ -glyphosate. Approximately 0.0044-0.0072% of this dose was found in the bone marrow after 30 minutes. The half-life of glyphosate in bone marrow was 7.6 hours for males and 4.2 hours for females. In addition, the study determined that the half life of glyphosate in plasma was 1 hour for both sexes (US EPA, 1993).

Glyphosate is also poorly absorbed following dermal applications, as indicated by two dermal absorption studies performed by Wester et al. (1991; 1996). One of the studies was performed using skin from human cadavers. In this study, the cadaver skin was exposed to undiluted glyphosate herbicide formulations (i.e., containing more of the POEA surfactant) for eight hours, and diluted formulations for up to 16 hours. Based on 16-hours of exposure to the diluted formulations, first-order dermal absorption rates ranged from  $1.3 \times 10^{-4}$  to  $1.0 \times 10^{-3} \text{ h}^{-1}$  (average:  $4.1 \times 10^{-4} \text{ h}^{-1}$ ), while first-order dermal absorption rates after 8-hours of exposure to the more

concentrated formulation ranged from  $7.5 \times 10^{-5}$  to  $5.1 \times 10^{-4}$  (USDA, 2003). The results of this study indicate that glyphosate containing the POEA surfactant does not absorb more rapidly than a glyphosate formulation with a less concentrated solution of surfactant. A second study was performed on monkeys and found that after 12 hours of exposure, approximately 1.5% of the glyphosate was absorbed, which is equivalent to a first-order dermal absorption rate of  $1.3 \times 10^{-3} \text{ hour}^{-1}$  (Wester, 1991). Wester's dermal absorption rates are used later in the occupational exposure assessment. Wester's measurements and methods are consistent with other derived values and standard methods used to estimate first-order dermal absorption rates (USDA, 2003).

#### *3.1.4 Acute Systemic Toxicology*

As is common with most chemicals, acute exposure to glyphosate and its commercial formulation may be toxic at sufficiently high levels. An experiment performed by Williams et al. (2000) on rats and mice found that acute oral  $\text{LD}_{50}$  values (the lethal dosage required to kill 50 percent of a population of test animals) of glyphosate range from approximately 2,000 to 6,000 mg/kg and acute oral intraperitoneal  $\text{LD}_{50}$  values, which are about 10 times lower in value, range from 134 to 234 mg/kg (USDA, 2003). Additionally, systemic differences in toxicity do not appear to exist among species when doses of glyphosate are expressed in units of mg/kg body weight.

Documentation suggests that exposure to glyphosate with a POEA surfactant is a common means of suicide, and this fact can be used to make a determination about its effects on humans. In an analysis of suicide cases in Taiwan, doses of glyphosate/surfactant formulations in the range of  $330 \pm 42 \text{ mL}$  were associated with fatalities and the survivors were correlated with doses of  $122 \pm 12 \text{ mL}$ . Gastrointestinal effects (vomiting, abdominal pain, diarrhea), irritation, congestion, or other forms of damage to the respiratory tract, pulmonary edema, decreased urinary output sometimes accompanied by acute renal tubular necrosis, hypotension, metabolic acidosis, and electrolyte imbalances, probably secondary to the gastrointestinal and renal effects, are seen in human cases of glyphosate/surfactant exposure. It is speculated that the POEA surfactant component in the glyphosate formulations may be the dominant contributing factor leading to the effects seen in these suicide cases (USDA, 2003).

This occupational risk assessment only considers the increased use of glyphosate as an herbicide. According to EPA, glyphosate is considered to be of low acute toxicity by oral, dermal, and ocular routes of exposure, since all studies are in Toxicity Category III or IV. Toxicity Categories III and IV denote slight to practically non-toxic effects, respectively. Furthermore, an acute inhalation study was waived by EPA because glyphosate is a non-volatile solid and the studies conducted on the end-use product formulation are considered sufficient (US EPA, 2006; 1993). Additionally, according to the World Health Organization (WHO) (1996), glyphosate has been classified as unlikely to present an acute hazard in normal use. EPA's acute toxicity profile for glyphosate is presented in table M-4.

**Table M-4. Acute Toxicity Profile of Glyphosate (US EPA, 2006)**

| US EPA Guideline No. | Study Type              | MRID(s)  | Results                                                                   | Toxicity Category |
|----------------------|-------------------------|----------|---------------------------------------------------------------------------|-------------------|
| 870.1100             | Acute oral              | 41400601 | LD <sub>50</sub> > 5,000 mg/kg                                            | IV                |
| 870.1200             | Acute dermal            | 41400602 | LD <sub>50</sub> > 5,000 mg/kg                                            | IV                |
| 870.1300             | Acute inhalation        | None     | The requirement for an acute inhalation LC <sub>50</sub> study was waived | None              |
| 870.2400             | Acute eye irritation    | 41400603 | Corneal opacity or irritation clearing in 7 days or less                  | III               |
| 870.2500             | Acute dermal irritation | 41400604 | Mild or slight irritant                                                   | IV                |
| 870.2600             | Skin sensitization      | 41642307 | Not a sensitizer                                                          | None              |

### 3.1.5 General Subchronic and Chronic Systemic Toxicology

Loss of body weight is one of the more consistent signs of subchronic or chronic exposure to glyphosate. This effect has been noted in mice, rats, dogs, and rabbits. Observed weight loss is consistent with experimental data indicating that glyphosate may be an uncoupler of oxidative phosphorylation. Additionally, the loss of body weight observed was not associated with a significant decrease in food consumption. Other general and non-specific signs of toxicity include liver weight, blood chemistry (may suggest mild liver toxicity), liver pathology, and changes in pituitary weight (USDA, 2003). The results of several subchronic and chronic toxicity studies are presented in table M-5 and discussed in the subsequent paragraphs.

**Table M-5. Subchronic and Chronic Toxicity Profile of Glyphosate (US EPA, 2006)**

| US EPA Guideline No./ Study Type                                            | Results                                                                                                                                                                                       |
|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 870.3100<br>90-Day oral toxicity (Mouse)                                    | NOAEL = 1500 mg/kg/day in males and females<br>LOAEL = 4500 mg/kg/day in males and females based on decreased body weight.                                                                    |
| 870.3100<br>90-Day oral toxicity (Range finding)                            | NOAEL = not established<br>LOAEL = 50 mg/kg/day in males and females based on possible increased phosphorus and potassium values.                                                             |
| 870.3150<br>90-Day oral toxicity (Rat) - AMPA - glyphosate plant metabolite | NOAEL = 400 mg/kg/day in males and females<br>LOAEL = 1200 mg/kg/day in males and females based on body weight loss and histopathological lesions of the urinary bladder.                     |
| 870.3200<br>21/28-Day dermal toxicity (Rabbit)                              | NOAEL = 1000 mg/kg/day in males and females<br>LOAEL = 5000 mg/kg/day based on slight erythema and edema on intact and abraded skin of both sexes, and decreased food consumption in females. |
| 870.3485<br>28-Day inhalation toxicity (rat)                                | NOAEL = 0.36 mg/L (highest dose tested; HDT)<br>LOAEL = not established based on 6 hours/day, 5 days/week for 4 weeks                                                                         |
| 870.4100b<br>Chronic toxicity (dog)                                         | NOAEL = 500 mg/kg/day in males and females (HDT)<br>LOAEL = not established.                                                                                                                  |

One of the studies included in table M-5 is a 90-day oral toxicity study in rats exposed to AMPA. As noted in the table and previously discussed, AMPA is a metabolite of glyphosate, and in soil and environmental water samples it is found more regularly than glyphosate. AMPA is considered slightly more toxic than glyphosate. However, while AMPA is a common environmental metabolite, only trace amounts of it are formed in mammals, with the remainder being excreted unchanged. For this reason, direct exposures to AMPA, as an endogenous metabolite in animals, are encompassed by the existing toxicity data on glyphosate. For further

discussion of the occurrence of environmental concentrations of glyphosate or its metabolite AMPA, see the technical report: *Potential Impacts to Wildlife, Amphibians, Plants, and Ecosystems from Increased Glyphosate and Other Chemical Usage* (appendix N).

Two subchronic feeding studies in rodents conducted at the time of the 1993 RED showed effects in the blood and pancreas. In the first 90-day feeding study, Sprague-Dawley rats were fed glyphosate for three months in doses equivalent to 0, 63, 317, or 1,267 mg/kg/day for males and 0, 84, 404, or 1,623 mg/kg/day for females. Males and females in all treated groups showed increased serum phosphorus and potassium. The mid-dose group had increased serum glucose. Likewise, the high-dose had increased serum glucose, blood urea nitrogen, and serum alkaline phosphatase and an increased occurrence of pancreatic lesions. EPA determined that based on these results, the no observed effect level (NOEL) should be <63 mg/kg/day for males and <84 mg/kg/day for females. However, these results were considered only possibly treatment related, and the NOEL dose for each sex was not determined definitively (US EPA, 1993).

In the second subchronic feeding study, CD-1 mice were fed diets containing 0, 250, 500 or 2,500 mg/kg/day of glyphosate for 90 days. The risk assessment parameters were set based on decreases of body weight gains in the high-dose males and females of about 24% and 18%, respectively. Based on the observed decrease in body weight gain, the NOEL recommended for both sexes is 500 mg/kg/day and the recommended lowest observed effect level (LOEL) is 2,500 mg/kg/day (US EPA, 1993).

### 3.1.6 Effects on Nervous System

There was no evidence of neurotoxicity in any of the toxicology studies conducted and there are no data requirements for neurotoxicity studies. Moreover, analysis of detailed literature on health outcomes of accidental and intentional gross over-exposures, such as suicides, to glyphosate or its commercial formulations also do not implicate it in neurotoxicity effects. The weight of evidence suggests that any neurological symptoms associated with glyphosate exposures were secondary to other toxic effects and cannot be attributed to exposures directly (USDA, 2003). Based on weight of evidence considerations, EPA determined that it is not necessary to conduct a developmental neurotoxicity study with glyphosate to evaluate the potential for developmental neurotoxic effects (US EPA, 1993; 2006; USDA, 2003).

A selection of relevant neurotoxicity studies are discussed in the following paragraphs. Many of the other neurological studies conducted presented results that were not considered scientifically robust and, therefore, are not discussed in further detail in this section (USDA, 2003).

Glyphosate has been tested for neurotoxicity in rats after both acute and subchronic exposures, and has been tested for delayed neurotoxicity in hens (USDA, 2003). In an acute study, 10 male and 10 female rats were given doses of 50, 100, or 200 mg of glyphosate a.e./kg and were observed for 2 weeks. In a subchronic study, 12 female and 12 male rats were exposed to glyphosate in their diet at concentrations of 2,000, 8,000, or 20,000 ppm for 13 weeks. In both studies, glyphosate was negative for signs of neurotoxicity. In a third study, twenty hens were given a single gavage dose of 2,000 mg/kg of glyphosate. A slight decrease in brain AchE

activity occurred, but there were no signs of delayed motor ataxia or neuropathology (USDA, 2003).

An additional subchronic study in rats and mice, preformed by the National Toxicology Program (NTP) (1992), suggests that glyphosate may produce histological changes in the salivary glands in both organisms. While glyphosate may produce changes of the salivary gland by acting through an adrenergic pathway or by producing an adrenergic-mediated stimulation through some indirect mechanism, the mechanism causing this effect is not understood clearly and no signs of neurotoxicity were observed (USDA, 2003).

In an investigation of the effects of glyphosate on sensory mechanisms, a 1 mM or 10 mM dose of glyphosate was applied to the tongue of anesthetized gerbils. As a result, their taste tester response (to table salt, sugar, and acids) decreased. Due to the possibility of outside variables affecting experimentation, these results were not classified clearly as a glyphosate-induced neurological effect (USDA, 2003).

### 3.1.7 Effects on Immune System

Glyphosate has been tested for effects on the immune system in humans and experimental animals, in both *in vivo* and *in vitro* studies. In an *in vivo* study preformed by Blakley (1997), mice were exposed to glyphosate in their drinking water, at concentrations of 0, 0.35, 0.70, or 1.05 percent, for 26 days. Their antibody immune response was evaluated using sheep red blood cell challenge. The study found that the response in exposed mice did not differ from that of the unexposed mice (controls). Additionally, an *in vitro* study using human immunocompetent cells also indicated that glyphosate at concentrations ranging from 0.01 to 10  $\mu$ moles had no effect on the immune system (Flaherty et al., 1991). Furthermore, there is also no evidence to suggest that glyphosate causes dermal sensitization or morphologic abnormalities, in experimental animals, which could implicate an effect on the immune system (USDA, 2003).

In studies performed on humans, there has been no confirmation that glyphosate directly causes photoirritation, photosensitization, or allergic responses (Maibach, 1986; Jauhiainen et al., 1991; Williams et al., 2000). In a study by Maibach (1986), a group of volunteers were exposed to Roundup® via direct dermal application and no significant responses were observed.

### 3.1.8 Effects of Endocrine Function

Of the specific tests conducted to determine potential effects of glyphosate on the endocrine system, none have reported any potential estrogen, androgen, and/or thyroid mediated toxicity resulting from exposure to glyphosate (US EPA, 2006; USDA, 2003).

Glyphosate was inactive as an estrogen receptor agonist in MCF-7 human breast cancer cells (Lin and Garry, 2000) and in yeast and trout hepatocyte assays (Petit et al, 1997). Additionally, in another study, the steroidogenic acute regulatory (StAR) protein, which mediates the rate-limiting step in the mitochondrial synthesis of steroid hormones, was not disrupted by glyphosate. Therefore, glyphosate did not inhibit steroid synthesis in MA-10 mouse Leydig tumor cells. In a third test, glyphosate, with surfactant, was found to inhibit steroid synthesis. It should be noted that all of these studies were conducted *in vitro* and were used to assess whether

a plausible biological mechanism exists for glyphosate to act as an endocrine disruptor (USDA, 2003).

### *3.1.9 Reproductive and Teratogenic Effects*

Exposure to glyphosate has been evaluated for its effects on reproduction and ability to cause birth defects (i.e., teratogenic effects). Most of the literature indicates that glyphosate does not directly cause reproductive or teratogenic effects (US EPA, 1993; 2006; USDA, 2003). Four studies on the maternal, reproductive, and developmental toxicity of glyphosate were submitted for reregistration of glyphosate in 1993 (US EPA, 1993; 2006). The studies are discussed in the following paragraphs and the results are presented in table M-6.

In the first study, Charles River COBS CD rats were dosed with 0, 300, 1,000, or 3,500 mg/kg/day of glyphosate by gavage during gestation days six through 19. The high dose dams showed signs of diarrhea, decreased mean body weight, breathing rattles, inactivity, red matter around the nose, mouth, forelimbs, and dorsal head, decreases in total implantations per dam and fetuses per dam, and mortality. Developmental effects were also only seen in the high-dose group and included increased litter numbers and fetuses with unossified sternebrae and decreased mean fetal body weights. Based on these results, the recommended maternal and developmental toxicity no observed adverse effect level (NOAEL) and the lowest observed adverse effect level (LOAEL) are 1,000 mg/kg/day and 3,500 mg/kg/day, respectively (US EPA, 1993; 2006; USDA, 2003).

In a second developmental and maternal toxicity study, Dutch Belted rabbits administered 0, 75, 175, or 350 mg/kg/day during gestation days six through 27 showed treatment-related findings at the highest dose only. These effects included diarrhea, nasal discharge, and death. There were no developmental effects observed, which could be attributable to the high maternal mortality level (62.5% at the highest dose). The NOAEL and LOAEL for maternal toxicity are 175 mg/kg/day and 350 mg/kg/day, respectively (US EPA, 1993; 2006; USDA, 2003).

In a three-generation reproduction study on male and female Sprague-Dawley rats administered 0, 3, 10, or 30 mg/kg/day of glyphosate continuously through diet, increased incidence of focal tubular dilation of the kidney was seen in the high-dose male third generation pups. The recommended NOEL for reproductive toxicity is  $\geq 30$  mg/kg/day. The recommended developmental toxicity NOAEL and LOAEL are 10 mg/kg/day and 30 mg/kg/day, respectively (US EPA, 1993; 2006; USDA, 2003).

A two-generation reproduction study showed treatment-related effects at the high dose when Sprague-Dawley rats were administered 0, 100, 500, or 1,500 mg/kg/day of glyphosate continuously through the diet. These effects included soft stools in the F<sub>0</sub> and F<sub>1</sub> generations, decreased food consumption and body weight gain in the F<sub>0</sub> and F<sub>1</sub> generations during the growth period, and decreased body weight gain in the F<sub>1</sub> and F<sub>2</sub> generations during the second and third week of lactation. Based on these effects, the recommended reproductive and developmental NOEL is 500 mg/kg/day and the recommended reproductive and development LOEL is 1,500 mg/kg/day (US EPA 1993; 2006).



**Table M-6. Reproductive and Teratogenic Toxicity Profile for Glyphosate (US EPA, 2006)**

| Study Type                                                         | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|--------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 870.3700a<br>Prenatal developmental in rodents (Rat)               | <b>Maternal</b> NOAEL = 1,000 mg/kg/day<br>LOAEL = 3,500 mg/kg/day based on inactivity, mortality, stomach hemorrhages and reduced body weight gain.<br><b>Developmental</b> NOAEL = 1,000 mg/kg/day<br>LOAEL = 3,500 mg/kg/day based on increased incidence in the number of fetuses and litters with unossified sternebrae and decreased fetal body weight.                                                                                                                                                                                                                |
| 870.3700b<br>Prenatal developmental in (Rabbit)                    | <b>Maternal</b> NOAEL = 175 mg/kg/day<br>LOAEL = 350 mg/kg/day based on mortality, diarrhea, soft stools, and nasal discharge.<br><b>Developmental</b> NOAEL = 350 mg/kg/day (HDT)<br>LOAEL = not established.                                                                                                                                                                                                                                                                                                                                                               |
| 870.3800<br>Reproduction and fertility effects, 3-generation (Rat) | <b>Parental/Systemic</b> NOAEL = 30 mg/kg/day (HDT)<br><b>Reproductive</b> NOAEL = 30 mg/kg/day (HDT)<br><b>Offspring</b> NOAEL = 10 mg/kg/day<br>LOAEL = 30 mg/kg/day based on focal dilation of the kidney in male F <sub>3b</sub> pups.                                                                                                                                                                                                                                                                                                                                   |
| 870.3800<br>Reproduction and fertility effects, 2-generation (Rat) | <b>Parental/Systemic</b> NOAEL = 500 mg/kg/day in males and females<br>LOAEL = 1,500 mg/kg/day in males and females based on soft stools, decreased body weight gain and food consumption. Focal dilation of the kidney observed at 30 mg/kg/day in the 3-generation study was not observed at any dose level in this study.<br><b>Reproductive</b> NOAEL ≥ 1,500 mg/kg/day (HDT) in males and females.<br><b>Offspring</b> NOAEL = 500 mg/kg/day in males and females<br>LOAEL = 1,500 mg/kg/day in males and females based on decreased body weight gain during lactation. |

Additional studies conducted to evaluate the reproductive and teratogenic effects of glyphosate, include subchronic and chronic exposure studies, which attempted to examine the impacts of glyphosate exposure on morphology of reproductive organs, mammary glands, and endocrine glands (including the testis, ovary, pituitary, thyroid, adrenal, pancreas, parathyroid, and thymus). In both subchronic and chronic studies, no treatment-related effects on reproductive organs or endocrine glands were observed at or below the maximally tolerated dose of 20,000 ppm in the diet in the chronic study (Stout and Ruecker, 1990) and 50,000 ppm in the subchronic study (NTP, 1992).

Furthermore, according to USDA (2003), two studies suggest conflicting results of glyphosate's effect on mating, fertility, and reproduction parameters (including libido level, ejaculate volume, sperm count, semen fructose level and osmolarity, and number of abnormal or dead sperm) (Yousef et al., 1996; Schroeder and Hogan, 1981. Yousef et al. (1996) found that all of the effects seen in rabbits were statistically significant; however the study does not provide the actual doses used, nor does it specify the exact formulation. The study by Schroeder and Hogan (1981) suggests no treatment-related effects of glyphosate at doses of 3, 10, or 20 mg/kg body weight, although some changes in kidney morphology were observed at 30 mg/kg/day. The basis for inconsistency lies in the reporting and experimental design limitations and deficiencies in Yousef's study. Also, the use of gelatin capsules in Yousef et al. (1995) makes the study less comparable and relevant to potential human exposure (USDA, 2003).

With regard to human health effects, several epidemiological studies have been conducted to assess the relationship between general or overall pesticide exposure, or assumed pesticide exposure, and reproductive health outcomes. However most of them have not characterized exposures to specific pesticides (Arbuckle and Sever, 1998). Of the few studies that have linked exposure to glyphosate to potential risks, no adverse reproductive effects were noted. For example, the Ontario Farm Health Study, three retrospective cohort studies (Arbuckle et al., 2001; Curtis et al., 1999; Savitz et al., 1997) collected data on the relationship between pregnancy outcomes and pesticide use among couples living on farms in Ontario. Risk of miscarriage, spontaneous abortions, and fecundity were all found to be unrelated to glyphosate formulation use and exposure (USDA, 2003).

### *3.1.10 Carcinogenicity and Mutagenicity*

EPA (1993; 2002) and WHO (1994) have reviewed information regarding the carcinogenicity and mutagenicity of glyphosate. EPA classified glyphosate as a Group E carcinogen (evidence of non-carcinogenicity for humans). In the RED, EPA (1993) concluded that glyphosate is not carcinogenic at any of the levels tested in three studies. These studies are discussed in the following paragraphs. EPA (2002) reconfirmed this decision in a subsequent tolerance publication for glyphosate.

In the first study considered in the RED, Sprague-Dawley rats were fed glyphosate at levels of 0, 3, 10 or 31 mg/kg/day in males and 0, 3, 11 or 34 mg/kg/day in females for 26 months. The high dose groups showed signs of increased incidence of thyroid C-cell carcinomas in females and interstitial cell testicular tumors, but EPA determined that these neoplasms were not treatment-related, noted that the incidence of thyroid carcinomas was not statistically significant, and determined that the incidence of testicular tumors was within historical levels. Therefore, EPA determined that glyphosate was not considered carcinogenic in this study (US EPA, 1993).

A second carcinogenicity feeding study was also conducted using Sprague-Dawley rats fed diets containing 0, 89, 362, or 940 mg/kg/day in males and 0, 113, 456, or 1183 mg/kg/day in females of glyphosate. The low- and high-dose males and females showed an increase incidence of pancreatic islet cell adenomas and hepatocellular (liver) adenomas. The mid- and high-dose animals also showed an increased incidence of thyroid C-cell adenomas. However, the pancreatic islet cell adenomas were not associated with a statistically significant positive dose-related trend, a progression to carcinomas, or dose-related increase in pancreatic hyperplasia. Additionally, a statistically significant increase in incidence of hepatocellular adenomas was not seen. The incidence was within historical range, there was no progression to carcinomas, and the incidence of hyperplasia was not compound-related. In terms of thyroid C-cell adenomas, there was no statistically significant dose-related trend in occurrence or a statistically significant increase in incidence, no progression to carcinomas, and no significant dose-related increase in hyperplasia. Therefore, glyphosate was not considered to be carcinogenic (US EPA, 1993)

Another carcinogenicity study involved an 18-month feeding study conducted with CD-1 mice using doses of glyphosate equivalent to 0, 150, 750, or 4500 mg/kg/day. The effects in the high-dose group included decreased body weight gain in both sexes, increased hepatocellular

hypertrophy, hepatocellular necrosis and interstitial nephritis in males, increased incidence of proximal tubule epithelial basophilia and hypertrophy in females, and increased incidence of renal tubular adenomas in males. Based on the effects listed above, the recommended NOAEL is 750 mg/kg/day for both sexes and the recommended LOAEL is 4500 mg/kg/day for both sexes. However, it was determined by EPA and confirmed by other experts that the adenomas occurred spontaneously and that glyphosate is not considered carcinogenic based on the results of this study (US EPA, 1993; 2006).

In a subsequent assessment, EPA (2002) addressed concerns about studies performed by Hardell and Erickson (1999a, b). The first study found that individuals in Sweden with a history of glyphosate exposure had an increased risk of developing non-Hodgkin lymphoma (Hardell and Erickson, 1999a). The second study found this risk to be statistically significant (Hardell and Erickson, 1999b). After careful review, EPA concluded that these studies did not establish a definitive link to cancer and their results were based on unverified recollection of exposure. EPA maintained its classification of glyphosate as a Group E carcinogen.

In terms of its mutagenicity, glyphosate has been shown to cause an increase in chromosomal aberration in a plant (*Allium sp.*) associated with cell abnormalities in spindle fiber (Rank et al., 1993), DNA adduct formation in mice (Reluso et al., 1998), and single strand DNA breaks in mice (Bolognesi et al., 1997). *In vitro* studies conducted by Vyse and Vigfusson (1979) and Vigfusson and Vyse (1980) indicate a significant increase in sister chromatid exchanges in human lymphocytes and conclude that glyphosate is a slight mutagen. Another positive assay was confirmed in a fruit fly study (Kale et al., 1995; Kaya et al., 2000) as well as in a study of lymphocyte cultures (Lioi et al., 1998a; Lioi et al., 1998b). Most of the remaining screening studies for mutagenicity, however, were negative.

For example, four mutagenicity studies were submitted for the reregistration of glyphosate in 1993. These studies included a gene mutation assay in an Ames Test on *Salmonella typhimurium* strains, a gene mutation assay in Chinese hamster ovary cells/hypoxanthine – guanine – phosphoribosyl transferase assay, a Structural Chromosomal Aberration Assay in male and female Sprague-Dawley rats, and a combined study employing a rec-assay using *B. subtilis* and a reverse mutation assay using *E. coli* and *Salmonella typhimurium* strains. None of these studies showed a mutagenic or clastogenic response. EPA concluded that glyphosate is not a mutagen (US EPA, 1993; 2002; USDA, 2003).

### 3.1.11 Irritation and Sensitization

According to EPA, glyphosate is classified as mildly irritating to the eyes (Category III) and slightly irritating to the skin (Category IV) based on data collected from skin and eye irritation studies during the registration process (US EPA 1993; 2006). Different formulations of glyphosate have different irritation patterns (e.g., the free acid of glyphosate is severely irritating to the eyes, but the IPA salt of glyphosate is nonirritating to the skin and eyes) (USDA, 2003). Additionally, skin sensitization tests for glyphosate were all negative (US EPA, 1993; 2006).

### 3.1.12 Systemic Toxic Effects from Dermal Exposure

Systemic toxic effects from chronic dermal exposure are less damaging than those from chronic oral exposure because glyphosate is absorbed poorly from the skin. Acute dermal exposure effects are similar to those of acute oral exposure effects (USDA, 2003). EPA classified glyphosate as a Category III for oral and dermal toxicity. The LD<sub>50</sub> value for the acute oral toxicity of glyphosate is >5,000 mg/kg (US EPA, 2006).

The EPA (1993) RED for glyphosate provides further insight into the dermal toxicity of glyphosate. The RED cites a 1982 study (MRID 00098460) with rabbits in which glyphosate was applied to intact and abraded skin at doses of 10, 1000, or 5,000 mg/kg/day, five days a week, for three weeks. The effects were minimal and included slight irritation of the abraded skin, decreased food consumption, and decreased serum lactic dehydrogenase activity at 5,000 mg/kg. In a more recent study by Pinto (1996), dermal doses of 250, 500, or 1,000 mg/kg/day caused no effects on body weight, food consumption, hematology, clinical chemistry, or organ weights. There were also no signs of irritation or pathologic changes in tissue.

#### *3.1.13 Inhalation Effects*

EPA (1993; 2006) did not require an acute inhalation study for technical grade glyphosate because of its low volatility rate. The acute inhalation LC<sub>50</sub> value of the isopropylamine salt glyphosate is >6.37 mg/L, which is equivalent to a finding of no mortality in any of the five rats of each sex exposed to this concentration for four hours (USDA, 2003). A study conducted by Jamison et al., (1986) exposed a group of human volunteers to glyphosate treated flax dust and untreated flax dust. The glyphosate treated dust consistently caused a decrease in respiratory function. It is possible that the decrease in function may have been due to a greater distribution of smaller dust particles, which are more easily inhaled, in the glyphosate treated dust.

#### *3.1.14 Toxic Relevance of Surfactants in Glyphosate Formulations*

Various formulations of glyphosate contain POEA at a level of up to approximately 20 percent (200 g/L). Tallow contains a variety of fatty acids (e.g., oleic, palmitic, stearic, myristic, and linoleic acids), as well as smaller amounts of cholesterol, arachidonic, elaidic, and vaccenic acids. While surfactants are typically classified as “inert” components in herbicides, they are not toxicologically inert. In many cases, inerts are found to be more toxic than the herbicide itself (USDA, 2003).

A study evaluating the toxicity of the POEA surfactant includes a series of teratology tests in rats using glyphosate (98.7% purity), POEA used in glyphosate formulations, and the phosphate ester neutralized POEA. Groups of pregnant female rats were dosed with glyphosate at 300, 1,000, or 3,500 mg/kg/day; POEA at 15, 100, or 300 mg/kg/day, or the neutralized POEA at 15, 50, or 150 mg/kg/day on days 6 through 19 of gestation. Results indicate that severe maternal poisoning occurred at the 3,500 mg/mg/day dose of glyphosate, in association with reduced fetal body weight and sternal ossification, as well as fetal death. At a dose of 300 mg/kg/day of POEA and 150 mg/kg/day of neutralized POEA maternal deaths were also reported. Other noteworthy results in dams were signs of mild clinical toxicity and decreased food consumption that occurred at a dose of 100 mg/kg/day POEA surfactant. No fetotoxic effects were reported at any

dose level. Based on these results, the recommended NOAELs for glyphosate, POEA, and neutralized POEA were 1000 mg/kg/day, 15 mg/kg/day, and 50 mg/kg/day, respectively (USDA, 2003).

There has been some debate regarding the acute toxicity of POEA and the determination of its LD<sub>50</sub> value compared to glyphosate. It is generally agreed that the acute toxicity of glyphosate formulations (glyphosate and surfactant; LD<sub>50</sub> in rats 5400 mg/kg/day) is almost equivalent to that of glyphosate (LD<sub>50</sub> in rats 5600 mg/kg/day) (USDA, 2003). Additionally, based on drinking water studies on both glyphosate and Roundup® (i.e., glyphosate with POEA), the surfactant does not affect the rapid elimination rate of glyphosate in mammals (NTP, 1992).

### *3.1.15 Toxic Relevance of Impurities in Glyphosate Formulations*

#### *3.1.15.1 N-nitrosoglyphosate (NNG)*

Technical grade glyphosate contains at least one impurity, N-nitrosoglyphosate (NNG). EPA determined that the NNG content in glyphosate was not toxicologically significant because more than 92% of the individual technical glyphosate samples tested contained less than 1.0 ppm NNG. There is general concern for the carcinogenic potential of nitroso compounds but it is hard to quantify (US EPA 1993; USDA, 2003).

#### *3.1.15.2 1,4-Dioxane*

1,4-Dioxane is an impurity in POEA, and EPA considers it to be a carcinogen (Class B2: Probable human carcinogen) and has derived a cancer potency factor (i.e., slope factor) of 0.011 mg/kg/day. 1,4-Dioxane is present in Roundup® at a level of approximately 0.03% (Monsanto, 1999) or 300 mg/l (330 ppm). It has been demonstrated that dioxane does not present unique toxic effects. Therefore, its toxicity (except its role as a carcinogen) is encompassed by the available toxicity data on glyphosate (USDA, 2003).

## **3.2 Exposure Assessment**

As mentioned in section 2, there are five EUPs containing glyphosate that are recommended for use on Roundup Ready® alfalfa. These products include: Roundup Original Max®, Roundup Weather Max®, and Roundup Ultra Max II® (Monsanto, 2008). Two additional products, Honcho® and Honcho Plus®, are also listed in Greenbook, an online database that partners with chemical manufacturers such as Monsanto to provide information about agricultural products (Greenbook, 2008). Each of these products contains between 41 and 48% glyphosate (Monsanto, 2004; Monsanto, 2007a; Monsanto, 2007c; Monsanto, 2007d). For purposes of this analysis, exposure estimates to the chemical glyphosate are presented as opposed to exposure estimates to the EUPs. This is because toxicological data on the EUPs, which are required to assess risk to workers, were not available at the time of the analysis.

### *3.2.1 Routes of Exposure*

Workers exposed to glyphosate in products used to treat GT alfalfa may be exposed via dermal or inhalation routes of exposure. However, EPA determined in its RED for glyphosate that the

chemical is non-volatile (US EPA, 1993). For this reason, the inhalation route of exposure is not considered in this analysis. This analysis also does not consider incidental oral exposure to glyphosate for workers. For further discussion of oral exposure for the general public, please refer to the technical report: *Health and Safety Risks from Increased Glyphosate and Other Chemical Usage on Humans (Exclusive of Field Workers)* (appendix L).

EPA's RED for glyphosate indicated that occupational exposure to glyphosate has resulted in eye and skin irritation (US EPA, 1993). Accordingly, EPA recommended that personal protective equipment be worn by mixers, loaders, and applicators of products containing glyphosate. EPA set the restricted entry level (REI) for glyphosate at 12 hours due to the potential for acute dermal toxicity and skin and eye irritation immediately after products have been applied. However, it cannot be assumed that the recommendation for personal protective equipment and the REI will be honored universally. A subsequent EPA (2006) assessment of glyphosate for use on Indian mulberry and dried peas stated that the 12 hour REI has not been implemented universally. Thus, this exposure analysis and resulting risk characterization does not assume that personal protective equipment is worn, nor does it assume that workers wait 12 hours before entering a treated field.

### 3.2.2 Application Rates

Typical single application rates of products containing glyphosate range from less than 1.5 pounds of glyphosate a.i. per acre up to 3.75 pounds of glyphosate a.i. per acre; maximum label rate for a single application on GT alfalfa is 1.55 pounds of glyphosate a.e. (Monsanto, date unknown). Application rates were determined using specific product labels for each end use product (EUP) recommended for use on GT alfalfa. Application rates on these products were presented in volume (i.e., quarts or ounces) of active ingredient per acre. These values were converted to mass (i.e., pounds) per acre by multiplying the application volume by the density of the EUP (See equations M-1 and M-2).

Equation M-1

$$Density = Mass / Volume$$

thus,

Equation M-2

$$Mass = Density * Volume$$

Density values were provided by material safety data sheets (MSDS) for each EUP. When product density was not available, the specific gravity of the EUP was used to calculate density. The specific gravity is the ratio of the product density to the density of water. It was assumed that the density of water is 1000 kg/m<sup>3</sup> (See equations M-3 and M-4).

Equation M-3

$$Specific\ gravity = Product\ density / Water\ density$$

thus,

#### Equation M-4

$$\text{Product density} = \text{Specific gravity} * \text{Water density}$$

Labels also provided application rates for the EUP as opposed to the chemical alone. Because this exposure analysis focuses on the chemical as opposed to the EUP, the percent active ingredient (i.e., glyphosate) reported by the product label was considered in the exposure equation (See equation 3). The percent of glyphosate in EUPs ranged from 41 and 48.8% (See Table M-2).

#### Equation M-5

$$\text{Application rate of glyphosate} = \text{Application rate of EUP} * \text{Percent glyphosate in EUP}$$

Application rates of the five EUP recommended for use on GT alfalfa are presented in table M-7. Please refer to appendix M-4 in this technical report for further detail on the information used to calculate application rates.

**Table M-7. Application Rates of EUPs Recommended for Use on GT Alfalfa**

| Product               | Single Use Application Rate | Reference                                         |
|-----------------------|-----------------------------|---------------------------------------------------|
| Roundup Original Max® | 1.9 lb a.i./acre            | Monsanto, 2006; Monsanto, 2007e                   |
| Roundup Weather Max®  | 1.9 lb a.i./acre            | Monsanto, 2005a; Monsanto, 2005b; Monsanto, 2007f |
| Roundup Ultra Max II® | 1.9 lb a.i./acre            | Monsanto, 2004; Monsanto 2005c; Monsanto 2003     |
| Honcho®               | 2.0 lb a.i./acre            | Monsanto, 2007a; Monsanto, 2007b                  |
| Honcho Plus®          | 2.0 lb a.i./acre            | Monsanto, 2007c; Monsanto, 2007d                  |

### 3.2.3 Occupational Exposure Scenarios

Occupational exposure to glyphosate may be categorized as general worker exposure or as accidental worker exposure. General worker exposure estimates are based on the assumption of continuous contact with a chemical. Accidental worker exposure estimates are based on specific events that may not involve exposure over extended time periods.

#### 3.2.3.1 General Worker Exposure Scenarios

In general, pesticides are applied using one of three application methods: direct foliar, broadcast foliar, and aerial. According to Monsanto, the vast majority of Roundup® brand herbicides are applied using ground equipment, which could be for either direct or foliar broadcast applications (Monsanto, date unknown). Chronic general worker exposure scenarios are described by USDA (2003) and corresponding exposure algorithms are provided in a calculations worksheet presented to USDA by SERA (2006). Regardless of the application method, general worker absorbed dermal doses ( $AD_{\text{general}}$ ) of glyphosate may be estimated by multiplying the amount of the chemical handled per day by the absorbed dose rate (See equation M-6). The amount of chemical handled per day as well as the number of acres treated in a day may vary greatly (Acquavella et al., 2006). Using SERA's (2006) algorithms, the amount of the chemical handled per day ( $Amnt$ ) is the product of the application rate and the number of acres treated per day (See equation M-7). The number of acres treated per day ( $ATD$ ) may be calculated by multiplying the number of hours spent applying the chemical by the number of acres treated per hour (SERA, 2006) (See equation M-8).

Equation M-6  

$$AD_{general} = Amnt * ADR$$

Where:

$AD_{general}$  = absorbed dermal dose (mg/kg BW/day)  
 $Amnt$  = amount of chemical handled per day (lb/day)  
 $ADR$  = absorbed dermal dose rate (mg/kg BW per lb applied)

Equation M-7  

$$Amnt = AR * ATD$$

Where:

$Amnt$  = amount of chemical handled per day (lb/day)  
 $AR$  = application rate (lb/acre)  
 $ATD$  = acres treated per day (acres/day)

Equation M-8  

$$ATD = Hrs * APH$$

Where:

$ATD$  = acres treated per day (acres/day)  
 $Hrs$  = hours of application per day (hours/day)  
 $APH$  = acres treated per hour (acres/hour)

Absorbed dose rates ( $ADR$ ) for different application scenarios were estimated by SERA (2001). These rates will be considered constants for the present analysis. Central, upper, and lower bound rate estimate for directed foliar, broadcast foliar, and aerial application methods may be found in table M-8. USDA (2003) validated these rates for direct foliar applications by analyzing urine samples of agricultural workers exposed to glyphosate. Using biomonitoring data in addition to application rates and urinary output and bodyweight defaults, exposure rates were calculated. Three worker studies were examined and the results indicated that the upper range (0.01 mg/kg body weight per pound applied) is likely to overestimate exposure as all of the rates based on biomonitoring data were much lower. Therefore, these absorbed dose rates represent conservative assumptions that will be protective of the general worker population.

**Table M-8. Absorbed Dose Rates (in mg/kg body weight per pound of active ingredient applied)**

| Exposure Scenario | Central | Lower    | Upper  | Reference  |
|-------------------|---------|----------|--------|------------|
| Directed foliar   | 0.003   | 0.0003   | 0.01   | SERA, 2001 |
| Broadcast foliar  | 0.0002  | 0.00001  | 0.0009 |            |
| Aerial            | 0.00003 | 0.000001 | 0.0001 |            |

An application rate ( $AR$ ) of 2.0 pounds a.i. per acre was used because it is the more conservative of the single use application rates for the 5 EUPs recommended for use GT alfalfa (See table M-8). This rate is consistent with the range of application rates typical of Monsanto herbicides containing glyphosate (Monsanto, date unknown). (It is unlawful to apply glyphosate to GT alfalfa at a rate higher than 1.55 pounds of glyphosate a.e.)



Default values may also be used for the hours of application per day (*Hrs*) and the number of acres treated per hour (*APH*). USDA estimated that workers may spend between 6 (lower bound) and 8 (upper bound) hours applying chemicals per day (USDA, 1989). USDA (1989) also suggested default values for the number of acres treated per hour. These values differ depending on the pesticide application method. Workers using the direct foliar application method may cover approximately 0.625 acres/hour (range: 0.25 to 1 acre/hour). Workers using the broadcast foliar method may cover approximately 16 acres/hour (range: 11 to 21 acres/hour). Workers using the aerial application method may cover approximately 70 acres/hour (range: 40 to 100 acres/hour).

Central, lower, and upper bound exposure estimates were calculated for the three different application scenarios. Results are presented in table M-9. Central estimates for the three different application exposure scenarios ranged from 2.63E-02 to 2.94E-02 mg/kg body weight per day. Upper estimates ranged from 1.60E-01 to 3.02E-01 mg/kg body weight per day.

**Table M-9. Chronic Exposure Estimates for General Worker Exposure Scenarios (in mg/kg body weight per day)**

| Exposure Scenario | Central Estimate | Lower Estimate | Upper Estimate |
|-------------------|------------------|----------------|----------------|
| Directed foliar   | 2.63E-02         | 9.00E-04       | 1.60E-01       |
| Broadcast foliar  | 4.48E-02         | 1.32E-03       | 3.02E-01       |
| Aerial            | 2.94E-02         | 4.80E-04       | 1.60E-01       |

### 3.2.3.2 Accidental Worker Exposure Scenarios

Accidental exposure scenarios may involve multiple routes of exposure, including oral and inhalation in addition to dermal exposure. However, due to a dearth of validated quantitative models to estimate oral and/or inhalation dose to workers, this analysis focuses on accidental dermal exposures only. There are many possible accidental exposure scenarios that could be considered. The scenarios included in this analysis are an accidental spill on the hands of the worker and an accidental spill on the lower legs of the worker. This analysis assumes that the worker was not wearing personal protective equipment on the hands or legs, thus the chemical contacted the skin directly. Acute scenarios for accidental worker exposure are described by USDA (2003) and corresponding exposure algorithms are provided in a calculations worksheet presented to USDA by SERA (2006).

The worker's absorbed dermal dose from a spill on the hands or lower legs ( $AD_{spill}$ ) may be estimated by dividing the product of the absorbed dermal dose from a chemical spill on the hands or legs and the proportion of the chemical absorbed by the body weight of the worker (see equation M-9). The amount of the chemical deposited on the skin ( $Amnt$ ) may be estimated by multiplying the amount of liquid that adheres to the worker's skin, the surface area of the workers hands or legs, and the concentration of the chemical in the solution (equation M-10). The proportion of the chemical absorbed over the time that the worker is exposed ( $Prop$ ) may be estimated using equation M-11.

Equation M-9

$$AD_{spill} = Amnt * Prop / BW$$

Where:

|              |   |                                                          |
|--------------|---|----------------------------------------------------------|
| $AD_{spill}$ | = | absorbed dermal dose from spill on hands or legs (mg/kg) |
| $Amnt$       | = | amount of chemical deposited on skin (mg)                |
| $Prop$       | = | proportion absorbed over exposure duration (unitless)    |
| $BW$         | = | body weight of worker (kg)                               |

#### Equation M-10

$$Amnt = L * SA * Conc$$

Where:

|           |   |                                                                          |
|-----------|---|--------------------------------------------------------------------------|
| $SkinDep$ | = | amount of chemical deposited on skin (mg)                                |
| $L$       | = | amount of liquid that adheres to the worker's skin (mL/cm <sup>2</sup> ) |
| $SA$      | = | surface area of the worker's hands or legs (cm <sup>2</sup> )            |
| $Conc$    | = | concentration of the chemical in the solution (mg/mL)                    |

#### Equation M-11

$$Props = 1 - \exp(-ka * ED)$$

Where:

|           |   |                                                       |
|-----------|---|-------------------------------------------------------|
| $PropAbs$ | = | proportion absorbed over exposure duration (unitless) |
| $ka$      | = | dermal absorption rate (per hour)                     |
| $ED$      | = | exposure duration (hours)                             |

Default values were used for some of the variables used to characterize accidental exposure to workers. The body weight ( $BW$ ) of the worker is assumed to be 71.8 kg which is the mean adult body weight recommended by the EPA's Exposure Factors Handbook (US EPA, 1997). The amount of liquid that can adhere to the skin ( $L$ ) at a given time was estimated by Mason and Johnson (1987). According to their analysis, 0.008 mL of liquid can adhere to 1 cm<sup>2</sup> of skin. Surface area ( $SA$ ) estimates of the worker's hands and lower legs are from EPA's Dermal Exposure Assessment: Principles and Applications report (1992). It is assumed that the worker's hands have a surface area of 840 cm<sup>2</sup> and that the lower legs have a surface area of 2070 cm<sup>2</sup>. The concentration of the chemical in the solution ( $Conc$ ) was found on the label of each EUP. The maximum concentration in solution is 540 mg/mL and the minimum is 365 mg/mL. Central and lower limit exposure estimates assume the minimum concentration while upper limit exposure estimates assume the maximum concentration in solution. Assumptions regarding the dermal absorption rate ( $ka$ ) are based on a study by Wester et al. (1991) on the ability of glyphosate to bind to the skin, absorb and distribute in tissue. Dermal absorption rates range from 1.3E-04 to 1.0E-03 per hour. Finally, it is assumed that a worker's skin or lower legs would be exposed for a period of one hour ( $ED$ ).

Central, lower, and upper bound exposure estimates were calculated for two accidental exposure scenarios in which the worker's hands or lower legs are exposed for one hour. Results are presented in table M-10. Central estimates for the accidental exposure scenarios ranged from 1.40E-02 to 3.45E-02 mg/kg body weight per day. Upper estimates ranged from 5.05E-02 to 1.24E-01 mg/kg body weight per day.

**Table M-10. Acute Exposure Estimates for Accidental Worker Exposure Scenarios (in mg/kg body weight per day)**

| Exposure Scenario | Central Estimate | Lower Estimate | Upper Estimate |
|-------------------|------------------|----------------|----------------|
| Spill on hands    | 1.40E-02         | 4.44E-03       | 5.05E-02       |
| Spill on legs     | 3.45E-02         | 1.09E-02       | 1.24E-01       |

### 3.2.4 Summary

#### 3.2.4.1 General Worker Exposure Scenarios

General worker exposure estimates from direct foliar application of herbicides recommended for use on GT alfalfa ranged from 9.00E-04 to 1.60E-01 mg/kg body weight per day. General worker exposure estimates from broadcast foliar application of herbicides recommended for use on GT alfalfa ranged from 1.32E-03 to 3.02E-01 mg/kg body weight per day. General worker exposure estimates from aerial application of herbicides recommended for use on GT alfalfa ranged from 4.80E-04 to 1.60E-01 mg/kg body weight per day. Section 3.4 places these exposure estimates in the context of a glyphosate-specific human health benchmark in order to estimate risk of potential adverse effects associated with chronic dermal exposure to glyphosate.

#### 3.2.4.2 Accidental Worker Exposure Scenarios

Exposure estimates from an accidental spill on a worker's hands ranged from 4.44E-03 to 5.05E-02 mg/kg body weight per day. Exposure estimates from an accidental spill on a worker's legs ranged from 1.09E-02 to 1.24E-01 mg/kg body weight per day. Section 3.4 places these exposure estimates in the context of a glyphosate-specific human health benchmark in order to estimate risk of potential adverse effects associated with acute dermal exposure to glyphosate.

## 3.3 Dose-Response Assessment

### 3.3.1 Overview

An RfD is defined as a level of exposure that will not result in any adverse effects in any individual. The oral RfD value for glyphosate proposed by EPA's Office of Pesticide Programs (EPA OPP) is 2 mg/kg/day, and is based on a teratogenicity study in rabbits in which there were no observed effects in offspring at any dose level, and maternal toxicity was noted at 350 mg/kg/day with a NOAEL of 175 mg/kg/day (Rodwell et al., 1980). The RfD of 2 mg/kg/day was derived by dividing the NOAEL by an uncertainty factor of 100 (i.e., 10 for sensitive individuals and 10 for species-to-species extrapolation) and rounding the result to one significant figure (US EPA 2006; 2002; 1993).

### 3.3.2 Existing Guidelines

This section reviews two chronic RfDs for glyphosate proposed by EPA OPP and WHO's comparable proposed acceptable daily intake (ADI) in its analysis. As discussed in the previous paragraph, the RfD of 2 mg/kg/day was derived from a teratogenicity study in rabbits and was first derived in the 1993 RED document for glyphosate (US EPA, 1993). EPA's Integrated Risk Information System (IRIS) also derived an RfD for glyphosate of 0.1 mg/kg/day (US EPA, 1990). This value is based on a dietary 3-generation reproduction study by Schroeder and Hogan

(1981), in which rats were exposed to glyphosate in their diet and no adverse effects were observed. The NOAEL from this study was 10 mg/kg/day and an uncertainty factor of 100 was applied to derive an RfD of 0.1 mg/kg/day.

The ADI proposed by WHO (1994) is based on a life-time feeding study in rats, as opposed to a reproductive toxicity study. A study by Lankas and Hogan (1981) dosed the diets of male and female rats daily with glyphosate for 26 months (0, 3.1, 10.3, or 31.5 mg/kg/day in males; 0, 3.4, 11.3, or 34.0 mg/kg/day in females). No effects were observed in any of the animals at any of the dose levels; therefore, WHO used a NOAEL of 31.5 mg/kg/day and an uncertainty factor of 100 to derive the ADI.

EPA's Office of Drinking Water (EPA ODW) proposed a 10-day health advisory for glyphosate of 17.5 mg/L, based on the NOAEL of 175 mg/kg/day, and a longer-term health advisory of 1 mg/L, based on the EPA RfD of 0.1 mg/kg/day. EPA ODW also derived a short-term RfD of 2 mg/kg/day, which is identical to the chronic RfD proposed by EPA OPP.

### *3.3.3 Dose-Response and Dose-Severity Relationships*

A threshold and non-threshold multistage model was used to estimate the LD<sub>50</sub> in humans. Both models approximated the LD<sub>50</sub> to be 3,000 mg/kg/day, similar to the range of 2,000 to 6,000 mg/kg reported in experimental mammals. The threshold version of the multistage model was also used to yield an estimate of the threshold dose of 445 mg/kg for systemic toxic effects. Below this dose, it is assumed that no individual in the population will respond (USDA, 2003).

In addition, dose severity relationships were analyzed for experimental mammals and humans. The available animal data were characterized using four standard severity levels: NOEL, NOAEL, AEL (adverse effect level), and FEL (frank effect level). Furthermore, three different groups of end points were determined: general systemic toxic effects, reproductive or developmental effects, and acute LD<sub>50</sub> values. Although the exposure periods for these studies ranged from one day to greater than two years, glyphosate was rapidly excreted from the body. Therefore, it may be assumed that duration of exposure is not a crucial parameter in assessing the toxicity of glyphosate (USDA, 2003).

The data for experimental animals was further analyzed using a categorical regression analysis in the next step of assessing the dose-severity relationships. The analysis correlates categorical responses with factors that may influence the response. Results of the categorical regression indicate that the probabilities of an adverse effect at the RfD of 0.1 mg/kg/day is 0.0005, at 1 mg/kg/day is 0.003, and at a dose of 10 mg/kg/day is 0.12. From these results, it was inferred that an RfD of 2 mg/kg is protective. It was further determined that the probability of a frank toxic effect (a sufficiently severe effect that can be observed in the whole organism without the use of invasive methods) at the RfD of 0.1 mg/kg/day is 0.00005 and at the RfD of 2 mg/kg/day increases to 0.0006 (USDA, 2003).

The consistency between the categorical analysis in experimental animals and the dose-response analysis using the multistage model for humans is relatively good. At 445 mg/kg, the estimated

threshold of human lethality, the probability of observing a frank toxic effects is approximately 0.04. At this dose in the non-threshold version of the multi-stage model, the probability is 0.02. At the estimated human LD<sub>50</sub> of approximately 3000 mg/kg, the probability of observing an adverse or frank effect, as determined by a categorical regression using two categories, is 0.7.

For glyphosate, the data suggest that humans are no more sensitive than experimental animals. Subsequently, this suggests that the current and proposed RfDs may be overly protective by a factor of 10 or greater.

#### 3.3.4 *Susceptible Populations*

In developmental studies in rats and rabbits and reproductive studies in rats, glyphosate exhibited no evidence of increased qualitative and quantitative susceptibility. Additionally, an acute RfD was not established for any population subgroup or the general population, including infants and children, based on the absence of an appropriate toxicological endpoint attributable to a single exposure (dose), including maternal toxicity in developmental toxicity studies (US EPA, 2006).

#### 3.3.5 *RfD Values Used in Risk Assessment*

The glyphosate database is large, complex, and open to many interpretations. The Joint Food and Agricultural Organization of the United Nation (FAO)/WHO on Pesticides Residues (JMPR) recommended an ADI for glyphosate of 0.3 mg/kg *per se*. This was based on a 26-month feeding study in rats with a resulting NOEL of >31 mg/kg/day and an uncertainty factor of 100. However, EPA determined a NOAEL of 175 mg/kg/day and an uncertainty factor of 100 because maternal mortality was observed at the highest dose group. As a result, in 1992, EPA OPP's Reference Dose Peer Review Committee recommended an oral reference dose for glyphosate of 2 mg/kg/day for long-term exposures (USDA, 2003). EPA ODW recommended an oral reference dose of 2 mg/kg/day for short-term exposures. As a result, the same RfD is recommended for both short- (i.e., acute) and long-term (i.e., chronic) exposures. Due to a lack of significant dose-response data for glyphosate, this approach was deemed appropriate (USDA, 2006; US EPA 1993; 2002). Glyphosate endpoints for this risk assessment are summarized in table M-11 below.

EPA did not include an RfD for dermal exposure to glyphosate (1993). However, following the lead of USDA (2003), a dermal RfD of 2 mg/kg/day was used for short- and long-term dermal exposures.

**Table M-11. Summary of Toxicological Doses and Endpoints for Chemical for Use in Human Health Risk Assessments (US EPA, 2006)**

| <b>Exposure Scenario</b>                                                                                              | <b>Dose Used in Risk Assessment, UF</b>                                                                                                                                    | <b>Special FQPA SF* and Level of Concern for Risk Assessment</b>                 | <b>Study and Toxicological Effects</b>                                                                                                                                                                                        |
|-----------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chronic Dietary (all populations)                                                                                     | NOAEL= 175 mg/kg/day<br>UF = 100<br><b>Chronic RfD</b> = 1.75 mg/kg/day = 2.0 mg/kg/day (rounded to one significant figure)                                                | FQPA SF = 1X<br><b>cPAD</b> = $\frac{cRfD}{FQPA\ SF}$<br>= <b>1.75 mg/kg/day</b> | Developmental Toxicity Study - rabbit<br>LOAEL = 350 mg/kg/day based on diarrhea, nasal discharge and death in maternal animals                                                                                               |
| Short-, and Intermediate-Term Incidental, Oral (Residential)                                                          | NOAEL = 175 mg/kg/day                                                                                                                                                      | LOC for MOE = 100                                                                | Developmental Toxicity Study - rabbit<br>LOAEL = 350 mg/kg/day based on diarrhea, nasal discharge and death in maternal animals                                                                                               |
| Short-, Intermediate- and Long-Term Dermal (1 - 30 days, 1-6 months, 6 months -lifetime ) (Occupational)              | 2.0 mg/kg/day [US EPA does not maintain a dermal RfD; however, USDA (2003) used an acute and chronic RfD to conduct a dermal exposure assessment for occupational workers] | None                                                                             | Based on the systemic NOAEL of 1,000 mg/kg/day in the 21 day dermal toxicity study in rabbits, and the lack of concern for developmental and reproductive effects, the quantification of dermal risks is not required.        |
| Short-, Intermediate- and Long-Term Inhalation (1-30 days, 1- 6 months, 6 months-lifetime) (Occupational/Residential) | None                                                                                                                                                                       | None                                                                             | Based on the systemic toxicity NOAEL of 0.36 mg/L (HDT) in the 28-day inhalation toxicity study in rats, and the physical characteristics of the technical (wetcake), the quantification of inhalation risks is not required. |
| Cancer (oral, dermal, inhalation)                                                                                     | <b>Classification:</b> Group E; no evidence of carcinogenicity; risk assessment not required                                                                               |                                                                                  |                                                                                                                                                                                                                               |

### 3.4 Risk Characterization

#### 3.4.1 Overview

As discussed in section 3.2, workers may be exposed to herbicides recommended for used on GT alfalfa via dermal contact with treated crops. Workers may also be exposed accidentally via spills to hands or legs. Glyphosate is considered a Category IV dermal toxicant and may cause slight skin irritation (US EPA 1993; 2006).

#### 3.4.2 Risk Characterization

To determine if workers are at risk of adverse effects associated with glyphosate, estimated exposure doses are compared with a health benchmark specific to glyphosate. As discussed in section 3.3, USDA (2003) used a dermal reference dose (RfD) for acute (i.e., accidental) and chronic (i.e., general) exposure scenarios for glyphosate of 2 mg/kg of body weight per day.

This means that individuals with dermal exposure doses equal to or less than 2 mg/kg of body weight per day should not be at risk of adverse effects associated with exposure to glyphosate. The risk metric used to determine if individuals are at risk of adverse effects is called the hazard quotient (HQ). The hazard quotient is the ratio of the estimated exposure dose to the chemical-specific health benchmark (e.g., RfD) (See equation M-12). If the HQ is estimated to be less than 1, no adverse effects are expected as a result of exposure to the chemical of concern. If the HQ is greater than 1, adverse health effects are possible. However, an HQ exceeding 1 does not indicate that adverse effects are certain to occur. Since glyphosate is considered a Group E carcinogen (i.e., signifies non-carcinogenicity in humans) (EPA, 1993), an analysis of cancer risk was not conducted.

Equation M-12.

$$HQ = \frac{Exposure}{RfD}$$

Where:

HQ = Hazard quotient (unitless)  
 Exposure = Estimated exposure dose (mg/kg BW per day)  
 RfD = Reference dose (mg/kg BW per day)

#### Risk Characterization for General Worker Exposure Scenarios

Chronic dermal exposure estimates for three occupational scenarios in which a worker applies glyphosate using a directed foliar, broadcast foliar, or aerial application method were presented in section 3.2. Results are summarized in table M-12. Please refer to the calculations worksheet submitted with this report for further explanation of exposure calculations.

**Table M-12. Chronic Dermal Exposure Estimates by Method of Application (in mg/kg BW per day)**

| Scenario         | Central Estimate | Lower Estimate | Upper Estimate | Worksheet |
|------------------|------------------|----------------|----------------|-----------|
| Directed Foliar  | 2.63E-02         | 9.00E-04       | 1.60E-01       | 1         |
| Broadcast Foliar | 4.48E-02         | 1.32E-03       | 3.02E-01       | 2         |
| Aerial           | 2.94E-02         | 4.80E-04       | 1.60E-01       | 3         |

Chronic dermal exposure estimates were compared to the chronic dermal RfD of 2 mg/kg of body weight per day. Results are presented in table M-13. Please refer to the calculations worksheet submitted with this report for further explanation of hazard quotient calculations.

**Table M-13. Chronic Dermal HQs for General Worker Exposure Scenarios**

| Scenario         | Central Estimate<br>(in mg/kg BW<br>per day) | Lower Estimate<br>(in mg/kg BW<br>per day) | Upper Estimate<br>(in mg/kg BW<br>per day) | RfD<br>(in mg/kg BW<br>per day) | Worksheet |
|------------------|----------------------------------------------|--------------------------------------------|--------------------------------------------|---------------------------------|-----------|
| Directed Foliar  | 0.0131                                       | 0.0005                                     | 0.0800                                     | 2                               | 7         |
| Broadcast Foliar | 0.0224                                       | 0.0007                                     | 0.1512                                     |                                 |           |
| Aerial           | 0.0147                                       | 0.0002                                     | 0.0800                                     |                                 |           |

### 3.4.2.2 Risk Characterization for Accidental Worker Exposure Scenarios

Acute dermal exposure estimates for two spill scenarios in which a worker spills glyphosate on the hands or legs were presented in section 3.2. Results are summarized in table M-14. Please refer to the calculations worksheet submitted with this report for further explanation of exposure calculations.

**Table M-14. Acute Dermal Exposure Estimates by Type of Spill (in mg/kg BW per day)**

| Scenario       | Central Estimate | Lower Estimate | Upper Estimate | Worksheet |
|----------------|------------------|----------------|----------------|-----------|
| Spill on hands | 1.40E-02         | 4.44E-03       | 5.05E-02       | 4         |
| Spill on legs  | 3.45E-02         | 1.09E-02       | 1.24E-01       | 5         |

Acute exposure estimates were compared to the acute dermal RfD of 2 mg/kg of body weight per day. Results are presented in table M-15. Please refer to the calculations worksheet submitted with this report for further explanation of hazard quotient calculations.

**Table M-15. Acute Dermal HQs for General Worker Exposure Scenarios**

| Scenario       | Central Estimate<br>(in mg/kg BW<br>per day) | Lower Estimate<br>(in mg/kg BW<br>per day) | Upper Estimate<br>(in mg/kg BW<br>per day) | RfD<br>(in mg/kg BW<br>per day) | Worksheet |
|----------------|----------------------------------------------|--------------------------------------------|--------------------------------------------|---------------------------------|-----------|
| Spill on hands | 0.007                                        | 0.002                                      | 0.025                                      | 2                               | 7         |
| Spill on legs  | 0.017                                        | 0.005                                      | 0.062                                      |                                 |           |

### 3.4.3 Summary of Results

This analysis assumes that workers exposed to glyphosate may have chronic or acute dermal exposure. The scientific literature demonstrates that general worker exposure estimates vary greatly because the amount of chemical handled per day and the number of acres treated in a day differs from scenario to scenario. Central, lower, and upper bound exposure and risk calculations are intended to capture some of this variability.

#### 3.4.3.1 Chronic Dermal Risk Characterization

Central, lower, and upper bound HQs for general worker exposure scenarios do not suggest that workers are at risk of adverse effects associated with chronic dermal exposure to glyphosate. HQs ranged from 0 to 0.8 for directed foliar application, from 0.001 to 0.15 for broadcast foliar application and from 0 to 0.08 for aerial application. The most exposed workers were those using a broadcast foliar application method. The upper bound HQ was 0.15, approximately 8% of the chronic dermal RfD.

#### 3.4.3.2 Acute Dermal Risk Characterization

Central, lower, and upper bound HQs for acute worker exposure scenarios do not suggest that workers are at risk of adverse effects associated with acute dermal exposure to glyphosate. HQs for a spill on the hands ranged from 0.002 to 0.025. HQs for a spill on the legs ranged from



0.005 to 0.062. The most exposed workers were those who spilled glyphosate on the legs. The upper bound HQ was 0.06, approximately 3% of the acute dermal RfD.

### 3.5 Summary of Findings

The use of currently registered pesticide products containing glyphosate in accordance with the labeling will not pose unreasonable risks or adverse effects to humans or the environment. In general, the herbicidal activity of glyphosate is due primarily to a metabolic pathway that does not occur in humans or other animals, and, thus, this mechanism of action is not directly relevant to the human health risk assessment. EPA considers glyphosate to be of low acute and chronic toxicity by the dermal route of exposure. Glyphosate is considered a Category IV dermal toxicant and is expected to cause only slight skin irritation.

General or chronic worker exposure estimates from directed foliar application of herbicides recommended for use on GT alfalfa ranged from 9.00E-04 mg/kg/day to 1.60E-01 mg/kg/day. Chronic exposure estimates from broadcast foliar application ranged from 1.32 E-03 to 3.02E-01 mg/kg/day. Chronic exposure estimates from aerial application ranged from 4.80E-04 to 1.60E-01 mg/kg/day.

Central, upper, and lower bound chronic HQs were all under 1, suggesting that workers using these methods of application to apply herbicides recommended for use on GT alfalfa are not at risk of adverse effects associated with dermal exposure to glyphosate. HQs for directed foliar application ranged from 0 to 0.8. HQs for broadcast foliar application ranged from 0.001 to 0.15. HQs for aerial application ranged from 0 to 0.08. The most exposed workers were those using a broadcast foliar application method. The upper bound HQ was 0.15, approximately 8% of the chronic dermal RfD.

Accidental or acute worker exposure estimates from an accidental spill of herbicides recommended for use on GT alfalfa on the hands ranged from 4.44E-03 mg/kg/day to 5.05E-02 mg/kg/day. Acute worker exposure estimates from an accidental spill on the legs ranged from 1.09E-02 mg/kg/day to 1.24E-01 mg/kg/day.

Central, upper, and lower bound HQs were all under 1, suggesting that workers who accidentally spill herbicides recommended for use on GT alfalfa on hands or legs are not at risk of adverse effects associated with acute exposure to glyphosate. HQs for a spill on the hands ranged from 0.002 to 0.025. HQs for a spill on the legs ranged from 0.005 to 0.062. The most exposed workers were those who spilled glyphosate on the legs. The upper bound HQ was 0.06, approximately 3% of the acute dermal RfD.

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## Appendix M-2. Literature Search

### 1.0 Literature Search Strategy

#### 1.1 Purpose

The purpose of this literature search is to locate references about the health and safety risks for field workers from increased glyphosate usage. These references will be used to examine the literature on potential health and safety risks for field workers.

We propose that the following DIALOG databases be included in the search:

The following DIALOG databases will be included in the search:

|                                    |                                                 |
|------------------------------------|-------------------------------------------------|
| File 5: BIOSIS                     | File 117: Water Resources Abstracts             |
| File 6: NTIS                       | File 144: PASCAL                                |
| File 34: SciSearch                 | File 154: MEDLINE                               |
| File 41: Pollution Abstracts       | File 156: ToxFile                               |
| File 40: Enviroline                | File 245: WATERNET™                             |
| File 72: EMBASE                    | File 250: CAB Abstracts                         |
| File 76: Environmental Sciences    | File 266: Federal Research In Progress (FEDRIP) |
| File 79: Aqualine                  | File 399: CA SEARCH®: Chemical Abstracts®       |
| File 98: General Science Abstracts |                                                 |

Descriptions of these files are available at <http://library.dialog.com/bluesheets/>.

#### 1.2 Scope of Search

The search will focus any published references after 1990. A reference list with abstracts will be screened for relevance to fermentation processes. English language only publications will be retrieved.

The following list will be retrieved and expanded upon.

#### 1.3 Strategy Overview

A list of search parameters is listed below.

#### 1.4 Synonyms

- Glyphosate
- Glyphosate, isopropylamine salt
- Glyphosate, sodium salt
- *N*-(phosphonomethyl) glycine
- Roundup®
- Rodeo®

- Glyphosate, potassium
- Glyphosate, ammonium
- Glyphosate, sulfosate
- Aqua Star
- Shackle®
- Roundup Ultra®

## 1.5 Keywords

- Acute
- Alfalfa
- Allowable daily intake
- Cancer\*
- Carcino\*
- Chronic
- Crop
- Degradation
- Derma\*
- Developmental
- Dietary risk
- Dose
- Emission
- Embryo
- Environmental impacts
- Exposure(s)
- Eye
- Farm
- Farmworker
- Fertility
- Fieldworker
- Health effect(s)
- Human health risk
- Incidental
- Ingest\*
- Inhal\*
- Inhibition
- Irritation
- Leach\*
- Metabo\*
- Mutagen\*
- Neuro\*
- Non-target crops
- Occupational
- Persistence
- Reproducti\*
- Residue
- Risk
- Sensitization
- Spray drift
- Subchronic
- Terato\*
- Tolerance
- Toxic\*
- Usage patterns
- Worker

## 1.6 Submission of Citations for Approval

Using reference management software, pooled information obtained from the various bibliographic databases will be screened to remove duplicates. Additionally, ICF will review the list prior to submission and eliminate any irrelevant citations. Information will include the following (when available):

Author(s). Publication Year. Title. Source Document Name, Volume, Page Numbers.

Abstract

Descriptors/Identifiers (*i.e.*, keywords and subject headings)

### Literature Search Results

File 10:AGRICOLA 70-2008/Apr  
(c) format only 2008 Dialog

File 154:MEDLINE(R) 1990-2008/Jun 02  
 (c) format only 2008 Dialog  
 File 266:FEDRIP 2008/Feb  
 Comp & dist by NTIS, Intl Copyright All Rights Res  
 File 156:ToxFile 1965-2008/May W4  
 (c) format only 2008 Dialog  
 File 55:Biosis Previews(R) 1993-2008/May W4  
 (c) 2008 The Thomson Corporation  
 File 6:NTIS 1964-2008/Jun W1  
 (c) 2008 NTIS, Intl Cpyrgh All Rights Res  
 File 117:Water Resources Abstracts 1966-2008/Mar  
 (c) 2008 CSA.  
 File 41:Pollution Abstracts 1966-2008/May  
 (c) 2008 CSA.  
 File 40:Enviroline(R) 1975-2008/Apr  
 (c) 2008 Congressional Information Service  
 File 44:Aquatic Science & Fisheries Abstracts 1966-2008/Mar  
 (c) 2008 CSA.  
 File 76:Environmental Sciences 1966-2008/Jun  
 (c) 2008 CSA.  
 File 144:Pascal 1973-2008/May W4  
 (c) 2008 INIST/CNRS  
 File 162:Global Health 1983-2008/Apr  
 (c) 2008 CAB International  
 File 50:CAB Abstracts 1972-2008/Apr  
 (c) 2008 CAB International  
 File 73:EMBASE 1974-2008/May 30  
 (c) 2008 Elsevier B.V.

S1 28882 GLYPHOSATE OR PHOSPHONOMETHYL()GLYCINE OR  
 ROUNDUP OR RODEO  
 OR AQUA()STAR OR SHACKLE OR GLYPHOSPHATE  
 S2 14787 RN=1071-83-6 OR PHOSPHONOMETHYLIMINOACETIC()ACID  
 OR SILGLIF OR PONDMASTER  
 S3 11254 (S1 OR S2)/2000:2008  
 S4 8322013 ACUTE OR SUBACUTE OR CHRONIC OR SUBCHRONIC OR  
 INGEST? OR I-  
 NHAL? OR AVERAGE()DAILY()INTAKE OR DOSE OR DOSAGE  
 OR DIETARY  
 S5 5982530 TOXIC? OR (HEALTH OR ADVERSE OR SIDE)(3N)(EFFECT  
 OR EFFECTS  
 OR RISK OR RISKS OR IMPACT OR IMPACTS) OR  
 NEUROTOXIC? OR GEN-  
 OTOXIC? OR IMMUNOTOXIC?  
 S6 5900953 CANCER? OR CARCINO? OR TUMOR? OR NEOPLAS?

S7 7007833 DERMA? OR SKIN OR EYE OR EYES OR OCCULAR? OR  
 REPRODUCTI? OR  
 EMBRYO? OR TERATOL? OR TERATOGEN? OR IRRITAT? OR  
 IRRITANT OR NEUROLOG?  
 S8 10892095 FERTILITY OR INFERTIL? OR MUTAGEN? OR MUTAT? OR  
 SENSITIZ? -  
 OR OCCUPATIONAL OR EXPOS? OR METABOLI?  
 S9 34112 (FARM OR FIELD OR MIGRANT OR AGRICULTURAL OR  
 PESTICIDE)()W-  
 ORKER? ? OR FARMWORKER? OR FIELDWORKER? OR  
 FARMHAND? ? OR FIELDHAND? ?  
 S10 3991193 USAGE()PATTERN? ? OR SPRAY()DRIFT? OR TOLERANCE  
 OR PERSIST-  
 ENCE OR INHIBITION OR INCIDENTAL OR DEGRADATION OR  
 ALFALFA OR LEACH?  
 S11 2348875 SAFETY OR SAFE OR POISON? OR INTOXICAT?  
 S12 4507 S3 AND (S4 OR S5 OR S6 OR S7 OR S8 OR S11)  
 S13 1122 S12 AND (S9 OR S10)  
 S20 25773370 HUMAN OR HUMANS  
 S23 2487202 FARM()(FAMILY OR FAMILIES) OR HOME OR HOMES OR  
 FARMER? ? OR  
 RANCH OR RANCHER? ? OR WORKER? ? OR WORKMEN OR  
 CHILDREN  
 S24 2294 S3 AND (S9 OR S10)  
 S25 5141 (S12 OR S24) NOT (S14 OR S15 OR S21)  
 S26 740 S25 AND (S23 OR S20)  
 S27 326 RD S26 (unique items)

# TITLES FROM VARIOUS COMBINATIONS OF THE SEARCH SETS

22/6/3 (Item 3 from file: 154)  
 14946077 PMID: 12507058  
 An analysis of \*glyphosate\* data from the California  
 Environmental  
 Protection Agency Pesticide Illness Surveillance Program.  
 \*2002\*

22/6/16 (Item 16 from file: 73)  
 0080039478 EMBASE No: 2004224625  
 \*Cancer\* mortality in a cohort of licensed herbicide  
 applicators  
 May 1, 2004

22/6/18 (Item 18 from file: 73)  
 0078903517 EMBASE No: 2002067195  
 Contact \*dermatitis\* caused by pesticides among banana  
 plantation workers in Panama

March 4, 2002

22/6/20 (Item 20 from file: 154)

14535687 PMID: 11890463

Current methods for assessing \*safety\* of genetically modified crops as exemplified by data on \*Roundup\* Ready soybeans.  
Jan-Feb \*2002\*

22/6/21 (Item 21 from file: 154)

16416941 PMID: 15929894

Differential effects of \*glyphosate\* and \*roundup\* on \*human\* placental cells and aromatase.  
Jun \*2005\*

22/6/27 (Item 27 from file: 50)

0008562363 CAB Accession Number: 20043013531

The effect of spray particle size and distribution on drift and efficacy of herbicides.

Publication Year: 2004

22/6/28 (Item 28 from file: 154)

14263603 PMID: 11564623

An exploratory analysis of the effect of pesticide \*exposure\* on the risk of spontaneous abortion in an Ontario farm population.  
Aug \*2001\*

22/6/31 (Item 31 from file: 73)

0078517319 EMBASE No: 2001123409

Frequency of sister-chromatid exchange among greenhouse farmers \*exposed\* to pesticides

April 5, 2001

22/6/32 (Item 32 from file: 73)

0081488433 EMBASE No: 2006551723

The farm family \*exposure\* study: Acquavella et al. respond [3]

November 1, 2006

22/6/33 (Item 33 from file: 73)

0080877664 EMBASE No: 2005522322

Farm Family \*Exposure\* Study: Methods and recruitment practices for a

biomonitoring study of pesticide \*exposure\*  
November 1, 2005

22/6/34 (Item 34 from file: 73)  
0081234988 EMBASE No: 2006297170  
Gliomas and farm pesticide \*exposure\* in men: The upper  
midwest health study  
December 1, 2004

22/6/35 (Item 35 from file: 162)  
0005035481 CAB Accession Number: 20053018188  
\*Glyphosate\*.  
Publication Year: 2004

22/6/37 (Item 37 from file: 154)  
16233423 PMID: 15694458  
A glyphosate-based pesticide impinges on transcription.  
Feb 15 \*2005\*

22/6/38 (Item 38 from file: 154)  
16165018 PMID: 15862083  
\*Glyphosate\* \*poisoning\*.  
\*2004\*

22/6/39 (Item 39 from file: 73)  
0080634337 EMBASE No: 2005278629  
\*Glyphosate\* results revisited (multiple letters) [2]  
June 1, 2005

22/6/42 (Item 42 from file: 154)  
15338586 PMID: 12937207  
Integrative assessment of multiple pesticides as risk  
factors for  
non-Hodgkin's lymphoma among men.  
Sep \*2003\*

22/6/43 (Item 43 from file: 73)  
0081540797 EMBASE No: 2006604398  
In utero pesticide \*exposure\* and childhood morbidity  
January 1, 2007

22/6/44 (Item 44 from file: 76)  
0001821739 IP ACCESSION NO: 6653001  
Mechanism of \*toxicity\* of commercial \*glyphosate\* formulatons:  
How  
important is the surfactant?  
PUBLICATION DATE: \*2005\*

22/6/45 (Item 45 from file: 73)  
 0080120735 EMBASE No: 2004304381  
 Non-Hodgkin's lymphoma among asthmatics \*exposed\* to  
 pesticides  
 August 20, 2004

22/6/48 (Item 48 from file: 73)  
 0078783023 EMBASE No: 2001389406  
 Protective headgear for midwestern agriculture: A limited wear  
 study  
 November 17, 2001

22/6/49 (Item 49 from file: 73)  
 0080171096 EMBASE No: 2004353558  
 Patterns of pesticide use and their determinants among wives  
 of farmer  
 pesticide applicators in the agricultural health study  
 August 1, 2004

22/6/50 (Item 50 from file: 162)  
 0005222326 CAB Accession Number: 20073099434  
 Pesticide contamination inside farm and nonfarm homes.  
 Publication Year: 2005

22/6/51 (Item 51 from file: 73)  
 0081560810 EMBASE No: 2006624680  
 Pesticides and adult respiratory outcomes in the agricultural  
 health study  
 ISSUE TITLE: Living in a Chemical World: Framing the Future in  
 Light of the Past  
 September 1, 2006

22/6/52 (Item 52 from file: 73)  
 0082048526 EMBASE No: 2007489590  
 Pesticide \*dose\* estimates for children of Iowa farmers and  
 non-farmers  
 November 1, 2007

22/6/53 (Item 53 from file: 154)  
 15493238 PMID: 14655902  
 Pesticide use among farmers in the Amazon basin of Ecuador.  
 Apr \*2003\*

22/6/55 (Item 55 from file: 154)  
 16149335 PMID: 15724348



Pesticide patch test series for the assessment of  
allergic contact  
\*dermatitis\* among banana plantation workers in panama.  
Sep \*2004\*

22/6/56 (Item 56 from file: 154)  
26616354 PMID: 18320729  
Pesticide-related \*dermatitis\* in Saku district, Japan, 1975-  
2000.  
Jan-Mar \*2008\*

22/6/59 (Item 59 from file: 73)  
0080634359 EMBASE No: 2005278651  
\*Roundup\* revelation. Weed killer adjuvants may boost  
\*toxicity\*  
June 1, 2005

22/6/60 (Item 60 from file: 73)  
0078058968 EMBASE No: 2000108216  
\*Safety\* of working conditions of \*glyphosate\* applicators on  
Eucalyptus  
forests using knapsack and tractor powered sprayers  
April 3, 2000

22/6/61 (Item 61 from file: 73)  
0081488432 EMBASE No: 2006551722  
Suggested corrections to the farm family \*exposure\* study [2]  
November 1, 2006

22/6/62 (Item 62 from file: 10)  
4632422 43919222 Holding Library: AGL  
Time- and \*Dose\*-Dependent Effects of \*Roundup\* on \*Human\*  
Embryonic and Placental Cells  
\*2007\*  
URL: <http://dx.doi.org/10.1007/s00244-006-0154-8>

22/6/64 (Item 64 from file: 10)  
4638864 43876156 Holding Library: AGL  
\*Toxicity\* assessment of the main pesticides used in Costa  
Rica  
\*2007\*  
URL: <http://dx.doi.org/10.1016/j.agee.2006.05.010>

28/6/3 (Item 3 from file: 154)  
26532387 PMID: 18358975  
\*Acute\* pancreatitis caused by severe \*glyphosate\*  
surfactant oral

\*intoxication\*.  
Mar \*2008\*

28/6/5 (Item 5 from file: 55)  
18548217 BIOSIS NO.: 200510242717  
Agricultural pesticide-related \*poison\* in Italy: Cases reported  
to the  
\*Poisoning\* Control Center of Milan in 2000-2001  
\*2004\*

28/6/8 (Item 8 from file: 154)  
25632929 PMID: 17984146  
Alteration of estrogen-regulated gene expression in \*human\*  
cells induced  
by the agricultural and horticultural herbicide \*glyphosate\*.  
Sep \*2007\*

28/6/14 (Item 14 from file: 73)  
0081251566 EMBASE No: 2006313832  
Analysis of 8000 hospital admissions for \*acute\* \*poisoning\*  
in a rural  
area of Sri Lanka  
May 1, 2006

28/6/18 (Item 18 from file: 162)  
0004850526 CAB Accession Number: 20023045993  
Aerial herbicide impact on \*farmers\* in Ecuador.  
Publication Year: 2001

28/6/20 (Item 20 from file: 55)  
18056718 BIOSIS NO.: 200400427507  
Avoiding the penalties of \*spray\* \*drift\* with a practical look  
at \*glyphosate\*  
\*2004\*

28/6/30 (Item 30 from file: 154)  
16614216 PMID: 16190155  
Biomonitoring for \*farm\* \*families\* in the \*farm\* \*family\*  
\*exposure\* study.  
\*2005\*

28/6/33 (Item 33 from file: 154)  
14660317 PMID: 12060842  
Birth defects, season of conception, and sex of  
\*children\* born to

pesticide applicators living in the Red River Valley of  
Minnesota, USA.

Jun \*2002\*

28/6/38 (Item 38 from file: 154)

17620883 PMID: 17432331

Coca and poppy eradication in Colombia: environmental and  
\*human\* health

assessment of aerially applied \*glyphosate\*.

\*2007\*

28/6/42 (Item 42 from file: 156)

021261 NLM Doc No: CIS/05/00367 Sec. Source ID: CIS/05/00367

Chemical use among \*farmers\*

\*2004\*

28/6/43 (Item 43 from file: 154)

17573764 PMID: 17365078

Chemical \*exposure\* among NZ \*farmers\*.

Feb \*2007\*

28/6/45 (Item 45 from file: 154)

13704636 PMID: 10958131

Clinical presentations and prognostic factors of a  
\*glyphosate\*

-surfactant herbicide \*intoxication\*: a review of 131 cases.

Aug \*2000\*

28/6/46 (Item 46 from file: 55)

0019973330 BIOSIS NO.: 200800020269

Clinical outcomes after suicidal \*ingestion\* of \*glyphosate\*  
surfactant

herbicide: Severity of \*intoxication\* according to amount  
\*ingested\*

\*2007\*

28/6/48 (Item 48 from file: 154)

15525131 PMID: 14705857

Comment on "An analysis of \*glyphosate\* data from the  
California

Environmental Protection Agency Pesticide Illness Surveillance  
Program".

\*2003\*

28/6/50 (Item 50 from file: 10)

4371758 43771446 Holding Library: AGL

Comparative effects of the \*Roundup\* and \*glyphosate\* on  
mitochondrial  
oxidative phosphorylation  
\*2005\*

28/6/51 (Item 51 from file: 73)  
0081478551 EMBASE No: 2006541781  
Comparative \*genotoxicity\* of the herbicides \*Roundup\*, Stomp  
and Reglone  
in plant and mammalian test systems  
November 1, 2006

28/6/54 (Item 54 from file: 154)  
16715180 PMID: 16315092  
A comparative risk assessment of genetically engineered,  
\*mutagenic\*, and  
conventional wheat production systems.  
Dec \*2005\*

28/6/59 (Item 59 from file: 55)  
17952638 BIOSIS NO.: 200400323402  
Comparison of the effect of \*Roundup\* Ultra 360 SL pesticide and  
its active  
compound \*glyphosate\* on \*human\* erythrocytes  
\*2004\*

28/6/64 (Item 64 from file: 154)  
16192679 PMID: 15626647  
\*Cancer\* incidence among \*glyphosate\*-\*exposed\* pesticide  
applicators in  
the Agricultural Health Study.  
Jan \*2005\*

28/6/74 (Item 74 from file: 55)  
0019750321 BIOSIS NO.: 200700410062  
Cysteine turnover in \*human\* cell lines is influenced by  
\*glyphosate\*  
\*2007\*

28/6/78 (Item 78 from file: 154)  
25632485 PMID: 17882442  
Defense against \*dermal\* \*exposures\* is only \*skin\* deep:  
significantly  
increased penetration through slightly damaged \*skin\*.  
Nov \*2007\*

28/6/79 (Item 79 from file: 55)  
0019648010 BIOSIS NO.: 200700307751  
Differential effects of \*glyphosate\* and \*roundup\* in gene  
expression of \*human\* peripheral blood mononuclear cells:  
Implications for hematological \*carcinogenesis\*.  
\*2007\*

28/6/80 (Item 80 from file: 156)  
4011073 NLM Doc No: 15929894  
Differential effects of \*glyphosate\* and \*roundup\* on  
\*human\* placental  
cells and aromatase.  
Jun \*2005\*

28/6/87 (Item 87 from file: 154)  
15857617 PMID: 15240034  
Determination of \*glyphosate\* in biological fluids by 1H  
and 31P NMR spectroscopy.  
Jul 16 \*2004\*

28/6/88 (Item 88 from file: 154)  
15169562 PMID: 12731658  
Determination of the herbicide \*glyphosate\* and its  
\*metabolite\* in biological specimens by gas chromatography-  
mass spectrometry. A case of \*poisoning\* by \*roundup\* herbicide.  
Apr \*2003\*

28/6/91 (Item 91 from file: 73)  
0082318049 EMBASE No: 2008142852  
\*Dietary\* \*exposure\* to pesticide residues in Yaounde: The  
Cameroonian total diet study  
April 1, 2008

28/6/92 (Item 92 from file: 154)  
13858726 PMID: 11139167  
Development of California Public Health Goals (PHGs) for  
chemicals in drinking water.  
Sep-Oct \*2000\*

28/6/107 (Item 107 from file: 10)  
3899354 22437401 Holding Library: AGL  
Influence of paraquat, \*glyphosate\*, and cadmium on the  
activity of some  
serum enzymes and protein electrophoretic behavior (in vitro)  
\*2001\*

28/6/108 (Item 108 from file: 55)

16070131 BIOSIS NO.: 200100241970  
 Effect of pesticides and CdCl<sub>2</sub> on serum enzyme and protein  
 electrophoretic  
 behaviour (in vitro)  
 \*2000\*

28/6/109 (Item 109 from file: 162)  
 0004952937 CAB Accession Number: 20033205456  
 The effects of refining consumer \*exposure\* assessments of  
 \*glyphosate\*.  
 Book Title: The BCPC International Congress: Crop  
 Science and  
 Technology, Volumes 1 and 2. Proceedings of an international  
 congress held  
 at the SECC, Glasgow, Scotland, UK, 10-12 November 2003  
 Publication Year: 2003

28/6/110 (Item 110 from file: 10)  
 4211069 43658629 Holding Library: AGL  
 Effects of refining predicted \*chronic\* \*dietary\* intakes  
 of pesticide  
 residues: a case study using \*glyphosate\*  
 \*2004\*

28/6/119 (Item 119 from file: 154)  
 16176902 PMID: 17134388  
 Environmental and human health impacts of growing  
 genetically modified  
 herbicide-tolerant sugar beet: a life-cycle assessment.  
 Jul \*2004\*

28/6/120 (Item 120 from file: 73)  
 0079340986 EMBASE No: 2003044076  
 Epidemiologic studies of \*occupational\* pesticide \*exposure\*  
 and \*cancer\*  
 : Regulatory risk assessments and biologic plausibility  
 January 1, 2003

28/6/124 (Item 124 from file: 154)  
 17063768 PMID: 16749554  
 Can early hemodialysis affect the outcome of the  
 \*ingestion\* of  
 \*glyphosate\* herbicide?  
 \*2006\*

28/6/126 (Item 126 from file: 154)

26532351 PMID: 18358936

The early prognostic factors of \*glyphosate\*-surfactant  
\*intoxication\*.

Mar \*2008\*

28/6/127 (Item 127 from file: 73)

0078416702 EMBASE No: 2001022513

Erratum: Rapid lethal \*intoxication\* caused by the herbicide  
\*glyphosate\*

-trimesium (touchdown) (\*Human\* & Experimental \*Toxicology\* vol.  
18(12)

(2000) (735-737))

December 1, 2000

28/6/129 (Item 129 from file: 55)

0019787949 BIOSIS NO.: 200700447690

Evaluation of DNA damage in an Ecuadorian population \*exposed\*  
to \*glyphosate\*

\*2007\*

28/6/131 (Item 131 from file: 156)

3686287 NLM Doc No: 11564623

An exploratory analysis of the effect of pesticide \*exposure\*  
on the risk

of spontaneous abortion in an Ontario farm population.

Aug \*2001\*

28/6/132 (Item 132 from file: 154)

16811634 PMID: 16357597

\*Exposure\* misclassification in studies of agricultural  
pesticides:

insights from biomonitoring.

Jan \*2006\*

28/6/135 (Item 135 from file: 154)

14733906 PMID: 12148884

\*Exposure\* to pesticides as risk factor for non-Hodgkin's  
lymphoma and

hairy cell leukemia: pooled analysis of two Swedish case-control  
studies.

May \*2002\*

28/6/140 (Item 140 from file: 55)

17061934 BIOSIS NO.: 200300020653

\*Farm\* \*family\* \*exposure\* study: Biomonitoring results for  
\*glyphosate\*.

\*2002\*

28/6/142 (Item 142 from file: 55)  
17543919 BIOSIS NO.: 200300498947  
Farm \*exposure\* to pesticides and glioma in women.  
\*2003\*

28/6/150 (Item 150 from file: 154)  
15655427 PMID: 14998747  
\*Glyphosate\* biomonitoring for \*farmers\* and their families:  
results from  
the \*Farm\* \*Family\* \*Exposure\* Study.  
Mar \*2004\*

28/6/151 (Item 151 from file: 154)  
15806818 PMID: 15182708  
\*Glyphosate\*-based pesticides affect cell cycle regulation.  
Apr \*2004\*

28/6/154 (Item 154 from file: 154)  
15847227 PMID: 15228468  
Glyphosate herbicide formulation: a potentially lethal  
ingestion.  
Jun \*2004\*

28/6/155 (Item 155 from file: 55)  
19155868 BIOSIS NO.: 200600501263  
\*Glyphosate\*-induced antioxidant imbalance in HaCaT: The  
protective effect  
of vitamins C and E  
\*2006\*

28/6/157 (Item 157 from file: 156)  
3973750 NLM Doc No: 15862083  
Glyphosate \*poisoning\*.  
\*2004\*

28/6/158 (Item 158 from file: 73)  
0079472981 EMBASE No: 2003178348  
\*Glyphosate\* \*poisoning\* - A rare case of herbicide  
\*poisoning\*  
July 1, 2002

28/6/160 (Item 160 from file: 10)  
4823604 44034732 Holding Library: AGL



\*Glyphosate\*-resistant crops: adoption, use and future considerations

\*2008\*

URL: <http://dx.doi.org/10.1002/ps.1501>

28/6/162 (Item 162 from file: 55)

18724863 BIOSIS NO.: 200600070258

\*Glyphosate\* surfactant herbicide-induced \*acute\* renal failure  
\*2005\*

28/6/164 (Item 164 from file: 73)

0080873358 EMBASE No: 2005518013

GMO: \*Human\* \*health\* \*risk\* assessment

August 1, 2005

28/6/169 (Item 169 from file: 10)

4795875 44017629 Holding Library: AGL

\*Genotoxic\* Potential of \*Glyphosate\* Formulations:  
Mode-of-Action  
Investigations  
\*2008\*

URL: <http://dx.doi.org/10.1021/jf072581i>

28/6/170 (Item 170 from file: 154)

26379341 PMID: 18084044

A gene-shuffled \*glyphosate\* acetyltransferase protein  
from *Bacillus*  
*licheniformis* (GAT4601) shows no evidence of allergenicity or  
\*toxicity\*.  
Apr \*2008\*

28/6/175 (Item 175 from file: 10)

4823622 44034750 Holding Library: AGL

Herbicides, \*glyphosate\* resistance and \*acute\* mammalian  
\*toxicity\*:  
simulating an environmental effect of \*glyphosate\*-resistant  
weeds in the USA  
\*2008\*

URL: <http://dx.doi.org/10.1002/ps.1497>

28/6/180 (Item 180 from file: 73)

0078408708 EMBASE No: 2001014519

Impact of pesticides use on \*human\* health in Mexico: A review  
December 1, 2000

28/6/181 (Item 181 from file: 10)

3979215 23250194 Holding Library: AGL

Implications of \*glyphosate\* \*toxicology\* and \*human\*  
biomonitoring data  
for epidemiologic research  
\*2001\*

28/6/186 (Item 186 from file: 73)  
0081657997 EMBASE No: 2007091481  
Inferring past pesticide \*exposures\*: A matrix of individual  
active  
ingredients in \*home\* and garden pesticides used in past decades  
February 1, 2007

28/6/190 (Item 190 from file: 156)  
3850884 NLM Doc No: 12937207  
Integrative assessment of multiple pesticides as risk  
factors for  
non-Hodgkin's lymphoma among men.  
Sep \*2003\*

28/6/193 (Item 193 from file: 55)  
0019466064 BIOSIS NO.: 200700125805  
In utero pesticide \*exposure\* and childhood morbidity  
\*2007\*

28/6/194 (Item 194 from file: 154)  
13655777 PMID: 10933758  
In vitro studies of cellular and molecular developmental  
\*toxicity\* of  
adjuvants, herbicides, and fungicides commonly used in Red  
River Valley, Minnesota.  
Jul 28 \*2000\*

28/6/195 (Item 195 from file: 55)  
18581240 BIOSIS NO.: 200510275740  
In vitro evaluation of \*glyphosate\*-induced DNA damage in  
fibrosarcoma  
cells HT1080 and Chinese hamster ovary (CHO) cells.  
\*2004\*

28/6/196 (Item 196 from file: 154)  
14266614 PMID: 11569770  
Investigation of the herbicide \*glyphosate\* and the  
plant growth  
regulators chlormequat and mepiquat in cereals produced in  
Denmark.  
Oct \*2001\*

28/6/206 (Item 206 from file: 55)  
19253044 BIOSIS NO.: 200600598439  
Molecular and cellular effects of \*glyphosate\* on \*human\*  
lymphocytes:  
Implications for non-Hodgkin's lymphoma.  
\*2006\*

28/6/212 (Item 212 from file: 55)  
17262052 BIOSIS NO.: 200300220771  
Non-specific alteration of steroidogenesis in MA-10 Leydig cells  
by supra-physiological concentrations of the surfactant in  
\*Roundup\*(R) herbicide.  
\*2003\*

28/6/213 (Item 213 from file: 156)  
190707 NLM Doc No: DART/TER/4001875 Sec. Source ID:  
DART/TER/4001875  
Neural Tube Defects And Maternal Residential Proximity To  
Agricultural  
Pesticide Applications.  
\*2004\*

28/6/223 (Item 223 from file: 55)  
0020239571 BIOSIS NO.: 200800286510  
\*Occupational\* rhinitis is associated with pesticide \*exposure\*  
among  
commercial pesticide applicators in the agricultural health  
study  
\*2008\*

28/6/225 (Item 225 from file: 154)  
16192106 PMID: 15596423  
Operator \*exposure\* when applying amenity herbicides by  
all-terrain  
vehicles and controlled droplet applicators.  
Jan \*2005\*

28/6/226 (Item 226 from file: 40)  
00640398 ENVIROLINE NUMBER: 03-07730  
Organophosphorus Pesticide \*Exposure\* of Urban and  
Suburban Preschool  
\*Children\* with Organic and Conventional Diets  
Mar 03

28/6/227 (Item 227 from file: 154)  
16224136 PMID: 15683179

Oral bioavailability of \*glyphosate\*: studies using two intestinal cell lines.

Jan \*2005\*

28/6/228 (Item 228 from file: 154)

26643404 PMID: 18442254

Oxidative damage mediated by herbicides on yeast cells.

May 28 \*2008\*

28/6/235 (Item 235 from file: 154)

14119755 PMID: 11391760

Parkinsonism after glycine-derivate \*exposure\*.

May \*2001\*

28/6/237 (Item 237 from file: 55)

0019886841 BIOSIS NO.: 200700546582

Parental \*occupational\* \*exposure\* to pesticides and the risk of childhood

leukemia in Costa Rica

\*2007\*

28/6/238 (Item 238 from file: 154)

17095239 PMID: 16787817

Parenteral \*glyphosate\*-surfactant herbicide \*intoxication\*.

Jul \*2006\*

28/6/246 (Item 246 from file: 154)

16487576 PMID: 16020099

Pesticide contamination inside farm and nonfarm \*homes\*.

Jul \*2005\*

28/6/247 (Item 247 from file: 154)

25071148 PMID: 17659274

Pesticide \*dose\* estimates for \*children\* of Iowa \*farmers\* and non-\*farmers\*.

Nov \*2007\*

28/6/249 (Item 249 from file: 73)

0080532622 EMBASE No: 2005176821

Pesticides and \*human\* health: Why public health officials should support

a ban on non-essential residential use

March 1, 2005

28/6/253 (Item 253 from file: 73)

0080107139 EMBASE No: 2004291195

Pesticide \*intoxications\* in the Centre of Portugal: Three  
years analysis  
July 16, 2004

28/6/254 (Item 254 from file: 154)  
14961841 PMID: 12549246  
Pesticide use and practices in an Iowa \*farm\*  
\*family\* pesticide  
\*exposure\* study.  
Nov \*2002\*

28/6/255 (Item 255 from file: 73)  
0082286261 EMBASE No: 2008100152  
Pesticides and prostate \*cancer\*: A review of epidemiologic  
studies with  
specific agricultural \*exposure\* information  
April 1, 2008

28/6/256 (Item 256 from file: 156)  
3971471 NLM Doc No: 15724348  
Pesticide patch test series for the assessment of  
allergic contact  
\*dermatitis\* among banana plantation \*workers\* in panama.  
Sep \*2004\*

28/6/257 (Item 257 from file: 154)  
25284275 PMID: 17976274  
Pesticide regulation, utilization, and retailers' selling  
practices in  
Trinidad and Tobago, West Indies: current situation and needed  
changes.  
Aug \*2007\*

28/6/258 (Item 258 from file: 156)  
4366648 NLM Doc No: 18320729  
Pesticide-related \*dermatitis\* in Saku district, Japan, 1975-  
2000.  
Jan-Mar \*2008\*

28/6/259 (Item 259 from file: 154)  
14540961 PMID: 11896679  
Pesticide \*Roundup\* provokes cell division dysfunction at  
the level of  
CDK1/cyclin B activation.  
Mar \*2002\*

28/6/263 (Item 263 from file: 154)

26291470 PMID: 18371753

Quantitative determination of \*glyphosate\* in \*human\* serum by 1H NMR spectroscopy.

Jan 15 \*2008\*

28/6/266 (Item 266 from file: 55)

16849926 BIOSIS NO.: 200200443437

A quantitative approach for estimating \*exposure\* to pesticides in the agricultural health study

\*2002\*

28/6/277 (Item 277 from file: 154)

25260805 PMID: 17915625

\*Roundup\* \*intoxication\* and a rationale for treatment.

Sep \*2007\*

28/6/284 (Item 284 from file: 154)

13617796 PMID: 10854122

\*Safety\* evaluation and risk assessment of the herbicide \*Roundup\* and

its active ingredient, \*glyphosate\*, for \*humans\*.

Apr \*2000\*

28/6/285 (Item 285 from file: 10)

3817140 22040661 Holding Library: AGL

\*Safety\* of working conditions of \*glyphosate\* applicators on Eucalyptus

forests using knapsack and tractor powered sprayers

\*2000\*

28/6/288 (Item 288 from file: 154)

26557440 PMID: 18407393

\*Skin\* decontamination of \*glyphosate\* from \*human\* \*skin\* in vitro.

Jun \*2008\*

28/6/289 (Item 289 from file: 154)

15959003 PMID: 15362602

\*Skin\* \*toxicity\* from \*glyphosate\*-surfactant formulation.

\*2004\*

28/6/295 (Item 295 from file: 73)

0078595998 EMBASE No: 2001202299

The surveillance of agrichemical spraydrift incidents in New Zealand 1999-2000

June 29, 2001

28/6/311 (Item 311 from file: 144)

15662712 PASCAL No.: 02-0368723

The \*toxicology\* of herbicides

\*2001\*

28/6/312 (Item 312 from file: 73)

0080836676 EMBASE No: 2005481309

\*Toxicity\* tests: "inert" and active ingredients (multiple letters) [5]

October 1, 2005

28/6/313 (Item 313 from file: 55)

0019458363 BIOSIS NO.: 200700118104

\*Toxicity\* assessment of the main pesticides used in Costa Rica

\*2007\*

28/6/317 (Item 317 from file: 154)

17473895 PMID: 16984946

Urinary pesticide concentrations among \*children\*, mothers and fathers

living in farm and non-farm households in iowa.

Jan \*2007\*

28/6/319 (Item 319 from file: 154)

16190994 PMID: 15620861

Vitamins C and E reverse effect of herbicide-induced \*toxicity\* on

\*human\* epidermal cells HaCaT: a biochemometric approach.

Jan 20 \*2005\*

## Appendix M-3. Summary of Toxicology Studies

**Table M-16. Summary of Toxicology Studies Included in USDA (2003) and US EPA (1993) Reports**

| Study Type                 | Species                   | Dose Range                                                                                                                                              | Result                                                                                                                                                                                                                                             | Primary Author(s) <sup>a</sup>                                                                                                              |
|----------------------------|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Acute Toxicity</i>      |                           |                                                                                                                                                         |                                                                                                                                                                                                                                                    |                                                                                                                                             |
| Acute Dermal               | Rabbit                    | Not provided                                                                                                                                            | > 2 g/kg (Category III)                                                                                                                                                                                                                            | Birch et al., 1970 (MRID 00067039)                                                                                                          |
| Acute Oral                 | Rat                       | Not provided                                                                                                                                            | > 4,320 mg/kg (Category III)                                                                                                                                                                                                                       | Birch et al., 1970 (MRID 00067039)                                                                                                          |
| Eye Irritation             | Not provided              | Not provided                                                                                                                                            | Mild irritation, clears in 7 days (Category III)                                                                                                                                                                                                   | Blaszczak, 1988c (MRID 41400603)                                                                                                            |
| Dermal Irritation          | Not provided              | Not provided                                                                                                                                            | Slight irritation (Category IV)                                                                                                                                                                                                                    | Blaszczak, 1988d (MRID 41400604)                                                                                                            |
| Skin Sensitization         | Not provided              | Not provided                                                                                                                                            | Negative                                                                                                                                                                                                                                           | Auletta et al., 1983a (MRID 00137137), Auletta et al., 1983b (MRID 00137138), Maibach, 1982 (MRID 0013139), and Franz, 1983 (MRID 00137140) |
| <i>Subchronic Toxicity</i> |                           |                                                                                                                                                         |                                                                                                                                                                                                                                                    |                                                                                                                                             |
| 90-Day Feeding             | CD-1 Mice                 | 0, 250, 500, or 2,500 mg/kg/day                                                                                                                         | NOEL: 500 mg/kg (both sexes)<br>LOEL: 2,500 mg/kg (both sexes)<br>Systemic toxicity<br><br>Based on body weight gains                                                                                                                              | Street et al., 1980 (MRID 00036803)                                                                                                         |
| 13-Week Feeding            | Mice                      | 3,125, 6,250, 12,500, 25,000 or 50,000 ppm (Males: 507, 1,065, 2,273, 4,776 or 10,780 mg/kg/day; Females: 753, 1,411, 2,707, 5,846 or 11,977 mg/kg/day) | Decreased body weight at two highest dose levels in both sexes, increased relative heart, kidney, liver, lung, thymus, and testis weight for males, salivary gland lesions, no effects on food consumption, sperm motility or estrous cycle length | NCI, 1992                                                                                                                                   |
| 21-Day Dermal              | New Zealand White Rabbits | 10, 1,000, or 5,000 mg/kg/day                                                                                                                           | NOEL: 1,000 mg/kg/day (both sexes)<br>LOEL: 5,000 mg/kg/day (both sexes)<br><br>Based on erythema, edema, food consumption, and serum changes                                                                                                      | Johnson et al., 1982 (MRID 00098460)                                                                                                        |



| Study Type                                                                                                                    | Species                   | Dose Range                                                                                                                                            | Result                                                                                                                                                                                                                                                                                                    | Primary Author(s) <sup>a</sup>                                                  |
|-------------------------------------------------------------------------------------------------------------------------------|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| 6-Weeks, gelatin capsule administered orally                                                                                  | New Zealand Rabbits, male | 1/10 <sup>th</sup> or 1/100 <sup>th</sup> of the LD <sub>50</sub>                                                                                     | Decreased body weight, libido, ejaculate volume, sperm concentrations, semen initial fructose and semen osmolarity, increases in abnormal and dead sperm                                                                                                                                                  | Yousef et al., 1995                                                             |
| 90-Day Feeding                                                                                                                | Sprague-Dawley Rats       | 0, 1,000, 5,000, or 20,000 ppm                                                                                                                        | NOEL: < 1,000 ppm (both sexes)<br>Systemic toxicity<br><br>Based on serum changes and pancreatic lesions                                                                                                                                                                                                  | Stout and Johnson, 1987 (MRID 40559401) and Lankas et al., 1981 (MRID 00093879) |
| 13-Week Feeding                                                                                                               | Rat                       | 3,125, 6,250, 12,500, 25,000, or 50,000 ppm (Males: 205, 410, 811, 1,678, or 3,393 mg/kg/day<br>Females: 213, 421, 844, 1,690, or 3,393 or mg/kg/day) | Decreased body weight in males (20%) and females (5%) at the highest dose level, mild liver toxicity in both sexes at all time points, 20% decrease in sperm counts at two higher doses, longer estrous cycle at the highest dose, frequency of salivary gland lesions increases with dose level.         | NCI, 1992                                                                       |
| <i>Chronic Toxicity</i>                                                                                                       |                           |                                                                                                                                                       |                                                                                                                                                                                                                                                                                                           |                                                                                 |
| One-Year Feeding                                                                                                              | Beagle Dogs               | 0, 20, 100, or 500 mg/kg/day                                                                                                                          | NOEL: ≥ 500 mg/kg/day<br>Systemic toxicity                                                                                                                                                                                                                                                                | Reyna, 1985 (MRID 00153374)                                                     |
| 24-Month Feeding<br><br>*U.S. EPA 1995[FR July 7, Vol 60, No. 130] indicates that the exposure duration was 18 months, not 24 | CD Mice                   | 1,000, 5,000, or 30,000 ppm (Males: 111-250, 519-1,264 or 3,465-7,220 mg/kg/day<br>Females: 129-288, 690-1,322, or 4,232-9,859 mg/kg/day)             | NOAEL: 5,000 ppm (750 mg/kg/day)<br><br>Based on non-neoplastic chronic effects, body weights, histopathological changes and chronic interstitial necrosis, proximal tubule epithelial cell basophilia and hypertrophy of the kidneys                                                                     | U.S. EPA, 1986                                                                  |
| 2-Year Feeding (Carcinogenicity)                                                                                              | Sprague-Dawley Rats       | 0, 2,000, 8,000, or 20,000 ppm (Males: 0, 89, 362, or 940 mg/kg/day<br>Females: 0, 113, 457 or 1,183 mg/kg/day)                                       | NOEL: 8,000 ppm (both sexes), Males: 362 mg/kg/day, Females: 457 mg/kg/day<br>LOEL: 20,000 ppm (both sexes), Males: 940 mg/kg/day, Females: 1,183 mg/kg/day<br>Systemic toxicity<br><br>Based on body weight, cataracts and lens abnormalities, urinary pH, liver weight, liver weight/brain weight ratio | Stout and Ruecker, 1990 (MRID 41643801)                                         |

| Study Type                                          | Species                              | Dose Range                                                                                              | Result                                                                                                                                                                                                                                                             | Primary Author(s) <sup>a</sup>                                               |
|-----------------------------------------------------|--------------------------------------|---------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| 26-Month Feeding                                    | Sprague-Dawley Rats                  | 0, 30, 100, or 300 ppm<br>(Males: 0, 3, 10 or 31 mg/kg/day<br>Females: 0, 3, 11, or 34 mg/kg/day)       | NOEL: $\geq$ 300 ppm (both sexes);<br>Males: 31 mg/kg/day, Females: 34 mg/kg/day<br>Systemic toxicity<br><br>Based on toxic signs, mortality, body weights, food consumption, hematology, clinical chemistry, urinalysis, organ weights and organ/tissue pathology | Lankas et al., 1981 (MRID 00093879)                                          |
| <i>Carcinogenicity</i>                              |                                      |                                                                                                         |                                                                                                                                                                                                                                                                    |                                                                              |
| 18-Month Feeding                                    | CD-1 Mice                            | 0, 150, 750, or 4,500 mg/kg/day                                                                         | NOEL: 750 mg/kg/day<br>LOEL: 4,500 mg/kg/day<br><br>Not carcinogenic based on body weight, hepatocellular hypertrophy or necrosis, interstitial nephritis, proximal tubule epithelial basophilia and hypertrophy, adenomas                                         | Knezevich and Hogan, 1983 (MRID 00130406) and McConnel, 1985 (MRID 00150564) |
| 2-Year Feeding (Chronic)                            | Sprague-Dawley Rats                  | Males: 0, 89, 362, or 940 mg/kg/day<br>Females: 0, 113, 457 or 1183 mg/kg/day                           | Not carcinogenic based on incidences of adenomas                                                                                                                                                                                                                   | MRID 41648301                                                                |
| 24-Month Feeding                                    | Sprague Dawley Rats                  | 2,000, 8,000, or 20,000 ppm<br>(Males: 89, 362 or 940 mg/kg/day<br>Females: 45, 113 or 1,183 mg/kg/day) | NOAEL: 8,000 ppm<br><br>Based on body weight, cataracts and lens abnormalities, urinary tract pH, liver weight and inflammation of gastric mucosa                                                                                                                  | Stout and Ruecker, 1990                                                      |
| 26-Month Feeding (Chronic)                          | Sprague-Dawley Rats                  | Males: 0, 3, 10, or 31 mg/kg/day<br>Females: 0, 3, 11 or 34 mg/kg/day                                   | Not carcinogenic based on incidences of carcinomas and tumors                                                                                                                                                                                                      | Lankas et al., 1981 (MRID 00093879)                                          |
| <i>Developmental Toxicity</i>                       |                                      |                                                                                                         |                                                                                                                                                                                                                                                                    |                                                                              |
| Gavage on days 6-27 of gestation                    | Dutch Belted Rabbits, pregnant       | 0, 75, 175, or 350 mg/kg/day                                                                            | NOEL: $\geq$ 175 mg/kg/day                                                                                                                                                                                                                                         | Rodwell et al., 1980b (MRID 00046363)                                        |
| Gavage on days 6-19 of gestation                    | Charles River COBS CD Rats, pregnant | 0, 300, 1,000, or 3,500 mg/kg/day                                                                       | NOEL: 1,000 mg/kg/day<br>LOEL: 3,500 mg/kg/day<br><br>Based on number of litters and fetuses with uossified sternebrae and fetal body weights                                                                                                                      | Rodwell et al., 1980a (MRID 00046362)                                        |
| Continuously in diet for two successive generations | Sprague-Dawley Rats                  | 0, 100, 500, or 1,500 mg/kg/day                                                                         | NOEL: 500 mg/kg/day<br>LOEL: 1,500 mg/kg/day<br><br>Based on soft stools, food consumption, and body weight                                                                                                                                                        | Reyna, 1990 (MRID 41621501)                                                  |

| Study Type                                                           | Species                              | Dose Range                                     | Result                                                                                                                                                                                                                                                  | Primary Author(s) <sup>a</sup>                                      |
|----------------------------------------------------------------------|--------------------------------------|------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|
| Continuously in diet for three successive generations                | Sprague-Dawley Rats                  | 0, 3, 10, or 30 mg/kg/day                      | NOEL: 10 mg/kg/day<br>LOEL: 30 mg/kg/day<br><br>Based on focal tubular dilation of kidney                                                                                                                                                               | Street, 1982 (MRID 00105995)                                        |
| <i>Maternal Toxicity</i>                                             |                                      |                                                |                                                                                                                                                                                                                                                         |                                                                     |
| Gavage on days 8-20 of gestation                                     | New Zealand Rabbits                  | 0, 100, 175, or 300 mg/kg/day                  | Maternal toxicity: 175 and 300 mg/kg/day<br>Fetal toxicity: 300 mg/kg/day<br><br>Based on diarrhea, fecal output, food intake, body weight and ossification                                                                                             | Moxon, 1996b                                                        |
| Gavage on days 6-27 of gestation                                     | Dutch Belted Rabbits, pregnant       | 0, 75, 175, or 350 mg/kg/day                   | NOEL: 175 mg/kg/day<br>LOEL: 350 mg/kg/day<br><br>Based on diarrhea, nasal discharge, and death                                                                                                                                                         | Rodwell et al., 1980b (MRID 00046363)                               |
| Gavage                                                               | CD Rats                              | 0, 300, 1,000, or 3,500 mg/kg/day              | NOAEL: 1,000 mg/kg/day (fetotoxicity and maternal toxicity), 3,500 mg/kg/day (teratogenicity)<br><br>Based on breathing, activity, diarrhea, stomach hemorrhages, weight gain, physical appearance, mortality and ossification of sternebrae in fetuses | Rodwell et al., 1980a; Cited as Monsanto Co., 1980 in U.S. EPA 1986 |
| Gavage on days 6-19 of gestation                                     | CD Rats, pregnant                    | 0, 300, 1,000, or 3,500 mg/kg/day (98.7% pure) | NOEL: 1,000 mg/kg/day<br>Maternal and developmental toxicity<br><br>Based on weight gain, mortality, and fetal weights, viability and ossification of sternebrae                                                                                        | Farmer et al., 2000b                                                |
| POEA by gavage on days 6-15 of gestation                             | CD Rats, pregnant                    | 0, 15, 100, or 300 mg/kg/day                   | NOEL: 15 mg/kg/day<br><br>Based on food consumption, body weight gain                                                                                                                                                                                   | Farmer et al., 2000b                                                |
| Phosphate ester neutralized POEA by gavage on days 6-15 of gestation | CD Rats, pregnant                    | 0, 15, 50, or 150 mg/kg/day                    | NOEL: 50 mg/kg/day<br><br>Based on mortality, food consumption, body weight gain                                                                                                                                                                        | Farmer et al., 2000b                                                |
| Gavage on days 6-19 of gestation                                     | Charles River COBS CD Rats, pregnant | 0, 300, 1,000, or 3,500 mg/kg/day              | NOEL: 1,000 mg/kg/day<br>LOEL: 3,500 mg/kg/day<br><br>Based on diarrhea, body weight, breathing, activity patterns, red matter around the mouth, total implantations/dam, inviable fetuses/dam, and deaths                                              | Rodwell et al., 1980 (MRID 00046362)                                |
| Gavage on days 7-16 of gestation                                     | Wistar Rats                          | 0, 250, 500, or 1,000 mg/kg/day                | No signs of maternal or developmental toxicity                                                                                                                                                                                                          | Moxon, 1996a                                                        |
| <i>Reproductive Toxicity</i>                                         |                                      |                                                |                                                                                                                                                                                                                                                         |                                                                     |
| 60-Day Feeding                                                       | Charles River CD Rats                | 0, 3, 10, or 30 mg/kg/day                      | No effects on rat survival, body weight, consumption, mating, pregnancy, fertility and gestation length observed                                                                                                                                        | Schroeder and Hogan, 1981                                           |

| Study Type                                                                                                                        | Species                                      | Dose Range                                    | Result                                                                                                                                                            | Primary Author(s) <sup>a</sup>       |
|-----------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|
| 2-Generation Feeding                                                                                                              | Sprague-Dawley Rats                          | 0, 100, 500, or 1,500 mg/kg/day               | NOEL: 1,500 mg/kg/day (reproductive); 500 mg/kg/day (systemic)<br>LOEL: 1,500 mg/kg/day (systemic)<br><br>Based on soft stools, food consumption, and body weight | Reyna, 1990 (MRID 41621501)          |
| 3-Generation Feeding                                                                                                              | Sprague-Dawley Rats                          | 0, 3, 10, or 30 mg/kg/day                     | NOEL: ≥ 30 mg/kg/day<br>Systemic and reproductive toxicity<br><br>Based on focal tubular dilation of kidney                                                       | Street, 1982 (MRID 00105995)         |
| 3-Generation Feeding                                                                                                              | CD Rats                                      | 0, 3, 10, or 30 mg/kg/day                     | No effects on any reproductive parameters                                                                                                                         | Farmer et al., 2000a                 |
| Feeding                                                                                                                           | CD Rats                                      | 0, 2,000, 10,000, or 30,000 ppm (97.7 % pure) | NOAEL: 10,000 ppm (740 mg/kg/day) Systemic and reproductive toxicity<br>LOAEL: 30,000 ppm (2268 mg/kg/day)<br><br>Based on body weight and litter size            | Farmer et al., 2000a                 |
| <i>Mutagenicity</i>                                                                                                               |                                              |                                               |                                                                                                                                                                   |                                      |
| Allium anaphase-telophase assay, glyphosate                                                                                       | Allium                                       | 1,440 or 2,880 µg/L                           | No effect                                                                                                                                                         | Rank et al., 1993                    |
| Allium anaphase-telophase assay, Roundup                                                                                          | Allium                                       | 1,440 or 2,880 µg/L                           | Statistically significant increase in chromosome aberrations                                                                                                      | Rank et al., 1993                    |
| <i>In vitro</i> lymphocyte cultures, glyphosate                                                                                   | Bovine                                       | 17-70 µM                                      | Statistically significant increase of structural aberrations, sister chromatid exchanges, and G6PD activity                                                       | Lioi et al., 1998a                   |
| Rec-assay, with and without metabolic activation                                                                                  | <i>B. subtilis</i> H17 (rec+) and M45 (rec-) | Not provided                                  | No effect, based on increases in mutations                                                                                                                        | Shirasu et al., 1978 (MRID 00078619) |
| Gene mutation assay in a Hypoxanthine – Guanine – Phosphoribosyl Transferase (HGPRT) assay, with and without metabolic activation | Chinese hamster ovary (CHO) cells            | Not provided                                  | No mutagenic response observed up to limit of cytotoxicity                                                                                                        | Li et al., 1983a (MRID 00132681)     |
| Sex-linked recessive lethal (SLRL), Roundup                                                                                       | Drosophila larvae                            | 1 ppm                                         | High frequency of lethals in laraval spermatocytes and in spermatogonia                                                                                           | Kale et al., 1995                    |
| Sex-linked recessive lethal (SLRL), Pondmaster                                                                                    | Drosophila larvae                            | 0.1 ppm                                       | High frequency of lethals in laraval spermatocytes and in spermatogonia                                                                                           | Kale et al., 1995                    |

| Study Type                                                                        | Species                                                                                                         | Dose Range                                            | Result                                                                                                                                                      | Primary Author(s) <sup>a</sup>                                               |
|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Reverse mutation assays, with and without metabolic activation                    | <i>E. coli</i> WP2 <u>hcr</u> and <i>Salmonella typhimurium</i> strains TA98, TA100, TA1535, TA1537, and TA1538 | Not provided                                          | No effect, based on increases in mutations                                                                                                                  | Shirasu et al., 1978 (MRID 00078619)                                         |
| <i>In vitro</i> lymphocyte cultures, glyphosate                                   | Human                                                                                                           | 5.0, 8.5, 17.0, or 51.0 µM                            | Dose-related increase in the percent of aberrant cells and an increase of SCE/cell                                                                          | Lioi et al., 1998b                                                           |
| SCE in human lymphocytes <i>in vitro</i> , Roundup                                | Human                                                                                                           | 0.25, 2.5, or 25 mg/mL                                | Statistically significant increase (p<0.001) in SCE at 0.25 and 2.5 mg/mL; no lymphocyte growth at highest dose                                             | Vyse and Vigfusson, 1979; and Vigfusson and Vyse, 1980                       |
| Bone marrow micronucleus assay, Roundup                                           | Mice                                                                                                            | 133 or 200 mg/kg                                      | No clastogenicity                                                                                                                                           | Rank et al., 1993                                                            |
| Erythrocyte micronuclei (MN) assay, Roundup                                       | Mice                                                                                                            | 0.5 mL (two injections in 24 hours)                   | No MN induction                                                                                                                                             | Grisolia, 2002                                                               |
| Structural Chromosomal Aberration Assay                                           | Sprague-Dawley Rats                                                                                             | 1 g/kg (single i.p. dose)                             | No significant effects, based on clastogenic (chromosome-damaging) effect in the bone marrow cells                                                          | Li et al., 1983b (MRID 00132683)                                             |
| Gene mutation assay in an Ames Test, with and without metabolic activation        | <i>Salmonella typhimurium</i> , strains TA98, TA100, TA1535, and TA1537                                         | Not provided                                          | No response, based on increases in reverse mutations                                                                                                        | Kier et al., 1978 (MRID 00078620)                                            |
| Plate incorporation assay, presence or absence of Aroclor induced S9 mix, Roundup | <i>Salmonella typhimurium</i>                                                                                   | 360, 720, 1,081, or 1,440 µg/plate                    | Slight but significant number of revertants at 360 µg/plate for TA98 (w/o S9) and at 720 µg/plate for TA100 (w/ S9)                                         | Rank et al., 1993                                                            |
| Alkaline SCG assay (24-hour exposure), Roundup                                    | Tadpole ( <i>Rana catesbeiana</i> )                                                                             | 1.69, 6.75, or 27 mg/L                                | Significant increases in DNA damage at 6.75 mg/L (p<0.05) and 27 mg/L (p<0.001), compared with controls, no significant increase in DNA damage at 1.69 mg/L | Clements et al., 1997                                                        |
| Erythrocyte micronuclei (MN) assay, Roundup                                       | <i>Tilapia rendalli</i>                                                                                         | 50, 100, or 200 mg/kg                                 | Statistically significant induction of MN frequencies at all doses                                                                                          | Grisolia, 2002                                                               |
| Frequency of micronucleated cells, glyphosate                                     | <i>Vicia faba</i>                                                                                               | 35, 70, 105, 140, 350, 700, 1,050, or 1,400 µg/g soil | No genotoxicity                                                                                                                                             | De Marco et al., 1992                                                        |
| <b>Metabolism</b>                                                                 |                                                                                                                 |                                                       |                                                                                                                                                             |                                                                              |
| Radiolabeled <sup>14</sup> C-glyphosate administered orally                       | Sprague-Dawley Rats                                                                                             | 10 mg/kg, single or repeated                          | No significant change in metabolism, distribution or excretion, based on absorption and excretion rates                                                     | Ridley and Mirly, 1981 (MRID 40767101) and Howe et al., 1988 (MRID 40767102) |

| <b>Study Type</b>                                      | <b>Species</b>         | <b>Dose Range</b>                    | <b>Result</b>                                                                             | <b>Primary Author(s)<sup>a</sup></b>      |
|--------------------------------------------------------|------------------------|--------------------------------------|-------------------------------------------------------------------------------------------|-------------------------------------------|
| Radiolabeled<br><sup>14</sup> C-glyphosate<br>injected | Sprague-Dawley<br>Rats | 1,150 mg/kg<br>(single i.p.<br>dose) | Rapidly eliminated from bone<br>marrow and plasma, based on<br>radioactivity measurements | Ridley et al.,<br>1983 (MRID<br>00132685) |

<sup>a</sup> All of the study summaries were derived from USDA (2003) and US EPA (1993). The original primary author citations are included for the purpose of reference. In order to obtain the full citation for these studies, please refer to USDA (2003) and US EPA (1993).

## Appendix M-4. Application Rates for Herbicides Recommended for use on Glyphosate-Tolerant Alfalfa

**Table M-17. Honcho®**

| <b>Final Max AR = Max AR*Percent AI*Product Density*Mass Conversion*Volume Conversion</b> |             |                        |                 |
|-------------------------------------------------------------------------------------------|-------------|------------------------|-----------------|
| Single Application                                                                        |             |                        |                 |
| Parameter                                                                                 | Value       | Units                  | Reference       |
| Max AR                                                                                    | 2           | quarts ae/acre         | Monsanto, 2007b |
| Percent AI                                                                                | 0.41        | unitless               | Monsanto, 2007b |
| Density                                                                                   | 1.1655      | g/cm <sup>3</sup>      | Monsanto, 2007a |
| Mass conversion                                                                           | 0.002204623 | lb/g                   | Constant        |
| Volume conversion                                                                         | 946.352946  | cm <sup>3</sup> /quart | Constant        |
| Final AR                                                                                  | 1.993946622 | lb AI/acre             | Equation        |

**Table M-18. Honcho Plus®**

| <b>Final Max AR = Max AR*Percent AI*Product Density*Mass Conversion*Volume Conversion</b> |             |                        |                 |
|-------------------------------------------------------------------------------------------|-------------|------------------------|-----------------|
| Single Application                                                                        |             |                        |                 |
| Parameter                                                                                 | Value       | Units                  | Reference       |
| Max AR                                                                                    | 2           | quarts ae/acre         | Monsanto, 2007d |
| Percent AI                                                                                | 0.41        | unitless               | Monsanto, 2007d |
| Density                                                                                   | 1.1655      | g/cm <sup>3</sup>      | Monsanto, 2007c |
| Mass conversion                                                                           | 0.002204623 | lb/g                   | Constant        |
| Volume conversion                                                                         | 946.352946  | cm <sup>3</sup> /quart | Constant        |
| Final AR                                                                                  | 1.993946622 | lb AI/acre             | Equation        |

Note: The density value came from the product MSDS. There appears to be a typo on this sheet. It was assumed that the density and specific gravity values would be comparable and that the density of Honcho Plus would be comparable to the density of a similar product, Honcho.

**Table M-19. Roundup Original Max®**

| <b>Final Max AR = Max AR*Percent AI*Product Density*Mass Conversion*Volume Conversion</b> |             |            |                 |
|-------------------------------------------------------------------------------------------|-------------|------------|-----------------|
| Single Application                                                                        |             |            |                 |
| Parameter                                                                                 | Value       | Units      | Reference       |
| Max AR                                                                                    | 44          | oz ae/acre | Monsanto, 2007e |
| Percent AI                                                                                | 0.487       | unitless   | Monsanto, 2007e |
| Density                                                                                   | 1360        | kg/m3      | Monsanto, 2006  |
| Mass conversion                                                                           | 2.204622622 | lb/kg      | Constant        |
| Volume conversion                                                                         | 2.95735E-05 | m3/oz      | Constant        |
| Final AR                                                                                  | 1.900019095 | lb AI/acre | Equation        |
| <b>Specific gravity = Product density/Water density</b>                                   |             |            |                 |
| Parameter                                                                                 | Value       | Units      | Reference       |
| Specific gravity                                                                          | 1.36        | unitless   | Monsanto, 2006  |
| Water density                                                                             | 1000        | kg/m3      | Constant        |
| Product density                                                                           | 1360        | kg/m3      | Equation        |

Note: Density was not provided on label or MSDS sheet. Density was calculated using the provided specific gravity value of 1.36 using the equation Density = Mass/Volume.

**Table M-20. Roundup Ultra MaxII®**

| <b>Final Max AR = Max AR*Percent AI*Product Density*Mass Conversion*Volume Conversion</b> |             |            |                                 |
|-------------------------------------------------------------------------------------------|-------------|------------|---------------------------------|
| Single Application                                                                        |             |            |                                 |
| Parameter                                                                                 | Value       | Units      | Reference                       |
| Max AR                                                                                    | 44          | oz ae/acre | Monsanto, 2004; Monsanto, 2005c |
| Percent AI                                                                                | 0.488       | unitless   | Monsanto, 2004                  |
| Density                                                                                   | 1360        | kg/m3      | Equation                        |
| Mass conversion                                                                           | 2.204622622 | lb/kg      | Constant                        |
| Volume conversion                                                                         | 2.95735E-05 | m3/oz      | Constant                        |
| Final AR                                                                                  | 1.903920572 | lb AI/acre | Equation                        |
| <b>Specific gravity = Product density/Water density</b>                                   |             |            |                                 |
| Parameter                                                                                 | Value       | Units      | Reference                       |
| Specific gravity                                                                          | 1.36        | unitless   | Monsanto, 2003                  |
| Density of water                                                                          | 1000        | kg/m3      | Constant                        |
| Density of product                                                                        | 1360        | kg/m3      | Equation                        |

Note: Density was not provided on label or MSDS sheet. Density was calculated using the provided specific gravity value of 1.36 using the equation Density = Mass/Volume.



**Table M-21. Roundup Weather Max®**

| <b>Final Max AR = Max AR*Percent AI*Product Density*Mass Conversion*Volume Conversion</b> |             |            |                                  |
|-------------------------------------------------------------------------------------------|-------------|------------|----------------------------------|
| Single Application                                                                        |             |            |                                  |
| Parameter                                                                                 | Value       | Units      | Reference                        |
| Max AR                                                                                    | 44          | oz ae/acre | Monsanto, 2007f; Monsanto, 2005b |
| Percent AI                                                                                | 0.488       | unitless   | Monsanto, 2007f                  |
| Density                                                                                   | 1360        | kg/m3      | Monsanto, 2005a                  |
| Mass conversion                                                                           | 2.204622622 | lb/kg      | Constant                         |
| Volume conversion                                                                         | 2.95735E-05 | m3/oz      | Constant                         |
| Final AR                                                                                  | 1.903920572 | lb AI/acre | Equation                         |
| <b>Specific gravity = Product density/Water density</b>                                   |             |            |                                  |
| Parameter                                                                                 | Value       | Units      | Reference                        |
| Specific gravity                                                                          | 1.36        | unitless   | Monsanto, 2005a                  |
| Density of water                                                                          | 1000        | kg/m3      | Constant                         |
| Density of product                                                                        | 1360        | kg/m3      | Equation                         |

Note: Density was not provided on label or MSDS sheet. Density was calculated using the provided specific gravity value of 1.36 using the equation Density = Mass/Volume.



**Appendix N.      Potential Impacts to Wildlife,  
Amphibians, Plants, and Ecosystems  
from Increased Glyphosate and Other  
Chemical Usage**

# Potential Impacts to Wildlife, Amphibians, Plants, and Ecosystems from Increased Glyphosate and Other Chemical Usage

## Executive Summary

### Increased Glyphosate and Other Herbicide Use on Glyphosate-Tolerant Crops

The adoption of GT (GT) crops has caused a shift in herbicide usage; generally glyphosate usage has increased while other herbicides have declined resulting in a reduction in total herbicide usage. Several reviews concerning genetically engineered crops and herbicide use have supported this conclusion (Brimner et al., 2005; Fernandez-Cornejo, 2006; Gianessi and Reigner, 2006; Kleter et. al., 2007; Sankula, 2006; Johnson et al., 2008). However, in 2004, Charles M. Benbrook asserted that herbicide usage increased based due to the adoption of herbicide-resistant crops. The data set used to determine these trends in herbicide usage were from USDA's National Agricultural Statistics Service (NASS), which is not comprehensive and the data differs yearly as to what is reported. For example, different states report glyphosate from year to year for instance corn or soybeans. This discrepancy in reporting and data collection causes controversy over the exact amount of national use of herbicides. However, all analyses agreed that the herbicide glyphosate usage increased due to the adoption of GT crop technologies. This technical report will focus mainly on the environmental risk of glyphosate in comparison to herbicides commonly used on conventional alfalfa. GT alfalfa is cultivated almost identically to conventional alfalfa except for the use of glyphosate during post emergence.

### Herbicides Associated With Alfalfa Farming

Herbicides related to alfalfa farming can be divided into two major groups. One group includes herbicides that do not kill alfalfa (e.g., 2,4-DB, benefin, bromonoxynil, clethodim, diuron, S-ethyl dipropyl(thiocarbamate) (EPTC), hexazinone, imazamox, imazethapyr, metribuzin, norfluzon, paraquat, pronamide, sethoxydim, terbacil, and trifluralin), and are, therefore, used to control weeds in alfalfa. The other group includes herbicides that kill alfalfa (e.g., 2,4-D, dicamba, clopyralid, and picloram), so they are used for stand removal. Adoption of GT alfalfa decreases the number of herbicides used to control weeds in alfalfa because glyphosate is a preferred broad spectrum herbicide for GT alfalfa.

On the other hand, relying on glyphosate alone as the only weed removal herbicide may increase glyphosate-resistant weeds; for more information on this subject, refer to the technical reports *Effects of Glyphosate-Resistant Weeds in Agricultural Systems* (appendix G) and *Effects of Glyphosate-Resistant Weeds in Non-Agricultural Ecosystems* (appendix H). With an increase in glyphosate resistant weeds due to the adoption of GT alfalfa, there may be a corresponding increase in the use of other herbicides used for stand removal. Overall, however, herbicide shifts due to stand removal would be smaller in magnitude than herbicide shifts due to weed control.

## Glyphosate Usage and Chemical Fate in the Environment

Glyphosate is a broad spectrum herbicide. It is a systemic, post-emergence herbicide widely used on agricultural commodities (food uses) and non-agriculture sites. Glyphosate's environmental fate data is considered complete. Glyphosate absorbs directly through plant leaves and rapidly spreads throughout the plant. The use of surfactants enables greater leaf penetration. Glyphosate's mode of action is as a potent and specific inhibitor of the enzyme, 5-enolpyruvylshikimate 3-phosphate synthase (EPSPS). This enzyme is located in the shikimate pathway and is essential for the biosynthesis of aromatic amino acids and other aromatic compounds in algae, higher plants, bacteria, fungi, and apicomplexan parasites. The shikimate pathway is absent in mammals.

Glyphosate adsorbs strongly to soil and is not expected to move vertically below the six inch soil layer; residues are expected to be immobile in soil (US EPA, 1993, 2006a). Glyphosate is primarily degraded by soil microbes in the environment. The major degradate of this process is aminomethyl phosphonic acid (AMPA), which further degrades in the soil to carbon dioxide. The half-life of glyphosate in soil laboratory studies is two days (US EPA, 1993, 2006a). In agricultural soils, the disappearance time for 50% of the pesticides (DT50) of glyphosate ranges from 1.7 to 197.3 days, but is typically less than 60 days depending upon edaphic and climatic conditions (Giesy et al., 2000). Due to glyphosate and AMPA's strong adsorptive characteristics, they are not likely to leach to groundwater from the soil; however, monitoring data by USGS demonstrates low amounts of glyphosate and AMPA in groundwater, especially in heavy agricultural areas. Further discussions of environmental concentrations of glyphosate are presented below. On the other hand, glyphosate and its metabolite adsorb to soil particles that become suspended in runoff water and can potentially contaminate surface waters as a result of erosion of this soil. Once in surface water, glyphosate and AMPA are not readily broken down by water or sunlight. Bacteria and other environmental microorganisms break down both chemicals rapidly and completely (US EPA, 1993, 2006a).

## Glyphosate Occurrence in the Environment

In a USGS monitoring study of surface water, groundwater, and soil conducted from 2001 to 2006, the metabolite AMPA was observed more frequently than the parent compound glyphosate (Scribner et al., 2007). The sample collections were from several USGS studies including: the National Stream Quality Accounting Network Program, the National Water-Quality Assessment Program, and the Toxic Substances Hydrology Program. Additionally, glyphosate and its metabolite AMPA were found in surface water more frequently than groundwater. Furthermore, higher occurrences of glyphosate and AMPA in ground and surface waters were observed when samples were taken from an area with greater proximity to agricultural land with recent applications of glyphosate and a recent rain event. Glyphosate was found in rain water; however, this was due to glyphosate's association with particulate matter (dust) and not to its existence as vapor. Soil samples indicate "trace levels" glyphosate and AMPA may persist from year to year (Scribner et al., 2007); however, this is in contradiction to environmental fate and transformation data. For an in depth discussion of soil, water, and air environmental levels of

glyphosate, refer to the technical report *Effects of Changes in Farming Practices on Water, Soil and Air Due to Use of Glyphosate-Tolerant Alfalfa* (appendix J).

## Glyphosate Residue on Crops and Livestock

Studies with a variety of plants indicate that uptake of glyphosate or AMPA from soil is limited (US EPA, 2006c). For the most part, the ratio of glyphosate to AMPA is 9 to 1 but can approach 1 to 1 in some cases (e.g., soybeans and carrots). Much of the residue data for crops reflects a detectable residue of parent glyphosate (0.05 - 0.15 ppm) along with residues below the level of detection (<0.05 ppm) of AMPA (US EPA, 2006c). EPA determined that, based on toxicological considerations, AMPA need not be regulated and should be dropped from the tolerance expression (US EPA, 2006c). Metabolism studies submitted for genetically engineered GT canola and GT corn have indicated that metabolism in GT plants is essentially the same as that in normal plants (US EPA, 2006c). During a confined crop rotational study, the residues of glyphosate were undetected 30 days after treatment (US EPA, 2006c). Glyphosate is used on a large variety of crops, but only a limited number of uses generate residues in the edible parts of the crops; per Monsanto, GT alfalfa is not to be grown for human food (e.g., alfalfa sprouts). Further analysis of the human health dietary risks are discussed in the technical report, *Health and Safety Risks from Increased Glyphosate and Other Chemical Usage on Humans (Exclusive Of Field Workers)* (appendix L).

GT alfalfa is to be used as forage to many livestock. Studies with lactating goats, laying hens, rats, rabbits, and cows fed a mixture of glyphosate and AMPA indicate that the primary route of elimination is by excretion (urine and feces). The residues in eggs, milk, and livestock tissues consist of glyphosate and its metabolite, AMPA; there was no evidence of further metabolism of glyphosate or AMPA in these animals (US EPA, 2006c). Additionally the studies show that there is very little transfer of residues from feed to animal tissues and no bioaccumulation of residues occurs (US EPA, 2006c).

## Glyphosate Herbicide Usage on GT Alfalfa

Glyphosate is among the most widely used pesticides by volume in the United States and other glyphosate products are available; however, use data for GT alfalfa were only found for Monsanto products. The only products approved and that have a subsequent proposed maximum use rate for GT alfalfa are the following Monsanto glyphosate herbicide products: Honcho, Honcho Plus, Roundup Original MAX, Roundup WeatherMAX, and Roundup Ultra MAX II. Glyphosate products can be formulated to have different concentrations of glyphosate acid per gallon of product. To improve handling, performance, and concentration, the glyphosate acid is formulated as a salt compound. The term acid equivalent (a.e.) refers to the weight of the glyphosate acid, which is herbicidally active, while the term active ingredient (a.i.) is the weight of the glyphosate acid plus the salt. For the quantitative ecological Tier 1 risk assessment, the maximum use rate of 7.98 lbs a.e./acre year, with a single maximum use rate of 1.99 lb a.e./acre and a minimum reapplication rate of 7 days was used. The maximum single use rate for glyphosate on GT alfalfa is 1.55 lb a.e./acre.

## Modeled Glyphosate Residues

Exposure to aquatic species was estimated using GENEEC Version 2.1 as the Tier I simulation model. The peak concentration of glyphosate in a pond receiving runoff from a drainage basin treated 100% with glyphosate would be 15.66 µg/L (ppb) for Honcho® assuming the highest application rate. This does not exceed any Level of Concern (LOC), and longer term exposures would be lower; therefore risk is presumed to be below thresholds of concern.

Exposure to terrestrial species was estimated using Tier 1 TREX (Terrestrial Residue EXposure) simulation model (version 1.2.3) based on the maximum proposed application rate, re-application interval, and the default foliar dissipation half-life of 35 days at a rate of 1.99 lb ai/acre, applied 4 times at 30 day intervals. Residues on various terrestrial food items ranged from 61 to 968 mg/kg diet.

**Table N-1. Dietary-based Estimated Environmental Concentrations (EECs)s Upper Bound Kenaga Values from TREX model**

| <b>Food source</b>              | <b>Estimate concentration glyphosate (ppm)</b> |
|---------------------------------|------------------------------------------------|
| Short Grass                     | 968.42                                         |
| Tall Grass                      | 443.86                                         |
| Broadleaf plants/Small Insects  | 544.74                                         |
| Fruits/pods/seeds/Large insects | 60.53                                          |

These peak Estimated Environmental Concentrations (EECs) resulted in no LOC exceedences, except for the birds whose diet consists of broad leaf plants and small insects. This exceedence, however, was minor with a Risk Quotient (RQ) of 0.12; this value is slightly greater than the LOC (>0.1) for Acute Endangered Species: Endangered species may be adversely affected by use. It should be noted the EECs estimated above are based on worst case/high-end use scenario. The difference is minor and considered a minimal risk.

## Glyphosate Toxicity and Risk to the Environment

The US EPA's toxicological and ecotoxicology and fate databases on glyphosate are considered adequate and complete (US EPA, 1993; 2006a), and based on this data, glyphosate is considered to be a toxicologically and ecologically low-risk herbicide (Cerdeira and Duke, 2006). Based on the data available on glyphosate usage on GT alfalfa, chemical fate, and toxicity, and after a Tier 1 “high-end use case” scenario screening of hazard quotients, glyphosate is not expected to pose a risk to the following categories of wildlife:

- acute or chronic risk to birds
- acute or chronic risk to mammals
- acute or chronic risk to terrestrial invertebrates
- acute or chronic risk to aquatic invertebrates
- acute or chronic risk to fish

However, the use of glyphosate on GT alfalfa is expected to pose a possible risk to terrestrial and aquatic plants. Most plant species, when exposed to glyphosate, experience high levels of toxicity. Higher plants that use the shikimate pathway to produce aromatic amino acids will

experience toxic effects as they metabolize glyphosate. These toxic effects could include the inability to photosynthesize, the inability to complete respiration, and the inability to synthesize nucleic acids. Although the effects can be slow to progress, all of these toxic effects could result in plant death. Spray drift is one of the pathways of concern for non-target plants; however, if aerial applications are minimized the risk to non-target plants should be reduced. Standard toxicity studies as well as drift studies are available for several species of non-target terrestrial plants (USDA, 2003) and are presented below. AMPA, the primary degradation product of glyphosate, seems to be equally or less toxic than glyphosate; therefore, a separate risk characterization was not evaluated.

### Glyphosate Bird Toxicity

Glyphosate is practically non-toxic to birds and was not found to cause reproductive effects. Toxicity in birds was assessed using single-dose, dietary, and reproductive toxicity studies. Glyphosate acute toxicity in the Bobwhite quail was slightly toxic with the dose required to kill 50 percent of a population of test animals ( $LD_{50}$ )  $\geq 2,000$  milligrams per kilogram (mg/kg) (US EPA, 1993) or the concentration required to kill 50 percent of the test population ( $LC_{50}$ )  $> 3851$  mg a.e./kg tested as an acid (Giesy et al., 2000). Dietary studies (8-day feeding) in the Bobwhite quail and Mallard duck are considered slightly toxic for both birds  $> 4640$  mg/kg (US EPA, 1993, 2006a) and  $LC_{50} > 4640$  mg a.e./kg tested as an acid (Giesy et al., 2000). Reproductive studies did not indicate any effect after glyphosate treatment in Mallard duck or Bobwhite quail. The no observed effect concentration (NOEC) for both the mallard and Bobwhite quail was 1000 mg a.e./kg diet (US EPA, 1993, 2006a). Glyphosate tested as acid produced similar results in the Bobwhite quail and Mallard duck; studies with glyphosate tested as its isopropylamine (IPA) salt were not reported for review.

### Glyphosate Mammal Toxicity

Wild mammal toxicity testing is not required by US EPA for ecological risk assessments. In most cases, the rodent and rabbit toxicity values obtained from studies conducted to support human health risk assessments substitute for wild mammal testing. All of the acute toxicity (2,000 to 6,000 mg/kg and acute oral intraperitoneal) studies in rodents for glyphosate are slightly toxic to practically non-toxic, and a non-sensitizer. In terms of subchronic and chronic toxicity in rodents, one of the more consistent effects of exposure to glyphosate is loss of body weight. Glyphosate is a Group E carcinogen, which represents no evidence of carcinogenicity. Additionally, glyphosate is not a mutagen. Glyphosate was not found to cause reproductive or developmental effects. Glyphosate produced an acute oral  $LD_{50}$  of 5,700 mg a.e./kg/day in the goat (Giesy et al., 2000), with the product Roundup® having a  $LD_{50}$  of 4,860 mg of Roundup® product/kg/day. A robust summary of mammalian toxicity of glyphosate is provided in another technical report for this EIS entitled, *Health and Safety Risks from Increased Glyphosate and Other Chemical Usage on Humans (Exclusive of Field Workers)* (appendix M).

### Glyphosate Terrestrial Invertebrate Toxicity



Honeybees are the preferred species to assess non-target arthropod toxicity by US EPA. The LD<sub>50</sub> for glyphosate is >100 µg/honeybee (US EPA, 1993, 2006a), which is considered Practically Non-Toxic according to US EPA standards. Furthermore, formulations of glyphosate that are approved for use on GT alfalfa have LD<sub>50</sub>s that range from >100 to >326 µg/honeybee, which is also considered Practically Non-Toxic by US EPA standards (Giesy et al., 2000; Monsanto, 2005, 2006, 2007b, 2007d).

### Glyphosate Terrestrial Plant Toxicity

Glyphosate is toxic to plants. The NOEC for seed germination in both monocots and dicots is 4.5 lbs a.e./acre application rate (USDA, 2003). The highest reported NOEC for growth is 0.56 lb a.e./acre (USDA, 2003). Therefore, glyphosate is much less toxic to germinating plants than it is to the foliage of growing plants. In a vegetative vigor study (US EPA, 2006a), the most sensitive dicot was oilseed rape, displaying phototoxicity when exposed >0.038 lb a.i./A; the most sensitive monocot was winter wheat where dry weight was effects >0.049 lb a.i./A. Glyphosate was tested on 26 aquatic plant species for acute toxicity; EC<sub>50</sub> values (the concentration of a compound that produces an effect in 50 percent of the population) for glyphosate in algae are as low as 0.85 mg/L and as high as 590 mg/L (USDA, 2003). In chronic tests, the EC<sub>50</sub> for glyphosate ranged from 1.6 to 25.5 milligrams per liter (mg/L) (USDA, 2003).

### Glyphosate Soil Invertebrates and Microorganism Toxicity

Acute toxicity tests were not conducted on invertebrates and microorganisms since the life-cycles for these organisms are short. Soil microbes readily metabolize glyphosate into AMPA and other metabolites (USDA, 2003). Microorganisms produce aromatic amino acids through the shikimate pathway, similar to plants. Since glyphosate inhibits this pathway, it could be expected that glyphosate would be toxic to microorganisms. However, field studies show that glyphosate has little effect on soil microorganisms, and, in some cases, field studies have shown an increase in microbial activity (USDA, 2003).

Earthworm toxicity was evaluated over 14 days for glyphosate and for formulations of glyphosate that are approved for use on GT alfalfa. Glyphosate had a no mortality level of 3750 mg/kg soil and a NOEC of 118.7 mg kg/soil; the formulated products had LD<sub>50</sub>s ranging from > 5000 to > 10000 mg/kg dry soil (Giesy et al., 2000; Monsanto, 2005, 2006, 2007b, 2007d).

### Glyphosate Amphibian Toxicity

Glyphosate is slightly toxic to amphibians; however, some formulations of glyphosate with the surfactant polyethoxylated tallowamine POEA are very toxic to amphibians. Acute tadpole toxicity to glyphosate, measured as an LD<sub>50</sub>, ranged from > 343 to 466 mg a.e./L for the IPA salt and 78 to 180 mg a.e./L for the acid. Formulated products were more toxic in the acute tadpole tests (LC<sub>50</sub> = 8.1 to 175 mg product/L). POEA is a non-ionic surfactant used in many herbicide formulations to increase the ability of active ingredients to penetrate leaf cuticles. POEA has been found to be more toxic to amphibians and other aquatic animals than the herbicide itself (Lajmanovich, 2003). One study suggested that Roundup (in combination with POEA) could

cause high rates of mortality to amphibians (Relyea, 2005); however, the testing methods of this study have been called into question over the exposure doses exceeding application rates of glyphosate. A recent effects determination by EPA on the effect of glyphosate use on the California Red Legged Frog found no toxic effects at the maximum single application rate for glyphosate products labeled for GT alfalfa (1.55 lb/A a.e.)(<http://www.epa.gov/espp/litstatus/effects/redleg-frog/index.html#glyphosate> ).

### Glyphosate Aquatic Invertebrate Toxicity

As in amphibians and some salmonid fish, glyphosate is slightly toxic but formulations with certain surfactants are very toxic to aquatic invertebrates. Several acute and lifecycle toxicity tests have been performed and a variety of fresh water aquatic invertebrates on glyphosate and various herbicide formulations. The most sensitive species to glyphosate was *Chironomus plumosus* with a 48-hour LC<sub>50</sub> of 55 ppm (US EPA, 1993, 2006a), which is considered slightly toxic by EPA classification system. The 48-hour LC<sub>50</sub> for *Daphnia magna* ranged from 780 mg/L (tested as acid) (US EPA, 1993, 2006a) to 930 mg/L (tested as IPA salt), with a NOEC value of 560 mg/L (Giesy et al., 2000), which is considered Practically Non-Toxic according to US EPA standards. The most sensitive species to glyphosate herbicide end-use formulations was *Daphnia magna* with a 48-hour EC<sub>50</sub> of 3.0 mg/L (USDA, 2003) with orders of magnitude difference in toxicity from technical glyphosate as well. The 48-hour EC<sub>50</sub> for *Daphnia magna* ranged from 3.0 mg/L to 160 mg/L (USDA, 2003; Monsanto, 2005, 2006, 2007b, 2007d). A Maximum Allowable Toxicant Concentration (MATC) between 50 and 96 mg/L was observed for *Daphnia magna* in a flow-through study with glyphosate (US EPA, 1993, 2006a). Additionally, a flow-through study reported a 21-day NOEC of 100 mg/L (Giesey, et al., 2000), and a 21-day study identified a NOEC of 3.2 mg/L for *Daphnia magna* (Giesey, et al., 2000). In accordance with acute toxicity observations, formulations of glyphosate were more toxic to *Daphnia magna* as compared to technical glyphosate. Toxicity values (96-hour EC<sub>50</sub> or LC<sub>50</sub>) for *Gammarus pseudolimnaeus* ranged from 42 mg/L to 200 mg/L, with a NOEC value of 4.4 mg/L (Giesy et al., 2000).

### Glyphosate Fish Toxicity

A large number of studies have been performed in a variety of species of freshwater fish to determine the acute toxicity of glyphosate and glyphosate formulations approved for use on GT alfalfa. The most sensitive species to glyphosate is rainbow trout (fry), with a 96-hour LC<sub>50</sub> of 7.9 parts per million (ppm) (USDA, 2003). The 96-hour LC<sub>50</sub> for glyphosate exposure to rainbow trout ranges from 7.9 mg/L to 25,657 mg/L (USDA, 2003). This large range is most likely indicative of varying study conditions. Sockeye salmon was observed to have an 96-hour LC<sub>50</sub> ranging from 8.1 mg/L (fingerling) to 8.7 mg/L (fry), and Coho salmon was observed to have an 96-hour LC<sub>50</sub> ranging from 12.8 mg/L (fry) to 36 mg/L (glyphosate tested as acid) (USDA, 2003). Fathead minnow underwent a full life-cycle toxicity study, and the MATC was >25.7 mg/L glyphosate (US EPA, 1993). A 21-day chronic study in rainbow trout identified a NOEC of 52 mg/L (Giesy et al., 2000), whereas a study with Roundup identified a NOEC of 2.4 mg/L for rainbow trout.

Many studies have also been performed in a variety of species of freshwater fish to determine the acute toxicity of glyphosate formulations. The most sensitive species to the formulations considered was rainbow trout with a 96-hour LC<sub>50</sub> of 3.13 mg/L when treated with formulations similar to Roundup UltraMAX II and Roundup WeatherMAX (Monsanto, 2004, 2005). The 96-hour LC<sub>50</sub> for rainbow trout treated with glyphosate formulations ranged from 3.13 mg/L to 52 mg/L (Giesy et al., 2000; Monsanto, 2005, 2006, 2007b, 2007d). Sockeye salmon was observed to have a 96-hour LC<sub>50</sub> of 26.7 mg/L, and Coho salmon was observed to have a 96-hour LC<sub>50</sub> ranging from 13 ppm mg/L to 42 mg/L (Giesy et al., 2000).

### Glyphosate Marine Organism Toxicity

The saltwater and marine species tested for toxicity to glyphosate and glyphosate herbicide formulations for GT alfalfa were invertebrates. The most sensitive marine species to glyphosate was *Acartia tonsa* with a 48-hour LC<sub>50</sub> of 35.3 mg a.e./L or 49.3 mg a.e. as an IPA salt (Tsui and Chu, 2003). Additionally, a 48-hour LC<sub>50</sub> of 1.77 mg/L was determined for *Acartia tonsa* treated with the glyphosate formulation, Roundup®. Grass shrimp were reported to have a 96-hour LC<sub>50</sub> of 281 ppm (US EPA, 1993). The 48-hour level that produced toxic effects in 50 percent of the population (TL<sub>50</sub>) for Atlantic Oyster was determined to be > 10 mg/L (US EPA, 1993). The 48-hour TL<sub>50</sub> for Fiddler crab was determined to be 935 ppm (EPA, 1993).

### Other Herbicides Used on GT Alfalfa Chemical Fate in the Environment

This report was not an exhaustive examination of the chemical fate of the 20 pesticides used on GT alfalfa. Each pesticide's EPA Reregistration Eligibility Decision and MSDS were used as sources. The twenty other pesticides used on alfalfa have varying chemical fates. In general, most of these pesticides were more persistent and had higher mobility in soils, making them more apt to continually contaminate surrounding water systems. Few were even considered compounds that could bioaccumulate (e.g., clopyralid, EPTC, norflurazon, sethoxydim, and trifluralin).

### Environmental Impact of GT Alfalfa Herbicides Compared to Glyphosate

The most sensitive toxicity endpoints that were publicly available for all ecological receptors were used for the Environmental Impact Quotient (EIQ) assessment (Kovach et al., 1992 & updated annually). According to this assessment, all of the common alfalfa herbicides pose a higher risk to the environment than glyphosate, excluding EPTC. Thus with the possible replacement or decreased reliance on these pesticides with glyphosate on GT alfalfa the environmental risk is decreased. It is clear glyphosate usage trends are increasing and that it is more toxicologically and environmentally benign than the herbicides it may be replacing.

## 1.0 Introduction

### 1.1 Glyphosate-Tolerant Alfalfa Background

Alfalfa is one of the most important forage crops in the U.S. Farmers use alfalfa to feed their livestock, especially dairy cows. They grow more than 20 million acres of alfalfa across the U.S. Alfalfa is an important animal feed because of its high protein and low fiber content. Alfalfa ranks fourth on the list of most widely grown crops, behind corn, soybeans, and wheat, and it is the third most valuable crop to agriculture. Because it is widespread and typically grown as a perennial crop, alfalfa also serves as important habitat for wildlife (Hubbard, 2008).

Due to its importance, scientists have modified the genome of alfalfa to make it resistant to a herbicide. The Monsanto Company incorporated the gene sequence from a native soil microorganism, *Agrobacterium*, into the alfalfa genome to make alfalfa resistant to glyphosate, meaning it is able to survive applications of glyphosate. Glyphosate is the active ingredient in Roundup<sup>®</sup>, an herbicide produced by Monsanto. In June 2005, the U.S. Department of Agriculture approved the use of Roundup Ready<sup>®</sup> alfalfa. This glyphosate-tolerant (GT) alfalfa is the only commercially available genetically engineered alfalfa on the market. Monsanto produced GT alfalfa in partnership with the largest alfalfa seed company, Forage Genetics International. The transgene responsible for glyphosate tolerance was first introduced in soybeans in 1996, and has been commercialized in several other crops (e.g., corn, canola, and cotton). Alfalfa is the first perennial GT crop that was approved for commercial planting in the United States.

GT alfalfa will probably be used most by dairy farmers, because they often depend on pure alfalfa stands free of weeds and grasses, whereas beef cattle producers and horse owners typically feed their animals an alfalfa-grass mixed hay (Putnam, 2005). The majority of alfalfa acreage in the U.S. is planted to pure stands (40 percent), whereas a quarter is planted with grasses or another companion crop (Monsanto and Forage Genetics International, 2004).

### 1.2 Glyphosate and Other Herbicides Related to GT Alfalfa Cultivation

As mentioned above, glyphosate was first introduced as an herbicide under the trade name of Roundup by Monsanto in 1974. Before the introduction of GT crops, glyphosate was used in non-crop situations, before planting the crop, or with particular application equipment to avoid contact with the crop due to its toxicity to plants (Duke, 1988; Duke et al., 2003; Franz et al., 1997). Glyphosate is a systemic, post-emergence herbicide widely used on agricultural commodities (food uses) and non-agriculture sites. It is a very effective non-selective herbicide (Cerdeira and Duke, 2006). Glyphosate acts on various enzyme systems and inhibits amino acid metabolism in what is known as the shikimate acid pathway (Pesticide Action Network, 1996). More specifically, it is a potent and specific inhibitor of the enzyme 5-enolpyruvylshikimate 3-phosphate synthase (EPSPS) in plants. This enzyme is the sixth enzyme on the shikimate pathway and it is essential for the biosynthesis of aromatic amino acids and other aromatic compounds in algae, higher plants, bacteria, fungi, and apicomplexan parasites (US EPA, 1993, 2006a). The shikimate pathway is absent in mammals. "Glyphosate is particularly effective

because most plants metabolically degrade it very slowly or not at all, and it translocates well to metabolically active tissues such as meristems” (Cerdeira and Duke, 2006).

Essentially cultivation of GT alfalfa and conventional alfalfa are the same, except GT alfalfa has the ability to tolerate an in-crop glyphosate treatment. Herbicides related to alfalfa farming can be divided into two major groups. One group includes herbicides that do not kill alfalfa (e.g., 2,4-DB, benefin, bromoxynil, clethodim, diuron, *S*-ethyl dipropyl(thiocarbamate) (EPTC), hexazinone, imazamox, imazethapyr, metribuzin, norflurazon, paraquat, pronamide, sethoxydim, terbacil, and trifluralin), and are, therefore, used to control weeds in alfalfa. The other group includes herbicides that kill alfalfa (e.g., 2,4-D, dicamba, clopyralid, and picloram), so they are used for stand removal. It should be noted that adoption of GT alfalfa may increase use of some herbicides used for stand removal. For stand removal adoption of GT alfalfa may result in a shift from glyphosate to other herbicides. Herbicide shifts due to stand removal would be smaller in magnitude than herbicide shifts due to weeds control.

### 1.3 Herbicide Usage as Related to GT Crops

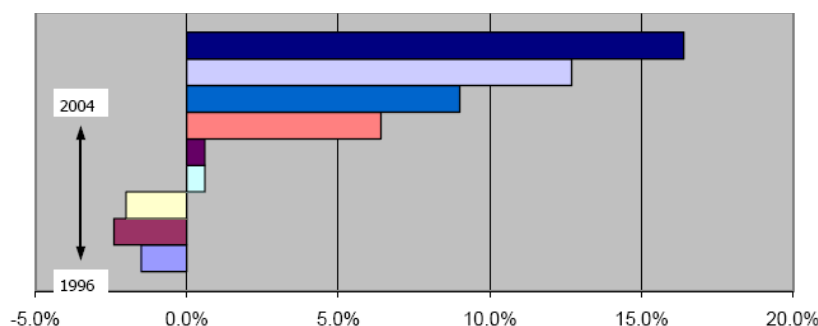
A controversy exists over whether herbicide usage has increased as a result of GT crops first adopted in 1996. A few studies have claimed that the volume of herbicide use is greater due to GT crops (Benbrook, 2004). While other studies demonstrate a decrease of overall herbicide usage related to the increased use of herbicide resistant crops, more details discussed below (Fernandez-Cornejo, 2006; Gianessi and Reigner, 2006; Sakula, 2006; Johnson et al., 2008; Hiemlich et al., 2000). Benbrook (2004) evaluated the USDA National Agricultural Statistics Service (NASS) data on genetically engineered (GE) crop acreage along with data on pesticide volumes used, from 1996 to 2004, and determined that GE corn, soybeans and cotton have led to a 138 million pound increase in herbicide use since 1996, which is a 5% increase. Benbrook (2004) attributes this increase to increasing weed resistance to glyphosate and reduction in glyphosate prices after the patent expired. Benbrook (2004) concluded that across all crops, GE crops reduced pesticide use from 1996 to 1998, but from 1999 to 2004, pesticide use increased.

The NASS data does not directly report amount of herbicide applied based on conventional versus GE varieties. NASS pesticide surveys report the percent of acres treated with a given pesticide, the average rate of application (for each distinct application), the average number of applications, the rate per crop year (average one-time rate multiplied by the number of applications), and the total pounds applied. NASS also reports total acres planted to corn, soybeans, and cotton by year and the percent of acres planted to various genetically modified crops. Using these two sources of data, Benbrook (2004), estimated herbicide use on conventional versus herbicide resistant crops using the following equation:

$$\frac{\text{Average herbicide rate (pounds per acre) for all acres of crop X} - \left[ \text{\% acres HT varieties for crop X} \times \text{Rate herbicide application (pounds per acre) on HT crop X} \right]}{\text{\% acres non-HT varieties of crop X}} = \text{Herbicide Pounds Applied per Acre of Non-HT Variety of Crop X}$$

The “rate of herbicide application in herbicide-tolerant acres” was estimated using NASS pesticide use data, coupled with information from herbicide manufacturers and universities.

At the request of Benbrook Consulting Services, USDA Economic Research Service (ERS) reported for only 1998, both the percent of total soybean acreage by category (conventional varieties, no glyphosate applied; conventional varieties, glyphosate applied (mostly on no-till acreage); Roundup Ready® varieties; and other HT varieties), as well as the average number of herbicides and pounds of herbicides applied in each category. The average acre of herbicide-tolerant soybeans in 1998 was treated with 0.07 pounds more herbicide than conventional acres. Benbrook’s (2004) summary is presented in figure N-1.



**Figure N-1: Annual percent change in pesticide use after introduction of genetically modified crops, 1996-2004 (Benbrook, 2004)**

On the other hand, others, such as Heimlich et al. (2000) have indicated there has not been a significant increase in the amount of herbicide usage since emergence of GT crops. Heimlich et al. (2000) noted that using glyphosate has resulted in the replacement of herbicides that are at least three times as toxic and persist almost twice as long as glyphosate, Gianessi and Carpenter (2000) had similar conclusions. Trewavas and Leaver (2001) conducted an analysis which revealed that 3.27 million kg of other herbicides have been replaced with 2.45 million kg of glyphosate in soybean fields in the U.S. Carpenter and Gianessi (2003) concluded that the introduction of GT soybeans has resulted in a decrease in the total volume of herbicides used. However, Gianessi’s (2005) calculations indicate that if GT sugar beets were adopted, reduction in herbicide use would not be as great as for combined GT crops, because the herbicides used now in non-transgenic sugar beets are mainly low use rate compounds in the U.S.

Gianessi and Reigner, 2006 noted that an increase in glyphosate usage coincided with a decrease in aggregate amount of herbicides by 61 million pounds (of active ingredient) between 1997 and 2002. Much of this reduction occurred in cotton and soybeans, where several herbicides were replaced by glyphosate (million lbs. reduction): bentazon (-4.4), disodium methanearsenate (DSMA) (-0.8), fluometuron (-4.5), imazethapyr (-1.0), metribuzin (-1.5), methylarsonic acid, sodium salt (MSMA) (-1.7), paraquat (-2.9), pendimethalin (-14.0), sethoxydim (-1.1), and trifluralin (-13.0). R/S Metolachlor, which accounted for 67 million pounds of herbicide use in 1997, was voluntarily withdrawn from the market prior to 2002, but S-Metolachlor replaced it on the market. Glyphosate was adopted on many soybean acres that were previously treated with metolachlor. Cyanazine was also voluntarily withdrawn from the market prior to 2002 and replaced with glyphosate for use on cotton and corn. Corn producers replaced cyanazine with

the following herbicides along with glyphosate: mesotrione, rimsulfuron, and simazine (Gianessi and Reigner, 2006).

Gianessi and Reigner (2006) used NASS data as did Benbrook (2004); however, Gianessi and Reigner (2006) supplemented the NASS data with the National Pesticide Use Database (NPUD), which is based on the following:

- Surveys by the NASS [2,631 records]
- USDA Crop Profiles/Strategic Management Plans [657 records]
- State of California Department of Pesticide Regulation [1,054 records] - The State of California requires full reporting of pesticides used in agriculture.
- Survey of Extension Service Specialists [4,830 records]
- Other Sources [538 records] - Mint Industry Research Council, Cranberry Institute, U.S. Hop Plant Protection Committee, Oregon Hop Commission, and the New England Vegetable and Berry Growers Association. Estimates for statewide aggregations for Arizona and Nevada. Individual survey reports prepared at the state-level were available for certain crops in several states: Nebraska, Washington, North Dakota, Georgia and Virginia.
- Assignments [567 records] - In cases where usage profiles for a crop in a state were Not reported from the above sources, usage estimates were assigned by assuming that a state's pesticide use profile for an active ingredient/crop combination is similar to that of a nearby state.

According to the NPUD (Gianessi and Reigner, 2006) data presented in table N-2 below, the same conclusion made by Gianessi and Reigner can be drawn; however, the data also illustrates the usage patterns of alfalfa. There is an increase in glyphosate from 1992 which predates the first GT crops used in 1996, this increase causes an overall increase on herbicides; however, when glyphosate is removed from the total herbicide used there is a 30% reduction when looking at herbicides commonly used on alfalfa. Other interesting findings are the increases in clethodim, clopyralid, and hexazinone; however, this increase does not correlate to the introduction of GT alfalfa (application rates of total herbicides on alfalfa was relatively the same from 1992, 1997, and 2002). Additionally, regardless of their increase the aggregate herbicide usage still shows a decrease.

**Table N-2. Alfalfa Herbicide Use Data (Gianessi and Reigner, 2006)**

| Herbicide                       | 1992             | 1997        | 2002        | Percent Difference<br>(1992 to 2002) |
|---------------------------------|------------------|-------------|-------------|--------------------------------------|
|                                 | Lbs a.i. applied |             |             |                                      |
| Glyphosate                      | 16,793,371       | 34,817,639  | 102,325,419 | +509                                 |
| 2,4-D                           | 41,938,491       | 40,589,955  | 40,071,957  | -4                                   |
| 2,4-DB                          | 980,980          | 603,975     | 522,486     | -47                                  |
| Benefin                         | 478,205          | 161,983     | 104,880     | -78                                  |
| Bromoxynil                      | 3,444,727        | 2,920,222   | 2,058,153   | -40                                  |
| Clethodim                       | 80,003           | 670,721     | 619,944     | +675                                 |
| Clopyralid                      | 89,112           | 891,662     | 956,046     | +973                                 |
| Dicamba                         | 9,064,161        | 10,447,441  | 7,558,786   | -17                                  |
| Diuron                          | 3,994,531        | 4,370,448   | 3,580,627   | -10                                  |
| EPTC                            | 14,457,278       | 8,791,984   | 5,593,753   | -61                                  |
| Hexazinone                      | 460,058          | 332,116     | 623,344     | +35                                  |
| Imazamox                        | -                | -           | 86,662      | Not Determined                       |
| Imazethapyr                     | 914,090          | 1,253,046   | 343,422     | -62                                  |
| Metribuzin                      | 3,440,715        | 3,320,231   | 1,802,371   | -48                                  |
| Norfluzon                       | 2,670,328        | 2,459,703   | 1,198,022   | -55                                  |
| Paraquat                        | 4,658,597        | 6,884,630   | 3,997,753   | -14                                  |
| Picloram                        | 2,042,016        | 1,322,430   | 1,915,653   | -6                                   |
| Pronamide                       | 239,773          | 206,779     | 212,166     | -12                                  |
| Sethoxydim                      | 1,350,566        | 1,717,271   | 638,796     | -53                                  |
| Terbacil                        | 298,026          | 342,277     | 243,730     | -18                                  |
| Trifluralin                     | 25,686,076       | 22,263,693  | 8,985,861   | -65                                  |
| Total                           | 133,081,104      | 144,368,206 | 183,439,831 | +37                                  |
| Total excluding Glyphosate      | 116,287,733      | 109,550,567 | 81,114,412  | -30                                  |
| Total Herbicide Used on Alfalfa | 4,921,532        | 3,960,058   | 4,325,029   | -12                                  |

NASS data was independently evaluated for this technical report for the purpose of examining herbicide use trends in glyphosate-tolerant crops (corn, cotton, soybeans and wheat) since 1996. Glyphosate usage in these crops was also examined. The data is inconsistent across crops and years, but a general trend of increased glyphosate usage can be seen (See figures N-2 and N-3), while a general decrease in other herbicide use can be seen for three other herbicides common to alfalfa (See figures N-4, N-5, and N-6). The exact trend depends on crop and herbicide, as well as weather but overall a decrease in other herbicide use on alfalfa and reported crops can be seen. The actual pounds of glyphosate applied per crop are listed in table N-3, with the percent increase given.



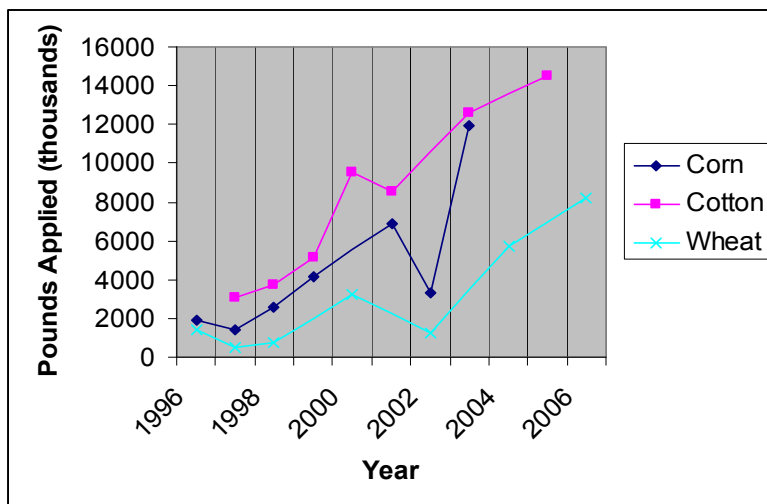


Figure N-2: Glyphosate use in corn, cotton, and wheat, 1996-2006

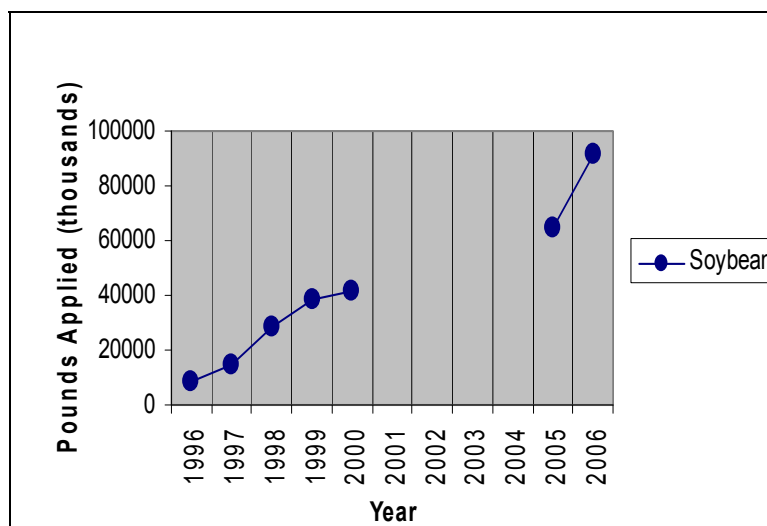


Figure N-3: Glyphosate use in soybeans, 1996-2006

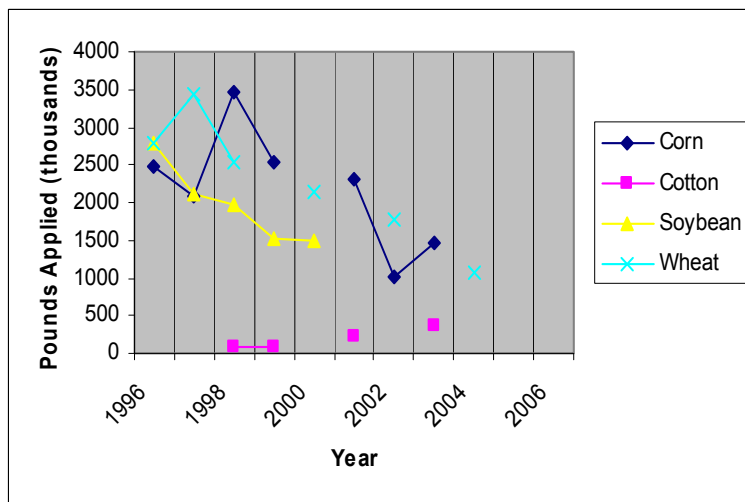
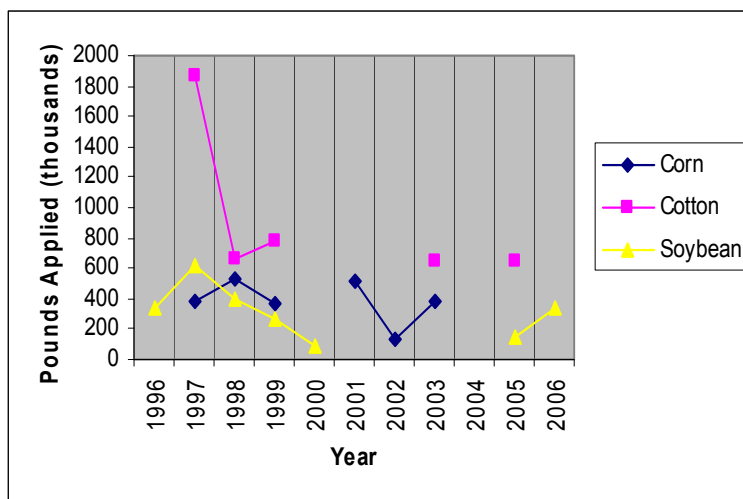
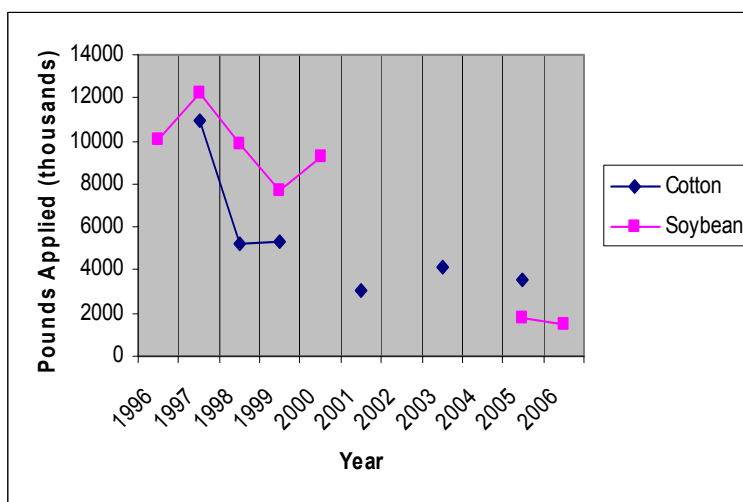


Figure N-4: 2,4-D Use in corn, cotton, soybeans and wheat, 1996-2006



**Figure N-5: Paraquat use in corn, cotton and soybeans, 1996-2006**

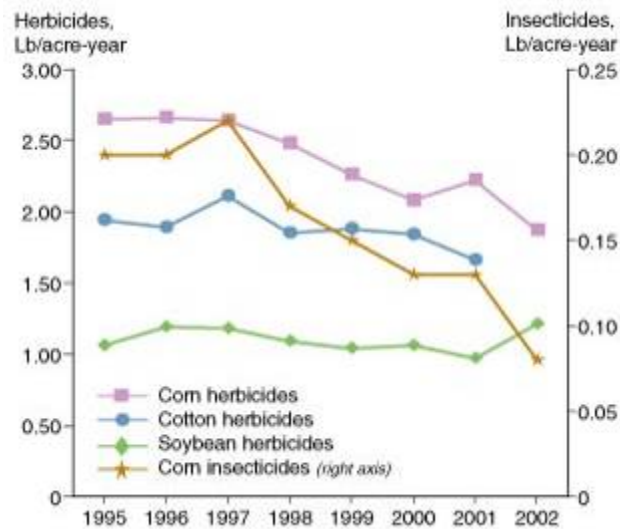


**Figure N-6: Trifluralin use in cotton and soybeans, 1996-2006**

**Table N-3. Glyphosate Use in Corn, Cotton, Soybeans, and Wheat, 1996-2006**

| Crop    | Thousand Pounds Applied (Year) |               | Percent Difference (%) | Thousand Pound Difference |
|---------|--------------------------------|---------------|------------------------|---------------------------|
| Corn    | 1,878 (1996)                   | 11,913 (2003) | 634                    | 10,035                    |
| Cotton  | 3,045 (1997)                   | 14,540 (2005) | 478                    | 11,495                    |
| Soybean | 8,687 (1996)                   | 91,640 (2006) | 1,055                  | 82,953                    |
| Wheat   | 1,421 (1996)                   | 8,215 (2006)  | 578                    | 6,794                     |

Overall, herbicide use in the United States shows a downward trend between 1995 and 2002, especially in corn (Fernandez-Cornejo, 2006). Figure N-7 from the USDA ERS Agricultural Resources and Environmental Indicators (AREI) report presents herbicide application rates in corn, cotton, and soybean from 1995 to 2002.



**Figure N-7: Pesticide use in major field crops (Fernandez-Cornejo, 2006)**

Sankula (2006) evaluated the impact of biotechnology-derived crops planted in the United States in 2005. A summary of the herbicide analysis follows:

- Herbicide-tolerant canola used less herbicide active ingredient per acre than conventional canola, which represented a reduction of 0.69 million pounds of herbicide use in 2005.
- Herbicide-tolerant corn reduced herbicide use in corn by 21.8 million pounds in 2005, which corresponds to a grower cost savings of \$269 million. Compared to 2004, grower returns were 94% higher and pesticide use was 18% lower due to a 67% increase in the adoption of herbicide resistant corn (due to EU approvals).
- Herbicide-tolerant cotton reduced pesticide use by 18 million pounds and reduced production costs by \$39 million.
- On average GT soybean programs used 1.03 pounds active ingredient per acre (lbs a.i./A) whereas conventional herbicide programs used an additional 0.32 lb a.i./A. This translates to a reduction of 39.4 million pounds of herbicide and a cost savings of \$134 million.

Johnson et al. (2008) evaluated the NASS database and concluded that herbicide use in 2006 was reduced by 100.5 million pounds of active ingredient based on estimates of biotechnology-derived crop replacement of conventional crops.

No calculations or speculation on GT alfalfa's impact on herbicide usage have been published. In 2005, when GT alfalfa was introduced commercially, only 0.2% of the total harvested alfalfa was GT alfalfa. In 2006, 3 million pounds of seed was made available for planting. Without reliable estimations on the market share of GT alfalfa estimating the increase in herbicides and glyphosate residue on the following assumptions:

- 90% of alfalfa acreage (Based on Sankula, 2006 using highest adoption herbicide-resistant crops, whereas, 88% national acreage of soybeans are herbicide-resistant)

- Annual USDA Crop Report 2007's alfalfa national acreage of 21,670,000 (USDA, 2008)
- Highest application of glyphosate allowed per year on GT crops of 7.32 pounds (see section 2.1 for details)

Therefore if the highest end application rate is used on the 19,503,000 acres glyphosate's highest estimation of usage would be 142,761,960 pounds. However 143 million pounds of glyphosate is an estimation of the potential amount of glyphosate due to adoption of GT alfalfa. As stated previously only 0.2% of the total harvest in 2005 was GT; however, glyphosate usage was not recorded. Glyphosate usage on GT crops would be dependant on the weather conditions, weed profile, and various other uncontrolled factors. This report will try to predict the environmental risks of the potential increase in glyphosate as well as comparing the risks of the 20 other herbicides used on alfalfa.

#### 1.4 Glyphosate Resistant Weeds Due to GT Alfalfa Cultivation

Weeds can develop resistance to herbicides for the following reasons: frequent exposure to a particular herbicide, the spread of naturally resistant weed seeds, and the outcrossing of herbicide-tolerant genes from genetically altered plants to weedy relatives. Certain weeds have become resistant to the herbicide glyphosate. Further details on glyphosate resistant weeds; refer to technical reports *Effects of Glyphosate-Resistant Weeds in Agricultural Systems* (appendix G) and *Effects of Glyphosate-Resistant Weeds in Non-Agricultural Ecosystems* (appendix H).

Although more recent figures are not reported, in 1998, a University of Wisconsin weed control specialist reported that herbicides are applied to less than 17 percent of U.S. alfalfa hay acreage (Wilke, 1998). Providing the option of spraying herbicides directly over alfalfa is likely to increase the amount of chemicals used in alfalfa production. In fact, the National Center for Food and Agriculture Policy estimates that GT alfalfa could result in the application of 200,000 pounds more herbicides per year in California alone (Hubbard, 2008).

Proper crop and weed management practices should be followed and the risk of glyphosate resistant weed development. Increased exposure to one herbicide, namely glyphosate, may cause a shift in glyphosate resistant weeds, and potential for weeds developing glyphosate resistance. Diversifying weed control tactics can delay herbicide resistance development and aid in controlling herbicide-resistant weeds, thus, preserving the herbicide efficacy. Using differing mode of action herbicides will decrease the chance of plants developing resistance to a single herbicide. GT crops should be rotated with non-GT crops to reduce the heavy reliance on glyphosate, thus, decreasing the risk of weeds developing resistance to glyphosate. Where no-till practices are in use, heavy tillage is another mitigation method to eradicate a glyphosate resistant weed. The Herbicide Resistance Action Committee (HRAC) is a consortium of agrochemical manufacturers that provides information about resistance cases and strategies for management (HRAC, 2002). US EPA and the Pest Management Regulatory Agency of Canada (PMRA) have worked closely with the HRAC and the Weed Science Society of America (WSSA) to address herbicide resistance. US EPA and Canada have developed voluntary resistance management guidelines based on rotation of herbicides based on mode of action for all agricultural use of pesticides (Canada PMRA 1999; US EPA 2001).

In the event of glyphosate resistant weeds, the management practices suggested are to use the following less-resistant prone herbicides recommended for use: paraquat/diquat, MSMA, phenoxy herbicide (e.g., 2,4-D, MCPA, trichlopyr, dicamba), tubulin inhibitors (e.g., benefin, fluchloralin, pendimethalin, ethanlfluralin, trifluralin), triazine (amitrole, atrazine, cyanazine, simazine, trietazine, metribuzin), bromoxynil, s-ethyl dipropylthiocarbamate (EPTC), imazamox, imazethapyr, sethoxydim, clethodim, glufosinate, and/or rare protox herbicides (acifluorfen). A list of glyphosate-tolerant weeds and suggested herbicides are presented in appendix N-4 of this technical report; however, the list is not exhaustive due to new weeds being registered or discovered regularly. These herbicides are more toxic and persistent in the environment, thus, they may exert a greater environmental impact; however, weed management is plant specific. In some cases of a multiple herbicide resistance, the preferred weed management practice is deep tillage. Currently, glyphosate resistant weeds have taken over two million acres of farmland in the U.S. (Hubbard, 2008). The spread of glyphosate resistant weeds has outpaced the development of new tools for controlling them, leaving farmers with few options for dealing with thousands of acres of “superweeds” that glyphosate cannot eliminate. Some of the resistant weeds also produce copious amounts of seeds, which can lay dormant in the soil for many years and germinate later on down the road, further compounding the problem of glyphosate resistant weeds and complicating the containment efforts by farmers. The most problematic glyphosate resistant weeds in the U.S. include pigweed (waterhemp), horseweed (marestail), common and giant ragweed, and ryegrass (Hubbard, 2008).

## 1.5 Methodology

In efforts to assess the potential impacts to wildlife, amphibians, plants, and ecosystems from increased glyphosate and other chemical usage due to the deregulation of GT alfalfa by USDA in 2005, a Tier 1 ecological risk assessment was conducted for glyphosate usage on GT alfalfa. In the preparation of this risk assessment, literature searches of glyphosate were conducted in the open literature using the literature search strategy presented in appendix N-2 of this technical report. Several DIALOG databases were searched. EPA’s Ecotox Database was searched for data on glyphosate (<http://cfpub.epa.gov/ecotox/>); the data tables generated are considerably large; therefore, the data were mined for missing toxicity data when needed and referenced in the toxicity tables as needed. Google and Google Scholar search engines supplemented the DIALOG search. References were selected from the extensive list of literature based on requesting the abstracts and determining if the data were not included in the four below ecological risk assessments or provided contrary or controversial information to these four highly reviewed ecological risk assessments. Primary sources of data were obtained from the following three documents: the US EPA’s 1993 Reregistration Eligibility Decision (RED) document on glyphosate (US EPA, 1993); the US EPA’s 2006 Glyphosate New Use (bent-grass): Environmental Fate and Effects Risk Assessment (US EPA, 2006a), the US EPA’s Glyphosate Human Health Risk Assessment for Proposed Use on Indian Mulberry and Amended Use on Pea, Dry. (US EPA, 2006c); the USDA, Forest Service 2003 human health and ecological risk assessment on glyphosate (USDA, 2003); and an ecotoxicological risk assessment for Roundup herbicide by John P Giesy and colleagues in 2000 (Giesy et al., 2000). Additional information was used from a risk assessment on the use of glyphosate by Monsanto (Honegger et al., 2008 ; Mortensen et al., 2008, Priester et al. 2007, 2008)

This ecological risk assessment presented is not a comprehensive summary of all of the available information and does not cite all of the available literature. As USDA determined in 2003, an all inclusive and detailed review of each ecotoxicological study would tend to obscure rather than inform. Therefore this document relies on the information that is likely to impact the risk assessment.

The application rate of glyphosate on GT alfalfa was determined by reviewing all the glyphosate herbicide formulations that report the maximum daily and yearly use rate on GT alfalfa. These formulations are all Monsanto Company products, as GT alfalfa is also a Monsanto product. It can be expected that other formulations for glyphosate herbicide could and may be used on GT alfalfa; however, to develop the quantitative risk assessment the maximum use rate was 1.99 lb a.e./acre for a single use, with minimum reapplication within 7 days and not to exceed 7.98 lb a.e./acre in a year. The legal maximum single use rate for glyphosate on GT alfalfa is 1.55 lb a.e./acre, with minimum reapplication within 7 days and not to exceed 5.96 lb a.e./acre in a year. Thus, the risk assessment conducted is a particularly conservative one.

## 2.0 Chemical Description and Commercial Formulations Glyphosate Herbicide

Glyphosate is a substituted glycine, the simplest amino acid. The glyphosate molecule has a methylphosphono group bonded to the nitrogen atom of the amino group of glycine as denoted in figure N-8 below.

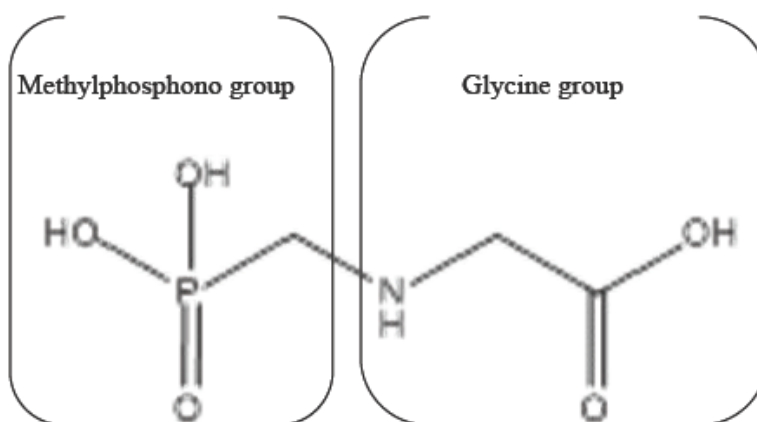


Figure N-8: Glyphosate molecular structure

Physical and chemical properties of glyphosate are in table N-4 below.

Table N-4. Physical and Chemical Properties of Glyphosate

| Property                                      | Value                                                                                    | Source       |
|-----------------------------------------------|------------------------------------------------------------------------------------------|--------------|
| Common Name                                   | Glyphosate                                                                               | US EPA, 1993 |
| Chemical Name                                 | <i>N</i> -(phosphonomethyl)glycine                                                       | US EPA, 1993 |
| Chemical Abstract Registry Number (CAS)       | 1071-83-6                                                                                | US EPA, 1993 |
| Smiles notation                               | OC(=O)CNCP(O)(O)=O                                                                       | EPI Suite    |
| PC Code                                       | 417300                                                                                   | US EPA, 1993 |
| Molecular Weight g                            | 169.07                                                                                   | USDA, 2003   |
| Density at 25°C                               | 1.7                                                                                      | US EPA, 1993 |
| Solubility in water at 25°C                   | 12,000 mg/L                                                                              | US EPA, 1993 |
| pKa                                           | 0.8 first phosphonic acid<br>2.3 carboxylate<br>6.0 second phosphonic acid<br>11.0 amine |              |
| Vapor Pressure at 25°C, Pa                    | $1.3 \times 10^{-7}$                                                                     | US EPA, 1993 |
| Henry's Law Constant (Pa m <sup>3</sup> /mol) | $2.1 \times 10^{-9}$                                                                     | US EPA, 1993 |

Glyphosate salts serve as the source of *N*-(phosphonomethyl)glycine. Several salts of glyphosate with different counter cations are currently marketed. Each salt has a different “glyphosate equivalent”, which is defined as the ratio of the molecular weight of *N*-(phosphonomethyl)glycine to the molecular weight of the salt. GT alfalfa has the following approved glyphosate herbicides approved for use in table N-5. GT alfalfa could tolerate other herbicide formulations with glyphosate; however, the five products listed below are the herbicides approved for use on GT alfalfa.

**Table N-5. End Use Products Approved for Use on GT Alfalfa**

| <b>Product Name</b>   | <b>% Salt</b> | <b>Glyphosate salt CAS No.</b>    | <b>USEPA PC Code</b> | <b>Surfactant</b>                                    | <b>Manufacture</b> |
|-----------------------|---------------|-----------------------------------|----------------------|------------------------------------------------------|--------------------|
| Honcho®               | 41            | Isopropylamine<br>CAS: 38641-94-0 | 103601               | Alkyl Tallow<br>Ethoxylated Amines<br>CAS 61791-26-2 | Monsanto, 2007a    |
| Honcho Plus®          | 41            | Isopropylamine<br>CAS: 38641-94-0 | 103601               | Trade Secret                                         | Monsanto, 2007c    |
| Roundup Original MAX® | 48.7          | Potassium<br>CAS: 70901-12-1      | 103613               | Trade Secret                                         | Monsanto, 2007e    |
| Roundup WeatherMAX®   | 48.8          | Potassium<br>CAS: 70901-12-1      | 103613               | Trade Secret                                         | Monsanto, 2007f    |
| Roundup Ultra MAX II® | 48.8          | Potassium<br>CAS: 70901-12-1      | 103613               | Trade Secret                                         | Monsanto, 2004     |

## 2.1 Application Rate Specific to GT Alfalfa

The Honcho and Honcho Plus products contain 41% of the isopropylamine salt of glyphosate, equivalent to 3 lbs of glyphosate equivalents per gallon (356 g glyphosate/L). The product is to be applied as over-the-top (spot treatment; broadcast ground application) for pre-plant, preemergence, and post-emergence uses. For the risk assessment, the maximum total application rate of 7.98 glyphosate equivalents per acre per year (2.6 gal of product per acre), with single use maximum applications of 1.99 lbs glyphosate a.e./acre. The minimum reapplication interval is 7 days. The maximum label rate for a single application of glyphosate to GT alfalfa is 1.55 lbs glyphosate a.e./acre, and the maximum total application rate for the year is 5.96 lbs glyphosate a.e./acre.

The Roundup Ready Original MAX®, Roundup WeatherMAX®, and Roundup Ultra MAX II® products contain 48.8% of the phosphate salt of glyphosate, equivalent to 4.5 lbs of glyphosate equivalents per gallon (540 g glyphosate/L). The product is to be applied over-the-top (spot treatment; broadcast ground application) for pre-plant, preemergence, and post-emergence uses. The maximum total application rate is 7.32 glyphosate equivalents per acre per year (2.4 gal of product per acre), with a single use maximum application of 1.90 lbs glyphosate/acre. The minimum reapplication interval is 7 days. The maximum label rate for a single application of glyphosate to GT alfalfa is 1.55 lbs glyphosate a.e./acre, and the maximum total application rate for the year is 5.96 lbs glyphosate a.e./acre.

## 2.2 Residue of Glyphosate on Crops and Livestock

Studies with a variety of plants indicate that uptake of glyphosate or AMPA from soil is limited. Foliar-applied glyphosate is readily absorbed and translocated throughout the trees or vines to the fruit of apples, coffee, dwarf citrus (calamondin), pears and grapes (US EPA, 2006c). For the most part, the ratio of glyphosate to AMPA is 9 to 1 but can approach 1 to 1 in a few cases (e.g., soybeans and carrots). Much of the residue data for crops reflects a detectable residue of parent glyphosate (0.05 - 0.15 ppm) along with residues below the level of detection (<0.05 ppm) of AMPA (US EPA, 2006c). EPA determined that, based on toxicological considerations, AMPA need not be regulated and should be dropped from the tolerance expression (US EPA, 2006c). Metabolism studies submitted for genetically engineered GT canola and GT corn have



indicated that metabolism in GT plants is essentially the same as that in normal plants (US EPA, 2006c). During a confined crop rotational study the residues of glyphosate were undetected 30 days after treatment (US EPA, 2006c).

Studies with lactating goats, laying hens, rats, rabbits, and cows fed a mixture of glyphosate and AMPA indicate that the primary route of elimination is by excretion (urine and feces). The residues in eggs, milk, and livestock tissues are glyphosate and its metabolite AMPA; there was no evidence of further metabolism in these animals (US EPA, 2006c).

## 2.3 Summary of Findings

At ambient temperatures, glyphosate is a white crystalline substance that is not volatile with high water solubility. In the crystalline form, glyphosate has both positive and negative regions, these dipolar ion species are sometimes referred to as a zwitterion. In aqueous solutions, the hydrogen atoms of the carboxylic acid (COOH) and phosphate (PO<sub>2</sub>H<sub>2</sub>) groups may be associated or dissociated depending on the pH of the solution. These dipolar ion species are the regions expected to bond to carbon containing molecules in the soil as discussed further in Chapter 3. Glyphosate is in a liquid form for herbicide formulations; generally, the composition of the herbicide is considered a trade secret. One formulation of glyphosate, Honcho®, has a tallow amine surfactant (Monsanto, 2007a). This and other surfactants are added to the herbicide formulations to increase leaf penetration. The maximum single use application of 1.99 lbs glyphosate/acre was based on Honcho and Honcho Plus products containing 41% of the isopropylamine salt of glyphosate, equivalent to 3 lbs of glyphosate equivalents per gallon (356 g glyphosate/L). This application rate and a minimum reapplication period of 7 days was used to estimate high-end use on GT alfalfa in efforts to quantify the risk to ecological organisms.

### 3.0 Glyphosate and Alfalfa Herbicide Fate in the Environment and Occurrence

#### 3.1 Glyphosate Fate

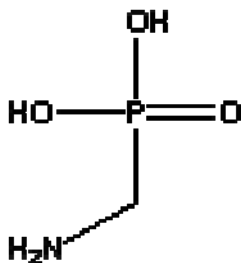
The environmental fate assessment is based on the US EPA's 1993 RED document on glyphosate (US EPA, 1993); the US EPA's 2006 Glyphosate New Use (bent-grass): Environmental Fate and Effects Risk Assessment, USDA, Forest Service 2003 human health and ecological risk assessment on glyphosate (USDA, 2003); an ecotoxicological risk assessment for Roundup herbicide by John P Giesy and colleagues in 2000 (Giesy et al., 2000), and recent relevant open literature studies related to the behavior of glyphosate in the environment.

Glyphosate has a low vapor pressure and Henry's law constant; thus, it has a low potential to volatilize from soil and water. Glyphosate is hydrophilic, with a low *n*-octanol-water partition coefficient; therefore, it has low potential to bioaccumulate in animals. It has a high solubility in water and does not undergo hydrolysis or photolysis. Due to glyphosate's strong adsorptive quality to soil, it is not expected to contaminate groundwater; however, runoff water could contain particulates with adsorbed glyphosate. The chemical fate properties of glyphosate are presented in table N-6 below.

**Table N-6. Chemical Fate Properties of Glyphosate**

| Property                                                                          | Value                                                                                                                     | Source              |
|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|---------------------|
| Common Name                                                                       | Glyphosate                                                                                                                | US EPA, 2006a, 1993 |
| Chemical Name                                                                     | <i>N</i> -(phosphonomethyl)glycine                                                                                        |                     |
| Log Kow                                                                           | -3                                                                                                                        |                     |
| Hydrolysis                                                                        | Stable ≥30 days at pH 3, 6, and 9 at 5 and 35°C                                                                           |                     |
| Photolysis                                                                        | Does not absorb light energy pH 5, 7, and 9                                                                               |                     |
| Metabolism in soil, half life                                                     | 1.85 – 2.06 day                                                                                                           |                     |
| Metabolism water-sediment system, half life                                       | Aerobic: 7 days<br>Anaerobic: 8.1 – 199 days                                                                              |                     |
| Soil Mobility, $K_{ads}$ , Freundlich                                             | 9.4 – 700 mL/g                                                                                                            | USDA, 2003          |
| Soil water partition coefficient $K_d$ (adsorption)                               | 62 Drummer silty clay loam<br>90 Ray silt<br>70 Spinks sandy loam<br>22 Lintonia sandy loam<br>175 Cattail swamp sediment |                     |
| Soil adsorption $K_{oc}$                                                          | 2100 (500 – 2600) (L/kg)<br>2600 – 4900 (L/kg)<br>8 to >500,000 (L/kg)<br>54 (L/kg)                                       |                     |
| Metabolite                                                                        | aminomethyl phosphonic acid (AMPA)                                                                                        |                     |
| Field dissipation (application rate: 7.95 lb ae/acre, 10.7 lb ai/acre), half life | 13.9 days (median)<br>2.6 days in Texas<br>140.6 days Iowa                                                                | US EPA, 2006a, 1993 |
| Aquatic field dissipation, half life                                              | 7.5 days and 120 days                                                                                                     |                     |
| Bioaccumulation in fish                                                           | 0.38X edible tissue<br>0.63X nonedible tissue<br>0.52X whole fish                                                         |                     |

In soil, sediment, or natural water, microbes degrade glyphosate quickly and the major metabolite is aminomethyl phosphonic acid (AMPA) which is further degraded to CO<sub>2</sub>, although at a slower rate than the parent glyphosate (US EPA, 2006a, 1993). Figure N-9 presents the chemical structure of AMPA.



**Figure N-9: Chemical structure of AMPA**

In the environmentally significant pH range of 5 to 9, the first phosphonic and carboxylate protons are fully dissociated. The dissociation of the second phosphonic proton increases above a pH of 6, but the amine proton is unlikely to dissociate in the environment.

The molecule of glyphosate can be envisioned as a ligand that binds via the oxygen atoms. These molecular characteristics of glyphosate have major implications in its mode of herbicide action and in the sorption behavior of glyphosate on soils.

In field studies (including soils) conducted in the coldest climates (i.e., Minnesota, New York and Iowa) were the longest and ranged from about 29 days up to about 140 days, indicating that glyphosate residues in the field are somewhat more persistent in cooler climates as opposed to milder ones (Georgia, California, Arizona, Ohio, and Texas). Also, glyphosate was shown to remain predominantly in the 0-6 inch soil layer at all field sites in one study.

### 3.2 Alfalfa Other Herbicide Comparative Fate Data

Sixteen herbicides are used on alfalfa and four are used to remove GT alfalfa fields. Table N-7 below has compiled environmental fate data on these twenty herbicides for the herbicides respective EPA RED documents, MSDSs, or PAN Pesticides Database. In general most of the 20 herbicides as compared to glyphosate are more persistent in the soil and more apt to bioaccumulate. In section 5.2 a comparison of the environmental impact of these herbicides via an indicator known as the Environmental Impact Quotient (EIQ) is made.

#### 3.2.1 Hydrolysis Alfalfa Herbicide Comparison Data

Most herbicides (2,4-D, 2,4-DB, benefin, clethodim, dicamba, diuron, EPTC, hexazinone, metribuzin, norflurazon, imazethapyr, picloram, picloram, sethoxydim, and terbacil) were stable to hydrolysis, including glyphosate. Bromoxynil was unstable at higher pHs (US EPA, 1998a);

sethoxydim was slightly unstable at lower pHs with a 9 day half-life at pH 5 (US EPA, 2005c). Four herbicides (imazamox, clopyralid, imazethapyr, and pronamide) had missing hydrolysis data. Details are in table N-7.

### *3.2.2 Photolysis Alfalfa Herbicide Comparison Data*

#### *3.2.2.1 Aqueous*

Seven herbicides were stable (>30 days: clopyralid, dicamba, diuron, EPTC, hexazinone, paraquat, and terbacil) to aqueous photolysis, including glyphosate. Six herbicides (2,4-D, 2,4-DB, bromoxynil, imazamox, norfluzaon, and picloram) were stable for 1 to 30 days in water. At least five herbicides (benefin, metribuzin, imazethapyr, sethoxydim, and trifluralin) were unstable and underwent photolysis in less than 48 hours. Three herbicides (clethodim, imazethapyr, and pronamide) had missing data. Details are in table N-7.

#### *3.2.2.2 Soil*

Many herbicides were stable (>30 days; 2,4-D, 2,4-DB, clopyralid, dicamba, diuron, EPTC, hexazinone, imazamox, imazethapyr, paraquat, picloram, pronamide, terbacil, and trifluralin) to soil photolysis, including glyphosate. Two herbicides (benefin and norfluzaon) were stable for 7 to 30 days in soil to photolysis. At least three of the herbicides (bromoxynil, metribuzin, and sethoxydim) underwent photolysis in less than 7 days. Three herbicides (metribuzin, clethodim, and imazethapyr) had missing data. Details are in table N-7.

### *3.2.3 Soil Metabolism Alfalfa Herbicide Comparison Data*

#### *3.2.3.1 Aerobic Soil*

Many herbicides had greater than 30 day half-lives in aerobic (benefin, clopyralid, diuron, EPTC, hexazinone, imazamox, imazethapyr, metribuzin, norfluzaon, paraquat, picloram, pronamide, terbacil, and trifluralin) soils. Six herbicides had a short half-life of <30 days in aerobic soil metabolism studies, including glyphosate (2,4-D, 2,4-DB, bromoxynil, clethodim, dicamba, and sethoxydim). All herbicide had aerobic soil metabolism data.

#### *3.2.3.2 Anaerobic Soil*

Many herbicides were stable in anaerobic soils (2,4-DB, dicamba, diuron, EPTC, hexazinone, imazamox, imazethapyr, metribuzin, paraquat, picloram, pronamide, sethoxydim, terbacil, and trifluralin) with greater than 30 day half lives and three herbicides (benefin, bromoxynil, and clethodim) with a short half life (<30 days) in anaerobic soil. Three anaerobic soil metabolism data (2,4-D, clopyralid, and glyphosate) were missing. Details are in table N-7.

### *3.2.4 Aquatic Metabolism Alfalfa Herbicide Comparison Data*

#### *3.2.4.1 Aerobic*

Many herbicides had missing data concerning aquatic metabolism for aerobic (benefin, clethodim, clopyralid, dicamba, EPTC, imazamox, imazethapyr, metribuzin, picloram, pronamide, terbacil, and trifluralin) systems. Some had greater than 30 day half-lives in aerobic (diuron, hexazinone, norfluzon) water tests. Three herbicides had a short half-life of <7 days in aerobic soil metabolism studies (bromoxynil, glyphosate, and sethoxydim). Four aerobic water metabolism studies on herbicides had a range of 1 week to a month half-lives (2,4-D, 2,4-DB, and paraquat). Details are in table N-7.

#### 3.2.4.2 Anaerobic

Many herbicides had missing data concerning anaerobic aquatic metabolism for anaerobic (bromoxynil, clethodim, clopyralid, dicamba, EPTC, imazamox, imazethapyr, metribuzin, paraquat, terbacil, and trifluralin). Some had greater than 30 day half-lives in anaerobic (diuron, hexazinone, norfluzon, picloram, and sethoxydim) water tests. Two herbicides (benefin and glyphosate) had a short half-life of >7 days in anaerobic soil. Two anaerobic water studies had a range of 1 week to a month half-lives (2,4-D and 2,4-DB). Details are in table N-7.

### 3.2.5 Soil Mobility Alfalfa Herbicide Comparison Data

Thirteen herbicides had a very low adsorption coefficient <1, suggesting they are highly mobile in the soil (bromoxynil, clopyralid, hexazinone, imazethapyr, metribuzin, picloram, pronamide, sethoxydim, and terbacil). One herbicide had soil adsorption coefficient between 1 and 50 (norfluzon). Four herbicides including glyphosate had limited or low mobility (>50 soil adsorption coefficient; benefin, imazamox, paraquat, and trifluralin), four herbicide had missing data on soil mobility (clethodim, dicamba, diuron, and EPTC). Details are in table N-7.

### 3.2.6 Soil Water Partition Coefficient ( $K_d$ ) Alfalfa Herbicide Comparison Data

Most of the soil water partition coefficient ( $K_d$ ) for herbicides used in alfalfa were missing (benefin, clethodim, clopyralid, dicamba, imazamox, imazethapyr, metribuzin, norfluzon, picloram, pronamide, sethoxydim, and terbacil). Three herbicides had >10 coefficients (diuron, glyphosate, and paraquat), five had moderate to mobile soil water partition coefficients of 0-10 (2,4-D, 2,4-DB, bromoxynil, EPTC, and hexazinone). The  $K_d$  value is simply a ratio of the sorbed phase concentration to the solution phase concentration at equilibrium and based more on surface area than organic matter; thus, lower numbers mean a higher affinity for the aqueous phase rather than suspended particulate matter. Details are in table N-7.

### 3.2.7 Soil Adsorption Coefficient ( $K_{oc}$ ) Alfalfa Herbicide Comparison Data

The  $K_{oc}$  is the partition coefficient of the herbicide in the organic fraction of the soil. The higher the value the more likely the compound is bound tightly to carbon rich soil. Only two herbicides had a lower than 10 partition coefficient, dicamba and hexazinone. Ten herbicides had >10 partition coefficients (2,4-D, 2,4-DB, benefin, bromoxynil, clethodim, diuron, EPTC, glyphosate, imazethapyr, picloram, and terbacil), whereas seven had missing data (clopyralid, imazamox, metribuzin, norfluzon, paraquat, pronamide, and sethoxydim). Details are in table N-7.

### *3.2.8 Terrestrial Field Dissipation Studies (half-life) Alfalfa Herbicide Comparison Data*

Thirteen herbicides were detected in the soil at least 30 days after application (2,4-D, 2,4-DB, benefin, bromoxynil, diuron, hexazinone, imazamox, imazethapyr, metribuzin, paraquat, picloram, sethoxydim, and terbacil); four herbicides were detected in less than 30 days (bromoxynil, EPTC, glyphosate [except in Iowa study: 140 days], and trifluralin), with five herbicides missing data (clethodim, clopyralid, dicamba, norfluzon, and pronamide). Details are in table N-7.

### *3.2.9 Bioaccumulation*

Five herbicides were found to have the potential to bioaccumulate (clopyralid, EPTC, norfluzon, sethoxydim, and trifluralin). Whereas five herbicides are not expected to bioaccumulate (<1; 2,4-D, 2,4-DB, glyphosate, hexazinone, and terbacil), eleven did not have data (benefin, bromoxynil, clethodim, dicamba, diuron, imazamox, imazethapyr, metribuzin, paraquat, picloram, and pronamide). Details are in table N-7.

#### *3.2.9.1 Aquatic Field Dissipation Studies (half-life) Alfalfa Herbicide Comparison Data*

Four of the twenty herbicides used on alfalfa had aquatic field dissipation studies the half lives were as follows: sethoxydim 1-9 days; glyphosate 7.5 days in water and 120 days in sediment; 2,4-D was stable up to 50 days; and diuron 115 to 177 days. Details are in table N-7.

**Table N-7. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties**

| Herbicide         | Environmental Fate Properties  |                                |                                                                                                                                 |                                                                                 |                                                                                                                      |                                             |                                           |                                 |                                                                                                                                                                                                                                                     |                                                                |                                                                         |                                          |
|-------------------|--------------------------------|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------------------------------|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|-------------------------------------------------------------------------|------------------------------------------|
|                   | Chem Name                      | Hydrolysis                     | Photolysis (t <sub>1/2</sub> )                                                                                                  | Soil Metabolism (t <sub>1/2</sub> )                                             | Aquatic Metabolism (t <sub>1/2</sub> )                                                                               | Soil Mobility K <sub>ads</sub> , Freundlich | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                                                                                                                                                                                                         | Terrestrial Field Dissip. (t <sub>1/2</sub> )                  | Bioaccumulation                                                         | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
| <b>Glyphosate</b> | N-phosphonomethyl glycine      | Stable at pH 3, 5, 6, 7, and 9 | <u>Aqueous Photolysis</u><br>Stable in pH 5, 7 and 9<br><br><u>Soil Photolysis</u><br>Stable                                    | <u>Aerobic</u><br>Kickapoo Sandy Loam = 1.85 days<br>Dupo Silt Loam = 2.06 days | <u>Aerobic</u><br>7 days in silty clay loam sediment<br><br><u>Anaerobic</u><br>8.1 days in silty clay loam sediment | 62 - 175                                    | 22 - 175                                  | 8 - >50,000                     | <u>Aerobic Soil</u> ,<br><u>Aerobic &amp; Anaerobic Aquatic</u><br>Aminomethyl phosphonic acid (AMPA)                                                                                                                                               | 13.9 days when applied at 7.95 lb a.e./acre, 10.7 lb a.i./acre | 0.38X = edible tissue<br>0.63X = nonedible tissue<br>0.52X = whole fish | 7.5 days (water) and 120 days (sediment) |
| <b>2,4-D</b>      | 2,4-dichlorophenoxyacetic acid | Stable at pH 5, 7, and 9       | <u>Aqueous Photolysis</u><br>12.9 calendar days or 7.57 days of constant light in pH 5<br><br><u>Soil Photolysis</u><br>68 days | <u>Aerobic</u><br>6.2 days                                                      | <u>Aerobic</u><br>15 days<br><br><u>Anaerobic</u><br>41-333 days                                                     | 0.17-0.52                                   | -                                         | 59-117 mL/g                     | <u>Aerobic Soil and Aquatic</u><br>2,4-dichlorophenol, 4-chlorophenol, 4-chlorophenoxyacetic acid, and chlorohydroquinone<br><br><u>Anaerobic Aquatic</u><br>2,4-DCP, 4-chlorophenol, 2-chlorophenol, CO <sub>2</sub> , 2,4-DCA, and 4-chlorophenol | 1.1-42.5 days                                                  | -                                                                       | -                                        |

| Herbicide                   | Environmental Fate Properties                                                       |                          |                                                                                        |                                                                                |                                                        |                                                                   |                                           |                                 |                                                             |                                                                                                                     |                                                       |                                          |
|-----------------------------|-------------------------------------------------------------------------------------|--------------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------|-------------------------------------------------------------------|-------------------------------------------|---------------------------------|-------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|------------------------------------------|
|                             | Chem Name                                                                           | Hydrolysis               | Photolysis (t <sub>1/2</sub> )                                                         | Soil Metabolism (t <sub>1/2</sub> )                                            | Aquatic Metabolism (t <sub>1/2</sub> )                 | Soil Mobility K <sub>ads</sub> , Freundlich                       | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                 | Terrestrial Field Dissip. (t <sub>1/2</sub> )                                                                       | Bioaccumulation                                       | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
| <b>2,4-DB/ 2,4-DB-DMAS</b>  | 4-(2,4-dichlorophenoxy) Butyric Acid/Dimethylamine 4-(2,4-dichlorophenoxy) Butyrate | Stable at pH 5, 7, and 9 | <u>Aqueous Photolysis</u><br>6.3 days at pH 5, 17.2 days at pH 7, and 6.9 days at pH 9 | <u>Aerobic</u><br>24.5 days in mineral soils<br><br><u>Anaerobic</u><br>Stable | 6.3 to 17.2 days                                       | 0.755-3.27 mg/L Very mobile to moderately mobile in mineral soils | 1.5 mL/g                                  | 154 (EP A); 370 at pH 7.9       | 2,4-D (2,4-dichlorophenoxyacetic acid)                      | 2 - 6.7 days                                                                                                        | Ionic -not expected to bioaccumulate; 280 mL/g (MSDS) | Stable up to 50 days in distilled water  |
| <b>Dicamba</b>              | 3,6-dichloro-o-anisic acid                                                          | Stable at all pH levels  | <u>Aqueous Photolysis</u><br>Slow<br><br><u>Soil photolysis</u><br>Slow                | <u>Aerobic</u><br>6 days<br><br><u>Anaerobic</u><br>141 days                   | Degrades more rapidly in aquatic systems with sediment | -                                                                 | -                                         | 2 g/mL                          | DCSA                                                        | -                                                                                                                   | -                                                     | -                                        |
| <b>Benefin/ Benfluralin</b> | [N-butyl-n-ethyl-alpha-alpha-trifluoro-2,6-dinitro-p-toluidine]                     | Stable at pH 5, 7 and 9  | <u>Aqueous Photolysis</u><br>5.5 to 9 hours<br><br><u>Soil photolysis</u><br>12.5 days | <u>Aerobic</u><br>20-86 days<br><br><u>Anaerobic</u><br>12 days                | <u>Anaerobic</u><br>38 hours                           | Low Mobility                                                      | -                                         | 9,840 – 11,660 L/kg             | 2,6 dinitro-4-trifluoromethyl-phenol (6% of parent in soil) | 22-79 days CA lettuce 79 days (spray incorp) GA peanuts 62 days (spray incorp) CA turf 22 days (granular broadcast) | Fish: 1580 mL/g - bioaccumulative                     | -                                        |



| Herbicide                                                  | Environmental Fate Properties        |                                                                                           |                                                                                   |                                                        |                                        |                                                                                                                          |                                           |                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                               |                                                                                            |                                          |
|------------------------------------------------------------|--------------------------------------|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|--------------------------------------------------------|----------------------------------------|--------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|--------------------------------------------------------------------------------------------|------------------------------------------|
|                                                            | Chem. Name                           | Hydrolysis                                                                                | Photolysis (t <sub>1/2</sub> )                                                    | Soil Metabolism (t <sub>1/2</sub> )                    | Aquatic Metabolism (t <sub>1/2</sub> ) | Soil Mobility K <sub>ads</sub> , Freundlich                                                                              | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Terrestrial Field Dissip. (t <sub>1/2</sub> ) | Bioaccumulation                                                                            | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
| <b>Bromoxynil /Bromoxynil phenol/ Bromoxynil octanoate</b> | 3,5-dibrom o-4-hydrox ybenz onitrile | 34.1 days at pH 5, 11.5 days at pH 7 and 1.7 days at pH 9, phenol stable at pH 5, 7 and 9 | <u>Aqueous photolysis</u> 4.6 days at pH 5<br><br><u>Soil photolysis</u> 2.6 days | <u>Aerobic</u> 2 days<br><br><u>Anaerobic</u> 3.7 days | <u>Aerobic</u> <12 hours               | Mobile in unaged columns of sand, sandy loam and loam soils;<br><br>Not mobile in aged soil columns and aquatic sediment | 7.0 mL/g                                  | 1003 mL/g                       | <u>Hydrolysis</u> bromoxynil (phenol) and 3,5-dibromo-dihydroxy-cyclohexadi enylnitrile<br><br><u>Aqueous Photolysis</u> 4-cyano-2-bromophen yl octanoate, bromoxynil (phenol) and phenyl carbamate<br><br><u>Aerobic Soil Metabolism</u> CO <sub>2</sub> and Bromoxynil (phenol)<br><br><u>Anaerobic Aquatic Metabolism</u> 4-Hydroxyben zonitrile and Bromoxynil (phenol)<br><br><u>Aerobic Aquatic Metabolism</u> bromoxynil (phenol), p-hydroxyben zonitrile; 3- | 1-14 days<br>CA = 14 days<br>NC = 1 day       | <u>Bluegill Sunfish</u> 63X – edible tissue<br>400X – inedible tissue<br>230X – whole fish | -<br>-                                   |

| Herbicide                                                    | Environmental Fate Properties                 |                          |                                                                              |                                                             |                                                         |                                             |                                           |                                 |                                                                                                                                                                                                           |                                                               |                 |                                          |
|--------------------------------------------------------------|-----------------------------------------------|--------------------------|------------------------------------------------------------------------------|-------------------------------------------------------------|---------------------------------------------------------|---------------------------------------------|-------------------------------------------|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|-----------------|------------------------------------------|
|                                                              | Chem Name                                     | Hydrolysis               | Photolysis (t <sub>1/2</sub> )                                               | Soil Metabolism (t <sub>1/2</sub> )                         | Aquatic Metabolism (t <sub>1/2</sub> )                  | Soil Mobility K <sub>ads</sub> , Freundlich | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                                                                                                                                                               | Terrestrial Field Dissip. (t <sub>1/2</sub> )                 | Bioaccumulation | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
|                                                              |                                               |                          |                                                                              |                                                             |                                                         |                                             |                                           |                                 | bromo-4-hydroxybenzotrile, and 3,5-dibromo-4-hydroxybenzoic acid.                                                                                                                                         |                                                               |                 |                                          |
| <b>Clethodim</b><br>Data Source =<br>PAN Pesticides Database | 2-(1-(((3-chloro-2-propenyl)oxy)imino)propyl) | 10 days                  | -                                                                            | <u>Aerobic</u><br>3 days<br><u>Anaerobic</u><br>10 days     | -                                                       | -                                           | -                                         | 10.00                           | -                                                                                                                                                                                                         | -                                                             | -               | -                                        |
| <b>Clopyralid</b>                                            | 3,6-Dichloro-2-pyridinecarboxylic acid        | -                        | <u>Aqueous photolysis</u><br>261 days<br><u>Soil photolysis</u><br>>12 years | <u>Aerobic</u> 71 days                                      | -                                                       | Very high potential                         | -                                         | -                               | -                                                                                                                                                                                                         | -                                                             | BCF < 100       | -                                        |
| <b>Diuron</b>                                                | 3-(3,4-dichlorophenyl)-1,1-dimethylurea       | Stable at pH 5, 7, and 9 | <u>Aqueous photolysis</u><br>43 days<br><u>Soil photolysis</u><br>173 days   | <u>Aerobic</u><br>372 days<br><u>Anaerobic</u><br>1000 days | <u>Aerobic</u><br>33 days<br><u>Anaerobic</u><br>5 days | -                                           | 7.9-28                                    | 468-1666                        | <u>Hydrolysis</u><br>3,4-dichloroaniline (3,4-DCA)<br><u>Aqueous Photolysis</u><br>CO <sub>2</sub> and 13 minor polar products<br><u>Soil Metabolism</u><br>N'-(3,4-dichlorophenyl)-N-methylurea (DCPMU), | 73-139 days<br>FL = 73 days<br>MS = 139 days<br>CA = 133 days | -               | -<br>115-177 days                        |

| Herbicide | Environmental Fate Properties    |            |                                |                                                                                                                           |                                        |                                                   |                                           |                                 |                                                                                                                                                                                                                                                                          |                                               |                                                          |                                          |
|-----------|----------------------------------|------------|--------------------------------|---------------------------------------------------------------------------------------------------------------------------|----------------------------------------|---------------------------------------------------|-------------------------------------------|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|----------------------------------------------------------|------------------------------------------|
|           | Chem. Name                       | Hydrolysis | Photolysis (t <sub>1/2</sub> ) | Soil Metabolism (t <sub>1/2</sub> )                                                                                       | Aquatic Metabolism (t <sub>1/2</sub> ) | Soil Mobility<br>K <sub>ads</sub> ,<br>Freundlich | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                                                                                                                                                                                                                              | Terrestrial Field Dissip. (t <sub>1/2</sub> ) | Bioaccumulation                                          | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
|           |                                  |            |                                |                                                                                                                           |                                        |                                                   |                                           |                                 | demethylated DCPMU (DCPU), dichloroaniline (DCA), and 3,3',4,4'-tetrachlorobenzene (TCAB)<br><br><u>Aerobic Aqueous Metabolism</u><br>N'-(3-chlorophenyl)-N,N-dimethylurea (MCPDMU), DCPMU and CPMU<br><br><u>Anaerobic Aqueous Metabolism</u><br>MCPDMU, PDMU and MCPMU |                                               |                                                          |                                          |
| EPTC      | S-Ethyl di propyl thiocarbamate. | Stable     | Stable                         | <u>Aerobic</u><br>10.3 to 36.9 days (nonlinear);<br>36.5 to 74.9 days (In-transformed)<br><br><u>bi-phasic 1st phase:</u> | -                                      | -                                                 | 0.77 to 2.99                              | 136 to 264                      | EPTC-Sulfoxide and dipropylamine.                                                                                                                                                                                                                                        | 2 to 18.8 days; mean 8.6 days                 | <u>Bluegill Sunfish</u><br>97X – Viscera<br>34X - Fillet | -<br>-                                   |

| Herbicide  | Environmental Fate Properties                             |                          |                                                          |                                                                                  |                                                                                                                     |                                             |                                           |                                 |                                                                                                                                                                                                                                                           |                                               |                 |                                          |
|------------|-----------------------------------------------------------|--------------------------|----------------------------------------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------------------------------|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|-----------------|------------------------------------------|
|            | Chem. Name                                                | Hydrolysis               | Photolysis (t <sub>1/2</sub> )                           | Soil Metabolism (t <sub>1/2</sub> )                                              | Aquatic Metabolism (t <sub>1/2</sub> )                                                                              | Soil Mobility K <sub>ads</sub> , Freundlich | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                                                                                                                                                                                                               | Terrestrial Field Dissip. (t <sub>1/2</sub> ) | Bioaccumulation | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
|            |                                                           |                          |                                                          | 12.7 to 27.7 days<br>2nd phase: 73.0 to 127 days<br><br>Anaerobic 31 to 127 days |                                                                                                                     |                                             |                                           |                                 |                                                                                                                                                                                                                                                           |                                               |                 |                                          |
| Hexazinone | 3-cyclohexyl-6-(dimethylamino)-1-methyl-2,4-(1H,3H)-dione | Stable at pH 5, 7, and 9 | Aqueous Photolysis Stable<br><br>Soil Photolysis 82 days | Aerobic Sterile 1440 days<br><br>Aerobic non-sterile 216 days                    | Anaerobic Sterile >1500 days<br><br>Anaerobic non-sterile 230 days<br><br>Aerobic Sterile and non-sterile >2 months | Mobile                                      | 0.24-10.8                                 | -                               | Soil Photolysis 3-cyclohexyl-6-(methylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione and CO <sub>2</sub><br><br>Aerobic Soil 3-hydroxy-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione and 3-(ketocyclohexyl)-6-(dimethylamino)-1- | DE & MS = 123-154 days                        | Low             | -<br>-                                   |

| Herbicide | Environmental Fate Properties |            |                                |                                     |                                        |                                                   |                                           |                                 |                                                                                                                                                                                                                                                                                                                                                                           |                                               |                 |                                          |
|-----------|-------------------------------|------------|--------------------------------|-------------------------------------|----------------------------------------|---------------------------------------------------|-------------------------------------------|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|-----------------|------------------------------------------|
|           | Chem. Name                    | Hydrolysis | Photolysis (t <sub>1/2</sub> ) | Soil Metabolism (t <sub>1/2</sub> ) | Aquatic Metabolism (t <sub>1/2</sub> ) | Soil Mobility<br>K <sub>ads</sub> ,<br>Freundlich | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                                                                                                                                                                                                                                                                                                                               | Terrestrial Field Dissip. (t <sub>1/2</sub> ) | Bioaccumulation | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
|           |                               |            |                                |                                     |                                        |                                                   |                                           |                                 | methyl-1,3,5-triazine-2,4(1H,3H)-dione<br><br><u>Anaerobic Aquatic</u><br>3-hydroxycyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione, 3-(ketocyclohexyl)-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione <u>and</u> 3-cyclohexyl-1-methyl-1,3,5-triazine-2,4,6-(1H,3H,5H)-trione<br><br><u>Aerobic Aquatic</u><br>[3-(4-ketocyclohexyl)-6- |                                               |                 |                                          |

| Herbicide                                             | Environmental Fate Properties              |                          |                                                                   |                                     |                                        |                                             |                                           |                                 |                                                                                                                                                                                                                                                                                        |                                               |                 |                                          |
|-------------------------------------------------------|--------------------------------------------|--------------------------|-------------------------------------------------------------------|-------------------------------------|----------------------------------------|---------------------------------------------|-------------------------------------------|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|-----------------|------------------------------------------|
|                                                       | Chem. Name                                 | Hydrolysis               | Photolysis (t <sub>1/2</sub> )                                    | Soil Metabolism (t <sub>1/2</sub> ) | Aquatic Metabolism (t <sub>1/2</sub> ) | Soil Mobility K <sub>ads</sub> , Freundlich | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                                                                                                                                                                                                                                            | Terrestrial Field Dissip. (t <sub>1/2</sub> ) | Bioaccumulation | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
|                                                       |                                            |                          |                                                                   |                                     |                                        |                                             |                                           |                                 | (dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione; 3-(2-hydroxycyclohexyl)-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione; 3-(cyclohexyl-6-(methylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione and 3-(cyclohexyl-1-methyl-1,3,5-triazine-2,4,6-(1H,3H,5H)-trione |                                               |                 |                                          |
| <b>Imazamox</b><br>Data Source = Pesticide Fact Sheet | 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)- | Stable at pH 5, 7, and 9 | <u>Aqueous Photolysis</u> 6.8 days<br><u>Soil Photolysis</u> slow | -                                   | -                                      | Immobile or moderately mobile               | -                                         | -                               | -                                                                                                                                                                                                                                                                                      | 15-130 days                                   | -               | -                                        |

| Herbicide                                                                                  | Environmental Fate Properties                                                                  |                                              |                                                                                         |                                                                                             |                                        |                                                                  |                                           |                                 |                                                                                       |                                                                           |                 |                                          |
|--------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|----------------------------------------------|-----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|----------------------------------------|------------------------------------------------------------------|-------------------------------------------|---------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------|-----------------|------------------------------------------|
|                                                                                            | Chem. Name                                                                                     | Hydrolysis                                   | Photolysis (t <sub>1/2</sub> )                                                          | Soil Metabolism (t <sub>1/2</sub> )                                                         | Aquatic Metabolism (t <sub>1/2</sub> ) | Soil Mobility<br>K <sub>ads</sub> ,<br>Freundlich                | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                                           | Terrestrial Field Dissip. (t <sub>1/2</sub> )                             | Bioaccumulation | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
|                                                                                            | 5-oxo-1H-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid                            |                                              |                                                                                         |                                                                                             |                                        |                                                                  |                                           |                                 |                                                                                       |                                                                           |                 |                                          |
| <b>Imazethapyr</b><br><br>Data Source = New York State Department of Environ. Conservation | (±)-2-[4,5-dihydro-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid | Stable                                       | <u>Aqueous Photolysis</u><br>46 hours<br><br><u>Soil Photolysis</u><br>33 months        | <u>Aerobic Metabolism</u><br>33 – 37 months<br><br><u>Anaerobic Metabolism</u><br>>2 months | -                                      | 0.45 - 0.82                                                      | -                                         | 97 – 283                        | 5-ethyl-3-pyridinecarboxylic acid                                                     | 2 – 4 months                                                              | -               | -                                        |
| <b>Metribuzin</b>                                                                          | 4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-                                                  | Stable at pH 5, 7, and 9 at 25°C in darkness | <u>Aqueous Photolysis</u><br>= 4.3 hours in pH 6.6 @ 25°C<br><br><u>Soil Photolysis</u> | <u>Aerobic</u><br>106 days<br><u>Anaerobic</u><br>112 days                                  | -                                      | <u>Unaged Soil</u><br>0.02-0.25<br><u>Aged Soil</u><br>0.13-0.51 | -                                         | -                               | <u>Aqueous Photolysis</u><br>deaminated metribuzin (DA)<br><br><u>Soil Photolysis</u> | Watsonville (CA) = 128 days<br>Fresno (CA) = 40 days<br>ME, MI & CA = 58- | -               | -                                        |

| Herbicide | Environmental Fate Properties                                       |                          |                                                                             |                                     |                                                            |                                              |                                           |                                 |                                                                                                                                                                                                                                                                                                              |                                               |                                                                          |                                          |
|-----------|---------------------------------------------------------------------|--------------------------|-----------------------------------------------------------------------------|-------------------------------------|------------------------------------------------------------|----------------------------------------------|-------------------------------------------|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|--------------------------------------------------------------------------|------------------------------------------|
|           | Chem. Name                                                          | Hydrolysis               | Photolysis (t <sub>1/2</sub> )                                              | Soil Metabolism (t <sub>1/2</sub> ) | Aquatic Metabolism (t <sub>1/2</sub> )                     | Soil Mobility K <sub>ads</sub> , Freundlich  | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                                                                                                                                                                                                                                                                  | Terrestrial Field Dissip. (t <sub>1/2</sub> ) | Bioaccumulation                                                          | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
|           | 1,2,4-triazin-5(4H)-one                                             |                          | = 2.5 days at temperatures up to 31°C                                       |                                     |                                                            |                                              |                                           |                                 | deaminated metribuzin (DA), pentylidene metribuzin and hexylidene metribuzin<br><br><u>Aerobic Soil</u> deaminated, diketo metribuzin (DADK), diketo metribuzin (DK), deaminated metribuzin (DA), 2-methyl-DADK, 4-methyl-DADK, and 3-amino-DA<br><br><u>Anaerobic Soil</u> DADK, DA, DK, and 2-methyl-DADK. | 107 days                                      |                                                                          |                                          |
| Norfluzon | 4-chloro-5-(methylamino)-2-(trifluoromethyl)-1H-1,2,4-triazin-3-one | Stable at pH 5, 7, and 9 | <u>Aqueous Photolysis</u> 2-3 days<br><br><u>Soil Photolysis</u> 12-15 days | <u>Aerobic</u> 130 days @ 22°C      | <u>Aerobic</u> 6-8 months<br><br><u>Anaerobic</u> 8 months | 0.14-7.11 – mobile in soils with low organic | -                                         | -                               | <u>Aqueous Photolysis</u> desmethyl norflurazon, deschloroflurazon and dimers of norflurazon                                                                                                                                                                                                                 | -                                             | Bluegill Sunfish 6-8X - Fillet 16-28X - Whole Fish 30-59X – Viscera, Low | -<br>-                                   |



| Herbicide              | Environmental Fate Properties                     |                                                         |                                                                                                                                      |                                                                                                                |                                           |                                                               |                                           |                                 |                                                                                                                |                                                                                                                                                        |                 |                                          |
|------------------------|---------------------------------------------------|---------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|-------------------------------------------|---------------------------------------------------------------|-------------------------------------------|---------------------------------|----------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------------------------------------------|
|                        | Chem. Name                                        | Hydrolysis                                              | Photolysis (t <sub>1/2</sub> )                                                                                                       | Soil Metabolism (t <sub>1/2</sub> )                                                                            | Aquatic Metabolism (t <sub>1/2</sub> )    | Soil Mobility<br>K <sub>ads</sub> , Freundlich                | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                                                                    | Terrestrial Field Dissip. (t <sub>1/2</sub> )                                                                                                          | Bioaccumulation | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
|                        | o-m-tolyl)-3-(2H)-pyridazinone                    |                                                         |                                                                                                                                      |                                                                                                                |                                           | content, clay content and cation exchange capacities (CECs)   |                                           |                                 | Soil Photolysis, Aerobic Soil and Anaerobic Aquatic metabolism desmethyl norflurazon                           |                                                                                                                                                        |                 |                                          |
| Paraquat Dichloride    | 1,1'-dimethyl-4,4'-bipyridinium dichloride        | Stable at pH 5, 7, and 9                                | <u>Aqueous Photolysis</u><br>Stable for 32 days @ 25°C<br><br><u>Soil Photolysis</u><br>Stable for 85 weeks when exposed to sunlight | <u>Aerobic</u><br>Stable in Sandy Loam @ 20 ± 2° C for 180 days.<br><br><u>Anaerobic</u><br>Stable for 60 days | <u>Aerobic</u><br><2 weeks                | Immobile in silty clay loam, loam, loamy sand, and sand soils | 68-50,000 mL/g                            | -                               | No Metabolites detected                                                                                        | Loamy sand soil (soybeans) = Decreased from 1.1 mg/kg to 0.76 mg/kg at 86 days and remained stable at 0.42-0.50 mg/kg from 296-657 days post-treatment | -               | -                                        |
| Picloram/Picloram Acid | 4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid | Stable to hydrolysis in acidic, neutral and basic media | <u>Aqueous Photolysis</u><br>2.6 days @ 25°C<br><br><u>Soil Photolysis</u><br>Stable when irradiated                                 | <u>Aerobic</u><br>167-513 days<br><br><u>Anaerobic</u><br>Stable after 300 days                                | <u>Anaerobic</u><br>Stable after 300 days | <1 for soils with organic matter (OM) content as high as 4.2% | -                                         | 13 <sup>#</sup>                 | <u>Aerobic Soil</u><br>CO <sub>2</sub> , 4-amino-3,5-dichloro-2-pyridinol and 4-amino-2,3,5-trichloro pyridine | SC (2.0 lb ai/A) = detectable 840 days post-application NC (2.0 lb ai/A) = detected in all samples beyond 8 weeks MT (1 lb ai/A) =                     | -               |                                          |

| Herbicide         | Environmental Fate Properties                                                |                                                          |                                                                                |                                                                   |                                                                     |                                                                                                                    |                                           |                                 |                                                                                                                                                                                                |                                                                                            |                                                              |                                          |
|-------------------|------------------------------------------------------------------------------|----------------------------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------|---------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|-------------------------------------------|---------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------|------------------------------------------|
|                   | Chem Name                                                                    | Hydrolysis                                               | Photolysis (t <sub>1/2</sub> )                                                 | Soil Metabolism (t <sub>1/2</sub> )                               | Aquatic Metabolism (t <sub>1/2</sub> )                              | Soil Mobility K <sub>ads</sub> , Freundlich                                                                        | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                                                                                                                                                    | Terrestrial Field Dissip. (t <sub>1/2</sub> )                                              | Bioaccumulation                                              | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
|                   |                                                                              |                                                          |                                                                                |                                                                   |                                                                     |                                                                                                                    |                                           |                                 |                                                                                                                                                                                                | detectable 790 days post-application WA (1 lb ai/A) = detectable 9 months post-application |                                                              |                                          |
| <b>Pronamide</b>  | 3,5-dichloro-N-(1,1-dimethyl-2-propynyl)benzamide                            | Stable                                                   | <u>Soil Photolysis</u><br>Stable<br><br><u>Aqueous Photolysis</u><br>Stable    | <u>Aerobic</u><br>13 months<br><br><u>Anaerobic</u><br>>13 months | -                                                                   | Mobile                                                                                                             | -                                         | -                               | -                                                                                                                                                                                              | -                                                                                          | -                                                            | -                                        |
| <b>Sethoxydim</b> | [2-[1-(ethoxymino)butyl]-5-[2-(ethylthio)propyl]3-hydroxy-2-cyclohexen-1-one | 8.7 days at pH 5, 155 days at pH 7, and 284 days at pH 9 | <u>Soil Photolysis</u><br>1 hour<br><br><u>Aqueous Photolysis</u><br>5.23 days | <u>Aerobic</u><br><1 day<br><br><u>Anaerobic</u><br>>60 days      | <u>Aerobic</u><br>0.7-1.0 days<br><br><u>Anaerobic</u><br>39.9 days | <1.00<br>Mobile to very mobile in sterile (autoclaved) sand, sandy loam, sandy clay loam, silt loam, and clay loam | -                                         | -                               | <u>Hydrolysis</u><br>6-(2-(ethylthio)propyl)-4-oxo-2-propyl-4,5,6,7-tetrahydrobenzoxazole<br><br><u>Aqueous Photolysis</u><br>2-(1-aminobutylidene)-5-(2-(ethylthio)propyl)-cyclohex-1,3-dione | Residues: 32 days                                                                          | 7X - edible fish<br>25X - nonedible fish<br>21X - whole fish | Residues: 1-9 days                       |

| Herbicide | Environmental Fate Properties        |                                |                                                                               |                                                                          |                                        |                                                         |                                           |                                 |                                                                                                                                                                                                                                                                                |                                                                                                           |                                               |                                          |
|-----------|--------------------------------------|--------------------------------|-------------------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------|---------------------------------------------------------|-------------------------------------------|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|-----------------------------------------------|------------------------------------------|
|           | Chem. Name                           | Hydrolysis                     | Photolysis (t <sub>1/2</sub> )                                                | Soil Metabolism (t <sub>1/2</sub> )                                      | Aquatic Metabolism (t <sub>1/2</sub> ) | Soil Mobility<br>K <sub>ads</sub> ,<br>Freundlich soils | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                                                                                                                                                                                                                                    | Terrestrial Field Dissip. (t <sub>1/2</sub> )                                                             | Bioaccumulation                               | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
|           |                                      |                                |                                                                               |                                                                          |                                        |                                                         |                                           |                                 | Soil<br>Photolysis,<br>Aerobic and<br>Anaerobic<br>Soil<br>2-(1-ethoxyimino<br>butyl)-5-(2-(ethylsulfinyl)<br>propyl)-3-hydroxycyclohex-2-enone                                                                                                                                |                                                                                                           |                                               |                                          |
| Terbacil  | 3-tert-butyl-5-chloro-6-methyluracil | Stable at pH 5, 7 and 9 @ 25°C | <u>Aqueous Photolysis</u><br>29-54 days<br><u>Soil Photolysis</u><br>122 days | <u>Aerobic</u><br>653 days @ 25°C<br><u>Anaerobic</u><br>235 days @ 25°C | -                                      | 0.39 to 1.3 ml/g<br>Very mobile in soil                 | -                                         | 44 to 61 ml/g                   | <u>Photolysis</u><br>5-chloro-6-methyluracil, 3-tert-butyl-6-methyluracil, and 6-chloro-2,3-dihydro-3,3,7-trimethyl-5H oxazolo (3,2-a)-pyrimidine-5-one, tert-butyl-5-acetyl-5-hydroxyhydantoin (Compound II), 3-tert-butyl-5-hydroxyhydantoin (Compound III), and 5-chloro-6- | 204-252 days<br>DE (5 lb a.i./A) = 212 days<br>IL (5 lb a.i./A) = 204 days<br>CA (5 lb a.i./A) = 252 days | Not expected to bioaccumulate in fish tissues | -<br>-                                   |

| Herbicide   | Environmental Fate Properties                        |            |                                                                                          |                                                                                                                                       |                                        |                                             |                                           |                                 |                                                                                                                                                                                                                                                                                                |                                               |                                                                                                    |                                          |
|-------------|------------------------------------------------------|------------|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|---------------------------------------------|-------------------------------------------|---------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|----------------------------------------------------------------------------------------------------|------------------------------------------|
|             | Chem. Name                                           | Hydrolysis | Photolysis (t <sub>1/2</sub> )                                                           | Soil Metabolism (t <sub>1/2</sub> )                                                                                                   | Aquatic Metabolism (t <sub>1/2</sub> ) | Soil Mobility K <sub>ads</sub> , Freundlich | Soil water Part. coeff. (K <sub>d</sub> ) | Soil Adsorp. (K <sub>oc</sub> ) | Metabolites                                                                                                                                                                                                                                                                                    | Terrestrial Field Dissip. (t <sub>1/2</sub> ) | Bioaccumulation                                                                                    | Aqua. Field. Dissip. (t <sub>1/2</sub> ) |
|             |                                                      |            |                                                                                          |                                                                                                                                       |                                        |                                             |                                           |                                 | methyl-(3',5')-5'-chloro-6'-methyl-5',6'-dihydro-6',2-anhydro-3'-tertbutyluracilyluracil (Compound VI)<br><br><u>Aerobic Soil</u><br>CO <sub>2</sub> , t-butylurea and 3-tert-butyl-6-methyluracil<br><br><u>Anaerobic Soil</u><br>t-butylurea and 3-tert-butyl-5-chloro-6-hydroxymethyluracil |                                               |                                                                                                    |                                          |
| Trifluralin | α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine | -          | <u>Aqueous Photolysis</u><br>8.93 hours at pH 7<br><br><u>Soil Photolysis</u><br>41 days | <u>Aerobic</u><br>Sandy Loam = 189 days<br>Clay Loam = 201 days<br>Loam Soils = 116 days<br><br><u>Anaerobic</u><br>25-59 days @ 22°C | -                                      | 54.8-155.6                                  | -                                         | -                               | <u>Aqueous Photolysis</u><br>2-ethyl-7-nitro-5-trifluoromethylbenzimidazole, 5-trifluoromethyl-3-nitro-1,2-benzene diamine and 2-ethyl-7-                                                                                                                                                      | 15-149 days                                   | <u>Bluegill Sunfish</u><br>2041X - edible tissue<br>9586X - nonedible tissue<br>5674X - whole fish | -<br>-                                   |

| Herbicide | Environmental Fate Properties |                |                                       |                                               |                                                  |                                                              |                                                       |                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                         |                     |                                                   |
|-----------|-------------------------------|----------------|---------------------------------------|-----------------------------------------------|--------------------------------------------------|--------------------------------------------------------------|-------------------------------------------------------|----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|---------------------|---------------------------------------------------|
|           | Chem<br>Name                  | Hydrolysi<br>s | Photolys<br>is<br>(t <sub>1/2</sub> ) | Soil<br>Metabolis<br>m<br>(t <sub>1/2</sub> ) | Aquatic<br>Metabolis<br>m<br>(t <sub>1/2</sub> ) | Soil<br>Mobil<br>ity<br>K <sub>ads</sub> ,<br>Freundli<br>ch | Soil<br>water<br>Part.<br>coeff.<br>(K <sub>d</sub> ) | Soil<br>Ads<br>orp.<br>(K <sub>oc</sub><br>) | Metabolit<br>es                                                                                                                                                                                                                                                                                                                                                                                                                         | Terrestri<br>al Field<br>Dissip.<br>(t <sub>1/2</sub> ) | Bioaccumulati<br>on | Aqua.<br>Field.<br>Dissip.<br>(t <sub>1/2</sub> ) |
|           |                               |                |                                       |                                               |                                                  |                                                              |                                                       |                                              | nitro-1-propyl-5-trifluoromethylbenzimidazole<br><br><u>Soil Photolysis</u><br>2,6-dinitro-N-propyl-4-trifluoromethylbenzamine, and<br>2-ethyl-7nitro-5-trifluoromethylbenzimidazole-3-oxide<br><br><u>Aerobic Soil</u><br>α,α,α-trifluoro-2,6-dinitro-N-propyl-p-toluidine;<br>α,α,α-trifluoro-5-nitro-4-propyl-toluene-3,4-diamine;<br>2-ethyl-7-nitro-1-propyl-5-(trifluoromethyl)benzimidazole-3-oxide; 2-ethyl-7-nitro-1-propyl-5- |                                                         |                     |                                                   |

| Herbicide | Environmental Fate Properties |                |                                       |                                               |                                                  |                                                              |                                                       |                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                         |                     |                                                   |
|-----------|-------------------------------|----------------|---------------------------------------|-----------------------------------------------|--------------------------------------------------|--------------------------------------------------------------|-------------------------------------------------------|----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|---------------------|---------------------------------------------------|
|           | Chem<br>Name                  | Hydrolysi<br>s | Photolys<br>is<br>(t <sub>1/2</sub> ) | Soil<br>Metabolis<br>m<br>(t <sub>1/2</sub> ) | Aquatic<br>Metabolis<br>m<br>(t <sub>1/2</sub> ) | Soil<br>Mobil<br>ity<br>K <sub>ads</sub> ,<br>Freundli<br>ch | Soil<br>water<br>Part.<br>coeff.<br>(K <sub>d</sub> ) | Soil<br>Ads<br>orp.<br>(K <sub>oc</sub><br>) | Metabolit<br>es                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Terrestri<br>al Field<br>Dissip.<br>(t <sub>1/2</sub> ) | Bioaccumulati<br>on | Aqua.<br>Field.<br>Dissip.<br>(t <sub>1/2</sub> ) |
|           |                               |                |                                       |                                               |                                                  |                                                              |                                                       |                                              | (trifluoromet<br>hyl)benzimi<br>dazole; 2-<br>ethyl-7-<br>nitro-5-<br>(trifluoromet<br>hyl)benzimi<br>dazole;<br>α,α,α-<br>trifluoro-2,6-<br>dinitro-p-<br>cresol <u>and</u><br>2,2'azoxybis<br>(α,α,α -<br>trifluoro-6-<br>nitro-N-<br>propyl-p-<br>toluidine<br><br><u>Anaerobic<br/>Soil</u><br>α,α,α-<br>trifluoro-5-<br>nitro-N4,N4-<br>dipropyl-<br>toluene-<br>3,4-diamine;<br>7-amino-2-<br>ethyl-1-<br>propyl-5-<br>(trifluoromet<br>hyl)benzimi<br>dazole, <u>and</u><br>α,α,α-<br>trifluoro-<br>N4,N4-<br>dipropyltolu<br>ene-3,4,5-<br>triamine |                                                         |                     |                                                   |

### 3.3 Glyphosate and Metabolite Occurrence

In a USDA monitoring study conducted on surface water, groundwater, and soil from 2001 to 2006, the metabolite AMPA was observed more frequently than the parent compound glyphosate (Scribner et al., 2007). The sample collections were from several USGS studies including: the National Stream Quality Accounting Network Program; the National Water-Quality Assessment Program; and the Toxic Substances Hydrology Program. Groundwater samples had measured concentrations of glyphosate, ranging from  $< 0.01$  to  $4.7 \mu\text{g/L}$  (68 detections out of 873 samples), and AMPA, ranging from  $< 0.01$  to  $2.6 \mu\text{g/L}$  (133 detections out of 873 samples). In surface water the range of glyphosate detected was  $< 0.01$  to  $427 \mu\text{g/L}$  (489 detections out of 1262 samples), and the range of AMPA detected was  $0.38$  to  $29 \mu\text{g/L}$  (489 detections out of 1262 samples).

In all of the samples, the maximum detections were from an agricultural ditch basin (Leary Weber ditch of the White River Basin in Indiana). In rainwater collected from the Indiana Leary Weber Ditch Basin, measured concentrations of glyphosate ranged from  $0.02$  to  $1.1 \mu\text{g/L}$  and AMPA ranged from  $0.02$  to  $0.47 \mu\text{g/L}$  in 12 of the 14 samples. Glyphosate detections in precipitation are more likely due to glyphosate associated with dust particles being washed down with rain than to glyphosate dissolved in rain). Soil samples from Indiana Leary Weber Ditch Basin indicate glyphosate and AMPA may persist from year to year with a glyphosate maximum concentration of  $476 \mu\text{g/L}$  (119 detections out of 193 samples) and an AMPA maximum concentration of  $956 \mu\text{g/L}$  (154 detections out of 193 samples) (Scribner et al., 2007); however, the detection of these large quantities may have coincided with a recent rain event and application. “The potential persistence of glyphosate in soils warrants further studies given the potential increase of use due to GT alfalfa” (Scribner et al., 2007).

### 3.4 Summary of Findings

Glyphosate has a low potential to leach to groundwater from the soil due to its rapid microbial degradation and strong soil binding properties (Giesy et al., 2000). In a worst case direct soil application field dissipation studies glyphosate and AMPA were found in the top 6 inches, also indicative of a non-leaching chemical. Glyphosate is applied to the foliage and direct soil contact is not expected unless a spill or recent rain event moves the glyphosate from the leaves to the soil. Due to glyphosate’s strong adsorptive qualities to soil groundwater contamination is not expected, as noted with no more than  $4.7 \mu\text{g/L}$  detected by USGS survey study (Scribner et al., 2007). Evaporation is not a major route of dissipation, nor will glyphosate degrade due to hydrolysis or photolysis; microbial degradation is the primary route of dissipation of glyphosate from most ecosystems regardless of the soil and climatic conditions (Giesy et al., 2000). Glyphosate exposure is also possible due to runoff after a rain soon after application, spray drift, inadvertent direct overspray, or wind transport of soil particulates loaded with adsorbed glyphosate. Glyphosate is not expected to bioaccumulate.

The twenty other pesticides used on alfalfa have varying chemical fates. In general most were more persistent and had higher mobility in soils, making them more apt to continually contaminate surrounding water systems. Few were even considered compounds that could

bioaccumulate (e.g., clopyralid, EPTC, norflurazon, sethoxydim, and trifluralin). In section 5.2 further environmental impacts of these herbicides in comparison to glyphosate will be discussed.



## 4.0 Ecotoxicity of Glyphosate and Glyphosate Commercial Formulations and AMPA

The terrestrial ecosystems potentially at risk include the treated area and areas immediately adjacent to the treated area that might receive drift or runoff (recent rain event after application), and might include other cultivated fields, fence rows and hedgerows, meadows, fallow fields or grasslands, woodlands, riparian habitats, or other uncultivated areas. For US EPA Tier 1 assessment purposes, risk is assessed to terrestrial animals or plants assumed to occur exclusively adjacent to the treated area.

Aquatic ecosystems potentially at risk include water bodies adjacent to, or down stream from, the treated field and might include impounded bodies such as ponds, lakes and reservoirs, or flowing waterways such as streams or rivers. The proposed use sites may be located either near freshwater or saltwater habitats. For uses in coastal areas, an aquatic habitat also includes marine ecosystems including estuaries. For US EPA Tier 1 assessment purposes, risk is assessed to aquatic animals and plants assumed to occur in small, static ponds receiving runoff and drift from treated areas.

**Table N-8. Taxonomic Groups and Test Species Evaluated for Ecological Effects in Screening-Level Risk Assessments**

| <b>Taxonomic Group</b>         | <b>Example(s) of Representative Species</b>                                                     |
|--------------------------------|-------------------------------------------------------------------------------------------------|
| Birds <sup>a</sup>             | Mallard duck ( <i>Anas platyrhynchos</i> )<br>Bobwhite quail ( <i>Colinus virginianus</i> )     |
| Mammals                        | Laboratory rat ( <i>Rattus norvegicus</i> )                                                     |
| Freshwater fish <sup>b</sup>   | Bluegill sunfish ( <i>Lepomis macrochirus</i> )<br>Rainbow trout ( <i>Oncorhynchus mykiss</i> ) |
| Freshwater invertebrates       | Water flea ( <i>Daphnia magna</i> )                                                             |
| Estuarine/marine fish          | Sheepshead minnow ( <i>Cyprinodon variegatus</i> )                                              |
| Estuarine/marine invertebrates | Eastern oyster ( <i>Crassostrea virginica</i> )<br>Mysid shrimp ( <i>Americamysis bahia</i> )   |
| Terrestrial plants             | Monocot and dicot                                                                               |
| Insects                        | Honeybee                                                                                        |
| Aquatic plants                 | Bluegreen alga<br>Green alga<br>Saltwater diatom<br>Duckweed ( <i>Lemna gibba</i> )             |

<sup>a</sup> Birds are considered surrogates for amphibians (terrestrial phase) and reptiles when no data are available.

<sup>b</sup> Freshwater fish may be surrogates for amphibians (aquatic phase) when no data are available.

Within each of these very broad taxonomic groups, an acute and/or chronic endpoint is selected from the available test data. A complete discussion of all toxicity data available for this risk assessment and the resulting measures of effect selected for each taxonomic group are discussed below.

All available data from US EPA's RED document on glyphosate (1993) and new use risk assessment for bent grass (2006); Giesy and colleagues (2000) risk assessment on glyphosate; USDA (2003) risk assessment on glyphosate for the Forest Service; and public literature on the toxicity of glyphosate to plants and animals were used in this risk assessment. Not all taxonomic groups are surveyed because of US EPA registration of pesticide study guideline limitations. Instead, some animals are used as surrogates for other groups based on the similarity of their

physiology and habitat. Therefore, extrapolation to other taxonomic groups may constitute a source of uncertainty in the ecological risk assessment.

## 4.1 Avian Toxicity

Several acute toxicity tests were conducted on birds for glyphosate and its formulations, as well as were several chronic toxicity tests on glyphosate. No data was available on chronic bird toxicity to glyphosate herbicide formulations. A few toxicity tests were also performed for the glyphosate metabolite aminomethyl phosphonate (AMPA). The toxicity study results are discussed in sections 4.1.1 through 4.1.4.

### 4.1.1 Acute Avian Toxicity to Glyphosate

Acute toxicity in birds was assessed using single-dose, dietary, and reproductive toxicity studies. US EPA's preferred test species is either Mallard duck (a waterfowl) or Bobwhite quail (an upland game bird). The results of acute glyphosate toxicity tests in birds are provided in table N-9 below. Glyphosate toxicity in the Bobwhite quail ranged from a dose required to kill 50 percent of a population of test animals ( $LD_{50}$ ) > 2000 mg/kg to a concentration required to kill 50 percent of a population of test animals ( $LC_{50}$ ) > 6300 mg/kg. The Mallard duck was slightly more toxic ( $LC_{50}$  ranged from >4640 to > 6300 mg/kg). Glyphosate tested as an acid produced similar results in the Bobwhite quail and Mallard duck. No toxicity studies were found testing glyphosate as the IPA salt.

**Table N-9. Acute Avian Toxicity to Glyphosate**

| Study Type<br>(% a.i.)                  | Species        | Results                            | Endpoint                                                                 | Reference          |
|-----------------------------------------|----------------|------------------------------------|--------------------------------------------------------------------------|--------------------|
| <b><i>Glyphosate</i></b>                |                |                                    |                                                                          |                    |
| Acute, Single-Dose, Oral (83%)          | Bobwhite quail | $LD_{50}$ = >2000 mg/kg            | Death, range and time frame exposure time not reported                   | US EPA, 1993       |
| 8-day, Dietary (98.5%)                  | Bobwhite quail | $LC_{50}$ = >4640 ppm              | Reproductive Impairment, range and time frame exposure time not reported | US EPA, 1993       |
| 8-day, Subacute toxicity                | Bobwhite quail | $LC_{50}$ = > 6300 mg/kg           | Death                                                                    | USDA, 2003         |
| Reproductive (83%)                      | Bobwhite quail | No effects up to 1000 ppm          | Reproductive Impairment                                                  | US EPA, 1993       |
| 8-day, Dietary (98.5%)                  | Mallard duck   | $LC_{50}$ = >4640 ppm              | Reproductive Impairment, range and time frame exposure time not reported | US EPA, 1993       |
| 8-day, Subacute toxicity                | Mallard duck   | $LC_{50}$ = > 6300 mg/kg           | Death                                                                    | USDA, 2003         |
| Reproductive (90.4%)                    | Mallard duck   | No effects up to 30 ppm            | Reproductive Impairment                                                  | US EPA, 1993       |
| Reproductive (83%)                      | Mallard duck   | No effects up to 1000 ppm          | Reproductive Impairment                                                  | US EPA, 1993       |
| <b><i>Glyphosate tested as acid</i></b> |                |                                    |                                                                          |                    |
| Acute, Oral                             | Bobwhite quail | $LC_{50}$ = > 3851 mg a.e./kg bw   | Death                                                                    | Giesy et al., 2000 |
| 8-day, Dietary                          | Bobwhite quail | $LC_{50}$ = > 4640 mg a.e./kg diet | Death                                                                    | Giesy et al., 2000 |
| 8-day, Dietary                          | Mallard duck   | $LC_{50}$ = > 4640 mg a.e./kg diet | Death                                                                    | Giesy et al., 2000 |

#### 4.1.2 Acute Avian Toxicity to Glyphosate Herbicide Formulations

The formulations of glyphosate (Honcho® Herbicide, Honcho® Plus Herbicide, Roundup Original MAX® Herbicide, and Roundup WeatherMAX® Herbicide) produced acute toxicity values between LD<sub>50</sub> > 2,250 mg/kg bw and LC<sub>50</sub> > 5,620 mg/kg diet in the Bobwhite quail. Quail were most sensitive to Roundup Original MAX® Herbicide. Acute toxicity values in the Mallard duck ranged from LC<sub>50</sub> > 4,640 mg/kg diet to > 5,620 mg/kg diet. Mallards were most sensitive to the Roundup Original MAX® and WeatherMAX® formulations.

**Table N-10. Acute Bird Toxicity to Glyphosate Herbicide Formulations**

| Study Type (% a.i.)                                                                                | Species        | Results                                       | Endpoint | Reference          |
|----------------------------------------------------------------------------------------------------|----------------|-----------------------------------------------|----------|--------------------|
| Acute, Single-Dose, (Roundup Original MAX® Herbicide)                                              | Bobwhite quail | LD <sub>50</sub> = > 2,250 mg/kg bw           | Death    | Monsanto, 2006     |
| Acute, Single-Dose, I (Roundup Original MAX® Herbicide [N-(phosphonomethyl)glycine; [glyphosate]]) | Bobwhite quail | LD <sub>50</sub> = > 3,851 mg/kg bw           | Death    | Monsanto, 2006     |
| Acute, Single-Dose, (Roundup WeatherMAX® Herbicide [N-(phosphonomethyl)glycine; [glyphosate]])     | Bobwhite quail | LD <sub>50</sub> = > 3,851 mg/kg bw           | Death    | Monsanto, 2005     |
| 5-day, Dietary (Roundup Original MAX® Herbicide [N-(phosphonomethyl)glycine; [glyphosate]])        | Bobwhite quail | LC <sub>50</sub> = > 4,640 mg/kg diet         | Death    | Monsanto, 2006     |
| 5-day, Dietary (Roundup WeatherMAX® Herbicide [N-(phosphonomethyl)glycine; [glyphosate]])          | Bobwhite quail | LC <sub>50</sub> = > 4,640 mg/kg diet         | Death    | Monsanto, 2005     |
| 5-day, Dietary (Honcho® Herbicide)                                                                 | Bobwhite quail | LC <sub>50</sub> = > 5,620 mg/kg              | Death    | USDA, 2003         |
| 5-day, Dietary (Honcho® Herbicide)                                                                 | Bobwhite quail | LC <sub>50</sub> = > 5,620 mg/kg diet         | Death    | Monsanto, 2007b    |
| 5-day, Dietary (Honcho® Plus Herbicide)                                                            | Bobwhite quail | LC <sub>50</sub> = > 5,620 mg/kg diet         | Death    | Monsanto, 2007d    |
| 8-day, Dietary (Roundup)                                                                           | Bobwhite quail | LC <sub>50</sub> = > 5,620 mg product/kg diet | Death    | Giesy et al., 2000 |
| 5-day, Dietary (Roundup Original MAX® Herbicide [N-(phosphonomethyl)glycine; [glyphosate]])        | Mallard duck   | LC <sub>50</sub> = > 4,640 mg/kg diet         | Death    | Monsanto, 2007b    |
| 5-day, Dietary (Roundup WeatherMAX® Herbicide [N-(phosphonomethyl)glycine; [glyphosate]])          | Mallard duck   | LC <sub>50</sub> = > 4,640 mg/kg diet         | Death    | Monsanto, 2005     |
| 5-day, Dietary (Honcho® Herbicide)                                                                 | Mallard duck   | LC <sub>50</sub> = > 5620 mg/kg               | Death    | USDA, 2003         |
| 5-day, Dietary (Honcho® Herbicide)                                                                 | Mallard duck   | LC <sub>50</sub> = > 5,620 mg/kg diet         | Death    | Monsanto, 2007b    |
| 5-day, Dietary (Honcho® Plus Herbicide)                                                            | Mallard duck   | LC <sub>50</sub> = > 5,620 mg/kg diet         | Death    | Monsanto, 2007d    |
| 8-day, Dietary (Roundup)                                                                           | Mallard duck   | LC <sub>50</sub> = > 5620 mg product /kg diet | Death    | Giesy et al., 2000 |
| 5-day, Dietary (Roundup)                                                                           | Zebra Finch    | LC <sub>50</sub> = > 8064 mg product /kg diet | Death    | Giesy et al., 2000 |

#### 4.1.3 Acute Avian Toxicity to AMPA

AMPA administered orally as a single dose to the Bobwhite quail produced LD<sub>50</sub> values of >2250 mg AMPA/kg. Administered in the diet for 8 days to Mallard ducks and Bobwhite quail, resultant LC<sub>50</sub> values were >5620 mg AMPA/kg. The no observed effect concentration (NOEC) for both species was 5620 mg AMPA/kg.

**Table N-11. Acute Avian Toxicity to AMPA**

| Study Type (%a.i.) | Species        | Results                      | Endpoint | Reference          |
|--------------------|----------------|------------------------------|----------|--------------------|
| Oral – single dose | Bobwhite quail | LC <sub>50</sub> >2250 mg/kg | Death    | Giesy et al., 2000 |
| 8 day - Dietary    | Bobwhite quail | LC <sub>50</sub> >5620 mg/kg | Death    | Giesy et al., 2000 |
| 8 day - Dietary    | Mallard duck   | LC <sub>50</sub> >5620 mg/kg | Death    | Giesy et al., 2000 |

#### 4.1.4 Chronic Avian Toxicity

Chronic effect levels of glyphosate (tested as acid) were deduced from long-term (16-17 wk) dietary studies. US EPA's preferred test species is either Mallard duck (a waterfowl) or Bobwhite quail (an upland game bird). The no observed effect concentration (NOEC) for both the mallard and Bobwhite quail was 1000 mg a.e./kg diet.

**Table N-12. Chronic Avian Toxicity to Glyphosate**

| Study Type (%a.i.) | Species        | Results                     | Endpoint             | Reference          |
|--------------------|----------------|-----------------------------|----------------------|--------------------|
| 17-wk, Dietary     | Bobwhite quail | NOEC = 1000 mg a.e./kg diet | Reproductive Effects | Giesy et al., 2000 |
| 16-wk, Dietary     | Mallard duck   | NOEC = 1000 mg a.e./kg diet | Reproductive Effects | Giesy et al., 2000 |

#### 4.1.5 Chronic Avian Toxicity to Glyphosate Herbicide Formulations

No data available on chronic bird toxicity to glyphosate herbicide formulations.

### 4.2 Mammal Toxicity

Several acute toxicity tests were conducted on mammals for glyphosate and its formulations, as well as were several chronic toxicity tests on glyphosate. Further details on mammalian toxicity are addressed in the technical reports with this EIS, *Health and Safety Risks from Increased Glyphosate and Other Chemical Usage on Humans (Exclusive of Field Workers)* (appendix L) and *Health and Safety Risks to Field Workers* (appendix M). No studies were found addressing the chronic toxicity of commercial formulations of glyphosate to terrestrial mammals. The toxicity study results are discussed in sections 4.2.1 through 4.2.4.

#### 4.2.1 Acute Mammal Toxicity to Glyphosate

Acute toxicity in terrestrial mammals was assessed using 21-day subacute oral studies. More in depth discussion of mammalian toxicity can be found in another technical report for this EIS entitled, *Health and Safety Risks from Increased Glyphosate and Other Chemical Usage on Humans (Exclusive of Field Workers)* (appendix L). All of the acute toxicity (2,000 to 6,000

mg/kg and acute oral intraperitoneal) studies in rodents for glyphosate are slightly toxic to practically non-toxic, and a non-sensitizer. The results of the acute glyphosate toxicity studies in terrestrial mammals including the goat, rabbit, rat, and hopping mouse and are summarized in table N-13 below. Acute oral LD<sub>50</sub>s for mammals range from 2,047 to > 5,000 mg a.e./kg/ day (d) for glyphosate. Glyphosate tested as IPA salt produced an acute oral LD<sub>50</sub> of 5,700 mg a.e./kg/d in the goat. No studies were reviewed with glyphosate tested as an acid.

**Table N-13. Acute Mammalian Toxicity to Glyphosate**

| Study Type (% a.i.)                  | Species | Results                                 | Endpoint                                                                 | Reference                          |
|--------------------------------------|---------|-----------------------------------------|--------------------------------------------------------------------------|------------------------------------|
| <b>Glyphosate</b>                    |         |                                         |                                                                          |                                    |
| Acute, Oral                          | Rat     | LD <sub>50</sub> = 2,047 mg a.e./kg/d   | Death                                                                    | Giesy et al., 2000                 |
| Acute, Oral                          | Rat     | LD <sub>50</sub> = > 5,000 mg a.e./kg/d | Death                                                                    | Giesy et al., 2000                 |
| Acute, Oral                          | Goat    | LD <sub>50</sub> = 3,500 mg a.e./kg/d   | Death                                                                    | Giesy et al., 2000                 |
| 21-day, Oral                         | Rabbit  | NOAEL = 175 mg a.e./kg/d                | Maternal toxicity: mortality, diarrhea, soft stools, and nasal discharge | Giesy et al., 2000<br>US EPA, 1993 |
| <b>Glyphosate tested as IPA salt</b> |         |                                         |                                                                          |                                    |
| Acute, Oral (tested as IPA salt)     | Goat    | LD <sub>50</sub> = 5,700 mg a.e./kg/d   | Death                                                                    | Giesy et al., 2000                 |

#### 4.2.2 Acute Mammalian Toxicity to Glyphosate Herbicide Formulations

In glyphosate herbicide formulations, the acute oral LD<sub>50</sub> was 4,860 mg product/kg/d. The No Observed Adverse Effects Level (NOAEL) for the hopping mouse was 16,000 mg product/kg diet. The results are presented in table N-14 below.

**Table N-14. Acute Mammalian Toxicity to Glyphosate Herbicide Formulations**

| Study Type (% a.i.)      | Species       | Results                                                                               | Endpoint           | Reference          |
|--------------------------|---------------|---------------------------------------------------------------------------------------|--------------------|--------------------|
| Acute, Oral (Roundup)    | Goat          | LD <sub>50</sub> = 4,860 mg product /kg/d<br>NML <sup>b</sup> = 2,100 mg product/kg/d | Death              | Giesy et al., 2000 |
| 4-day, Dietary (Roundup) | Hopping Mouse | NOAEL = > 16,000 mg product/kg diet                                                   | NOAEL <sup>a</sup> | Giesy et al., 2000 |
| 4-day, Dietary (Roundup) | Hopping Mouse | NOAEL = > 16,000 mg product/kg diet                                                   | NOAEL <sup>a</sup> | Giesy et al., 2000 |

<sup>a</sup> NOAEL: No Observable Adverse Effect Level

<sup>b</sup> NML: No mortality level

#### 4.2.3 Chronic Mammalian Toxicity to Glyphosate

Chronic effect levels of glyphosate (tested as an acid) were estimated from long-term (13-52 weeks) dietary studies in the rat, mouse, and dog models. In terms of subchronic and chronic toxicity in rodents, one of the more consistent effects of exposure to glyphosate is loss of body

weight. Toxicity varied significantly both within and across species. Across species, the NOAEL in mammals ranged from 30 mg a.e./kg/d to > 12,500 mg a.e./kg/diet. Within species, the rat showed the most extreme variation (NOAEL ranged from 30 mg a.e./kg/d to > 12,500 mg a.e./kg/diet), followed by the mouse (NOAEL ranged from 507 to 1,890 mg a.e./kg/d). Only one study using a dog model was reviewed and therefore variability cannot be assessed. A 3-generation reproduction study was conducted with male and female Sprague-Dawley rats which were administered 0, 3, 10, or 30 mg/kg/day of glyphosate continuously in the diet. The only effect observed was an increased incidence of focal tubular dilation of the kidney (both unilateral and bilateral combined) in the high-dose male F<sub>3b</sub> pups. Therefore, the NOEL for systemic and reproductive toxicity is 30 mg/kg/day (US EPA, 1993). A second reproductive study was conducted. In the 2-generation rat reproduction study, the offspring and parental NOAELs were 500 mg/kg/day based on decreased pup body weight during lactation (offspring) and soft stools, decreased body weight and food consumption (parents) at the LOAEL of 1500 mg/kg/day. The reproductive NOAEL was >1500 mg/kg/day. The focal tubular dilation of the kidneys was not observed at the 1500 mg/kg/day level in the subsequent 2-generation rat reproduction study. Therefore, the EPA concluded that the effect seen in the three generation study was a spurious rather than glyphosate-related effect. Therefore, the NOAELs for parental, reproductive or offspring toxicity were 30 mg/kg/day. The toxicity results are presented in table N-15.

**Table N-15. Chronic Mammalian Toxicity to Glyphosate**

| Study Type (%a.i.)     | Species | Results                          | Endpoint                                                                                                                                               | Reference                                 |
|------------------------|---------|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|
| 13-wk, Dietary         | Rat     | NOAEL = 205 mg a.e./kg/d         | NOAEL                                                                                                                                                  | Giesy et al., 2000                        |
| 13-wk, Dietary         | Rat     | NOAEL = 1,267 mg a.e./kg/d       | NOAEL                                                                                                                                                  | Giesy et al., 2000                        |
| 13-wk, Dietary         | Rat     | NOAEL = > 12,500 mg a.e./kg/diet | NOAEL                                                                                                                                                  | Giesy et al., 2000                        |
| 24-mon, Dietary        | Rat     | NOAEL = 410 mg a.e./kg/d         | NOAEL                                                                                                                                                  | Giesy et al., 2000                        |
| Chronic, Dietary       | Rat     | NOAEL = > 31 mg a.e./kg/d        | NOAEL                                                                                                                                                  | Giesy et al., 2000                        |
| 2 generations, Dietary | Rat     | NOAEL = 500 mg a.e./kg/d         | NOAEL: decreased body weight gain during lactation                                                                                                     | Giesy et al., 2000<br>US EPA, 1993, 2006c |
| 3 generations, Dietary | Rat     | NOAEL = > 30 mg a.e./kg/d        | NOAEL: increased incidence of focal tubular dilation of the kidney (both unilateral and bilateral combined) in the high-dose male F <sub>3b</sub> pups | Giesy et al., 2000<br>US EPA, 1993, 2006c |
| 13-wk, Dietary         | Mouse   | NOAEL = 507 mg a.e./kg/d         | NOAEL                                                                                                                                                  | Giesy et al., 2000                        |
| 13-wk, Dietary         | Mouse   | NOAEL = 1,890 mg a.e./kg/d       | NOAEL                                                                                                                                                  | Giesy et al., 2000                        |
| 24-mon, Dietary        | Mouse   | NOAEL = 814 mg a.e./kg/d         | NOAEL                                                                                                                                                  | Giesy et al., 2000                        |
| 52 wk, Oral (capsule)  | Dog     | NOAEL = > 500 mg a.e./kg/d       | NOAEL                                                                                                                                                  | Giesy et al., 2000                        |

#### 4.2.4 Chronic Mammalian Toxicity to Glyphosate Herbicide Formulations

No studies were found addressing the chronic toxicity of commercial formulations of glyphosate to terrestrial mammals.

### 4.3 Terrestrial Invertebrate Toxicity

Several acute toxicity tests were conducted on terrestrial invertebrates for glyphosate and its formulations. No studies were found addressing the chronic toxicity of glyphosate and its commercial formulations on terrestrial invertebrates. The toxicity study results are discussed in sections 4.3.1 through 4.3.4.

#### 4.3.1 Acute Terrestrial Invertebrate Toxicity to Glyphosate

Acute toxicity in non-target arthropods was assessed using contact, oral, and dietary studies. The preferred US EPA test species for non-target arthropods is the honeybee. Studies may also use spiders, butterflies, or other terrestrial arthropods (USDA, 2003). All reviewed studies reported a LD<sub>50</sub> for glyphosate of > 100 µg/honeybee. No studies were reviewed that tested glyphosate as an acid or IPA salt. The study results are presented in table N-16 below.

**Table N-16. Acute Terrestrial Invertebrate Toxicity to Glyphosate**

| Study Type (%a.i.)           | Species  | Results                                             | Endpoint | Reference          |
|------------------------------|----------|-----------------------------------------------------|----------|--------------------|
| Acute, Diet                  | Honeybee | LD <sub>50</sub> = 100; 2-day; range not reported   | Death    | Giesy et al., 2000 |
| Acute, Contact               | Honeybee | LD <sub>50</sub> = > 100; 2-day; range not reported | Death    | Giesy et al., 2000 |
| Acute, Oral                  | Honeybee | LD <sub>50</sub> = > 100 µg/bee                     | Death    | US EPA, 1993       |
| Acute, Contact               | Honeybee | LD <sub>50</sub> = > 100 µg/bee                     | Death    | US EPA, 1993       |
| Acute, Oral (36% MON2139)    | Honeybee | LD <sub>50</sub> = > 100 µg/bee                     | Death    | US EPA, 1993       |
| Acute, Contact (36% MON2139) | Honeybee | LD <sub>50</sub> = > 100 µg/bee                     | Death    | US EPA, 1993       |

#### 4.3.2 Acute Terrestrial Invertebrate Toxicity to Glyphosate Herbicide Formulations

The formulations of glyphosate (Honcho® Herbicide, Honcho® Plus Herbicide, Roundup Original MAX® Herbicide, and Roundup WeatherMAX® Herbicide) produced LD<sub>50</sub> values between 100 and 326 µg/honeybee. Non-target arthropods appeared most sensitive to Roundup WeatherMAX® and least sensitive to Honcho® products. The study results are presented in table N-17 below.

**Table N-17. Acute Terrestrial Invertebrate Toxicity to Glyphosate Herbicide Formulations**

| Study Type (% a.i.)                                    | Species  | Results                         | Endpoint | Reference          |
|--------------------------------------------------------|----------|---------------------------------|----------|--------------------|
| Acute, Diet (Roundup)                                  | Honeybee | LD <sub>50</sub> = > 100 µg/bee | Death    | Giesy et al., 2000 |
| Acute, Contact (Roundup)                               | Honeybee | LD <sub>50</sub> = > 100 µg/bee | Death    | Giesy et al., 2000 |
| 48-hr, Oral (Roundup WeatherMAX® Herbicide)            | Honeybee | LD <sub>50</sub> > 238.8 µg/bee | Death    | Monsanto, 2005     |
| 48-hr, Contact (Roundup WeatherMAX® Herbicide)         | Honeybee | LD <sub>50</sub> > 250 µg/bee   | Death    | Monsanto, 2005     |
| 48-hr, Contact (Roundup Original MAX® Herbicide)       | Honeybee | LD <sub>50</sub> > 273 µg/bee   | Death    | Monsanto, 2006     |
| 48-hr, Oral toxicity (Roundup Original MAX® Herbicide) | Honeybee | LD <sub>50</sub> > 281 µg/bee   | Death    | Monsanto, 2006     |
| 48-hr, Oral/Contact (Honcho® Herbicide)                | Honeybee | LD <sub>50</sub> > 326 µg/bee   | Death    | Monsanto, 2007b    |
| 48-hr, Oral/Contact (Honcho® Plus Herbicide)           | Honeybee | LD <sub>50</sub> > 326 µg/bee   | Death    | Monsanto, 2007d    |

### 4.3.3 Chronic Terrestrial Invertebrate Toxicity to Glyphosate and Glyphosate Herbicide Formulations

No studies were found addressing the chronic toxicity of glyphosate and commercial formulations of glyphosate to terrestrial invertebrates.

## 4.4 Plant Toxicity

Several acute toxicity tests were conducted on plants for exposure to glyphosate, as well as were several chronic toxicity tests on glyphosate and its formulations. Glyphosate is a broad-spectrum herbicide and will affect many types of nontarget plants if applied to the foliage. Therefore, a detailed risk assessment on the impact of foliar application of glyphosate in the treated area was not conducted. No studies were found addressing the acute toxicity of commercial formulations of glyphosate to plants. The toxicity study results are discussed in sections 4.4.1 through 4.4.4.

### 4.4.1 Acute Plant Toxicity to Glyphosate

Glyphosate is estimated to be equally toxic to both terrestrial and aquatic plants (USDA, 2003). US EPA has evaluated glyphosate's toxicity to aquatic plants based on studies submitted for the registration of the chemical and additional studies are also available (USDA, 2003). Table N-18 highlights glyphosate's acute toxicity levels for 26 aquatic plant species. EC<sub>50</sub> values for glyphosate in algae are as low as 0.85 mg/L (USDA, 2003). Aquatic macrophyte sensitivity to glyphosate is similar to that of algae (USDA, 2003).

**Table N-18. Acute Non-Target Aquatic Plants Toxicity to Glyphosate**

| Study Type (% a.i.)          | Species                          | Result                                                                         | Endpoint             | Reference    |
|------------------------------|----------------------------------|--------------------------------------------------------------------------------|----------------------|--------------|
| Aquatic Plant Growth (96.6%) | <i>Selenastrum capricornutum</i> | EC <sub>50</sub> = 12.5 mg/L, 4-day                                            | Not reported         | US EPA, 1993 |
| Aquatic Plant Growth (96.6%) | <i>Navicula pelliculosa</i>      | EC <sub>50</sub> = 39.9 mg/L, 4-day                                            | Not reported         | US EPA, 1993 |
| Aquatic Plant Growth (96.6%) | <i>Skeletonema costatum</i>      | EC <sub>50</sub> = 0.85 mg/L, 4-day                                            | Not reported         | US EPA, 1993 |
| Aquatic Plant Growth (96.6%) | <i>Anabaena flosaquae</i>        | EC <sub>50</sub> = 11.7 mg/L, 4-day                                            | Not reported         | US EPA, 1993 |
| Aquatic Plant Growth (96.6%) | <i>Lemna gibba</i>               | EC <sub>50</sub> = 21.5 mg/L, 7-day                                            | Not reported         | US EPA, 1993 |
| Aquatic Plant Growth (96.6%) | <i>Chlorella fusca</i>           | EC <sub>50</sub> = 377 mg/L, 1 generation cycle (24-hours), range not reported | Not reported         | USDA, 2003   |
| Aquatic Plant Growth (96.6%) | <i>Chlorella pyrenoidosa</i>     | EC <sub>50</sub> = 590 mg/L, 4-day                                             | Not reported         | USDA, 2003   |
| Aquatic Plant Growth (96.6%) | <i>Chlorococcum hypnosporum</i>  | EC <sub>50</sub> = 68 mg/L, 4-day                                              | Not reported         | USDA, 2003   |
| Aquatic Plant Growth (96.6%) | <i>Zygnema cylindricum</i>       | EC <sub>50</sub> = 88 mg/L, 4-day                                              | Not reported         | USDA, 2003   |
| Aquatic Plant Growth (96.6%) | <i>Anabaena flosaquae</i>        | EC <sub>50</sub> = 304 mg/L, 4-day                                             | Not reported         | USDA, 2003   |
| Aquatic Plant Growth         | <i>Cyclotella</i>                | 73% inhibition at 2.8                                                          | Inhibition of carbon | USDA, 2003   |



| Study Type (% a.i.)          | Species                          | Result                                                                                                                                                                                                                             | Endpoint                                                  | Reference  |
|------------------------------|----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|------------|
| (96.6%)                      | <i>meneghiana</i>                | mg/L                                                                                                                                                                                                                               | fixation after 24 hours                                   |            |
| Aquatic Plant Growth (96.6%) | <i>Nitzschia sp.</i>             | 77% inhibition at 2.8 mg/L                                                                                                                                                                                                         | Inhibition of carbon fixation after 24 hours              | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Scenedesmus quadricauda</i>   | 3% inhibition at 2.8 mg/L                                                                                                                                                                                                          | Inhibition of carbon fixation after 24 hours              | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Selenastrum capricornutum</i> | 18% inhibition at 2.8 mg/L                                                                                                                                                                                                         | Inhibition of carbon fixation after 24 hours              | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Microcystis aeruginosa</i>    | -41% inhibition <sup>a</sup> at 2.8 mg/L                                                                                                                                                                                           | Inhibition of carbon fixation after 24 hours              | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Microcystis aeruginosa</i>    | 16% inhibition at 2.8 mg/L                                                                                                                                                                                                         | Inhibition of carbon fixation after 24 hours              | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Oscillatoria sp.</i>          | -12% inhibition <sup>a</sup> at 2.8 mg/L                                                                                                                                                                                           | Inhibition of carbon fixation after 24 hours              | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Pseudoanabaena sp.</i>        | 12% inhibition at 2.8 mg/L                                                                                                                                                                                                         | Inhibition of carbon fixation after 24 hours              | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Anabaena inaequalis</i>       | 11% inhibition at 2.8 mg/L                                                                                                                                                                                                         | Inhibition of carbon fixation after 24 hours              | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Aphanizomenon flos-aquae</i>  | 74% inhibition at 2.8 mg/L                                                                                                                                                                                                         | Inhibition of carbon fixation after 24 hours              | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Lemna minor</i>               | No inhibition at 2.8 mg/L                                                                                                                                                                                                          | Inhibition of carbon fixation over 5 days                 | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Scenedesmus quadricauda</i>   | Growth stimulation at 0.2 mg/L; stimulation of photosynthesis at 0.2 mg/L; stimulation of chlorophyll-a synthesis at 0.02 mg/L; at $\geq 20$ mg/L complete inhibition of algal growth, photosynthesis, and chlorophyll-a synthesis | Algal growth, photosynthesis, and chlorophyll-a synthesis | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Scenedesmus acutus</i>        | NOEC = 2 mg/L<br>LOEC = 4 mg/L<br>EC <sub>50</sub> = 10.2 mg/L, 96-hour, no range reported                                                                                                                                         | Not reported                                              | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Scenedesmus quadricauda</i>   | NOEC = 3.2 mg/L<br>LOEC = 4.08 mg/L<br>EC <sub>50</sub> = 9.08 mg/L, 96-hour, no range reported                                                                                                                                    | Not reported                                              | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Scenedesmus acutus</i>        | NOEC = 3.2 mg/L<br>LOEC = 4.08 mg/L<br>EC <sub>50</sub> = 9.08 mg/L, 96-hour, no range reported                                                                                                                                    | Not reported                                              | USDA, 2003 |
| Aquatic Plant Growth (96.6%) | <i>Scenedesmus acutus</i>        | NOEC = 1.25 mg/L<br>LOEC = 2.5 mg/L<br>EC <sub>50</sub> = 9.09 mg/L, 96-hour, no range reported                                                                                                                                    | Not reported                                              | USDA, 2003 |

a.e.= glyphosate acid equivalent

<sup>a</sup> Negative values indicate stimulation

<sup>b</sup> Derived from an acute EC<sub>50</sub>/chronic NOEC ratio of 20

#### 4.4.2 Acute Plant Toxicity to Glyphosate Herbicide Formulations

No studies were found addressing the acute toxicity of commercial formulations of glyphosate to plants.

#### 4.4.3 Acute Plant Toxicity to AMPA

Table N-19 shows the acute plant toxicity of AMPA. The EC<sub>50</sub> was established to be 90 mg/L while the NOEC was 7.9 mg/L.

**Table N-19. Aquatic Plants Toxicity to AMPA**

| Study Type           | Species                        | Result                                         | Endpoint     | Reference          |
|----------------------|--------------------------------|------------------------------------------------|--------------|--------------------|
| 3-day Acute Toxicity | <i>Scenedesmus subspicatus</i> | NOEC = 7.9 mg/L;<br>EC <sub>50</sub> = 90 mg/L | Not reported | Giesy et al., 2000 |

#### 4.4.4 Chronic Plant Toxicity to Glyphosate

Table N-20 shows the chronic toxicity of glyphosate on three non-target aquatic plant species. A Tier II terrestrial seedling emergence study indicated <25% effects at a rate of 4.0 lbs ai/A (US EPA, 2006AA). In a Tier II vegetative vigor test on terrestrial plants, found that oil rape seed was the most sensitive dicot species, with phytotoxicity as the most sensitive effect; the EC<sub>25</sub> was 0.074 lb ai/A and NOAEL of 0.038 lb ai/A. The most sensitive monocot species was winter wheat, with dry weight as the most sensitive effect, the EC<sub>25</sub> was 0.159 lb ai/A and NOAEL of 0.049 lb ai/A (US EPA, 2006AA). EC<sub>50</sub> values for glyphosate are as low as 1.6 mg a.e./L (USDA, 2003).

In concentration ranges of 0.002 mg/L to 0.3 mg/L, glyphosate is used as a phosphorus nutrient source for some algae since glyphosate stimulates algal growth at these concentrations (USDA, 2003).

**Table N-20. Chronic Non-Target Aquatic Plants Toxicity to Glyphosate**

| Study Type | Species             | Result                                                                                          | Endpoint                                        | Reference          |
|------------|---------------------|-------------------------------------------------------------------------------------------------|-------------------------------------------------|--------------------|
| Chronic    | <i>Myriophyllum</i> | EC <sub>50</sub> = 1.6 mg a.e./L<br>NOEC = 0.08 <sup>b</sup> mg/L; 14-day,<br>no range reported | Growth Inhibition<br>(change in root<br>length) | Giesy et al., 2000 |
| Chronic    | <i>Lemna gibba</i>  | EC <sub>50</sub> = 10 mg a.e./L<br>7-day, no range reported                                     | Growth Inhibition                               | Giesy et al., 2000 |
| Chronic    | <i>Lemna gibba</i>  | EC <sub>50</sub> = 25.5 mg a.e./L<br>NOEC = 16.6 mg/L; 14-day,<br>no range reported             | Growth Inhibition                               | Giesy et al., 2000 |

<sup>b</sup> Derived from an acute EC<sub>50</sub>/chronic NOEC ratio of 20

### 4.5 Soil Invertebrates and Microorganisms Toxicity

The results of toxicity studies in soil invertebrates and microorganisms from exposure to glyphosate and its formulations are discussed in sections 4.5.1 through 4.5.4 below.

#### 4.5.1 Soil Invertebrates Toxicity to Glyphosate

The results of glyphosate toxicity studies in invertebrates are provided in table N-21. The sensitivity of the earthworm to glyphosate was tested in two 14-day dietary studies using glyphosate IPA salt. The NOEC was determined to be 118.7 mg/kg soil in one study, and the No mortality level was found to be 3,750 mg/kg soil in a second study.

**Table N-21. Soil Invertebrates Toxicity to Glyphosate**

| Study Type (% a.i.) | Species   | Results                 | Endpoint          | Reference          |
|---------------------|-----------|-------------------------|-------------------|--------------------|
| 14-day, Dietary     | Earthworm | NOEC = 118.7 mg/kg soil | NOEC <sup>a</sup> | Giesy et al., 2000 |
| 14-day, Dietary     | Earthworm | NML = 3750 mg/kg soil   | NML <sup>b</sup>  | Giesy et al., 2000 |

<sup>a</sup> NOEC: No Observed Effect Concentration

<sup>b</sup> NML: No Mortality Level

#### 4.5.2 Soil Invertebrates Toxicity to Glyphosate Herbicide Formulations

The sensitivity of the earthworm to Honcho® Herbicide, Honcho® Plus Herbicide, Roundup Original MAX® Herbicide, and Roundup WeatherMAX® was tested in 14-day dietary and acute toxicity studies. The acute toxicity values are provided in table N-22. The NOEC for earthworms was determined to be 500 mg/kg soil in one study, and the NML was found to be 5,000 mg/kg soil in a second study.

**Table N-22. Soil Invertebrates Toxicity to Glyphosate Herbicide Formulations**

| Study Type (% a.i.)                                      | Species   | Results                                  | Endpoint | Reference          |
|----------------------------------------------------------|-----------|------------------------------------------|----------|--------------------|
| 14-day, Dietary (Roundup)                                | Earthworm | NOEC = 500 mg/kg soil                    | NOEC     | Giesy et al., 2000 |
| 14-day, Acute toxicity (Honcho® Herbicide)               | Earthworm | LC <sub>50</sub> > 5,000 mg/kg dry soil  | Death    | Monsanto, 2007b    |
| 14-day, Acute toxicity (Honcho® Plus Herbicide)          | Earthworm | LC <sub>50</sub> > 5,000 mg/kg dry soil  | Death    | Monsanto, 2007d    |
| 14-day, Dietary (Roundup)                                | Earthworm | NML = 5000 mg/kg soil                    | NML      | Giesy et al., 2000 |
| 14-day, Acute toxicity (Roundup Original MAX® Herbicide) | Earthworm | LC <sub>50</sub> > 10,000 mg/kg dry soil | Death    | Monsanto, 2006     |
| 14-day, Acute toxicity (Roundup WeatherMAX® Herbicide)   | Earthworm | LC <sub>50</sub> > 10,000 mg/kg dry soil | Death    | Monsanto, 2005     |

#### 4.5.3 Soil Microorganism Toxicity to Glyphosate

Soil microbes readily metabolize glyphosate into AMPA and other metabolites (USDA, 2003). Microorganisms produce aromatic amino acids through the shikimate pathway, similar to plants. Since glyphosate inhibits this pathway, it could be expected that glyphosate would be toxic to microorganisms. However, field studies show that glyphosate has little effect on soil microorganisms, and, in some cases, field studies have shown an increase in microbial activity (USDA, 2003).

Studies tested the effects of glyphosate and glyphosate formulations on soil microbe's ability for nitrification, denitrification, dehydrogenase activity, nitrogen fixation, urea hydrolysis,

immobilization of ammonium, ammonification, and degradation of cellulose, starch, protein, and leaf litter. *In vitro* studies were excluded from this report due to challenges associated with extrapolating the results of *in vitro* environments to natural soil ecosystems.

The results of chronic glyphosate acid toxicity studies in soil microbes are provided in table N-23. Microbial activities including degradation of leaf litter, cellulose, starch, and protein showed the least sensitivity to glyphosate, while ammonification, denitrification, nitrification, and nitrogen fixation were more sensitive. However, one 3-day nitrification study produced no observable adverse effects up to a concentration of 76.7 mg a.e./kg. Alfalfa is a legume that forms a symbiotic relationship with the nitrogen-fixing bacterium, *Sinorhizobium meliloti*. The result is the conversion of atmospheric nitrogen to fixed nitrogen in the soil, resulting in a net increase in available nitrogen to the soil. GT alfalfa does not alter the symbiotic association with *S. meliloti* and does not negatively affect the availability of nitrogen in the soil.

**Table N-23. Soil Microorganism Toxicity to Glyphosate**

| Study Type (% a.i.)                               | Species            | Result <sup>a</sup>       | Endpoint <sup>b</sup> | Reference          |
|---------------------------------------------------|--------------------|---------------------------|-----------------------|--------------------|
| 7-day, Ammonification                             | Soil Microorganism | NOAEC = 10 mg a.e./kg     | NOAEC                 | Giesy et al., 2000 |
| 7, 14-day, Denitrification                        | Soil Microorganism | NOAEC = 10 mg a.e./kg     | NOAEC                 | Giesy et al., 2000 |
| 14-day, Nitrification                             | Soil Microorganism | NOAEC = < 10 mg a.e./kg   | NOAEC                 | Giesy et al., 2000 |
| 21-day, Nitrification                             | Soil Microorganism | NOAEC = 10 mg a.e./kg     | NOAEC                 | Giesy et al., 2000 |
| 3-day, Nitrification                              | Soil Microorganism | NOAEC = < 76.7 mg a.e./kg | NOAEC                 | Giesy et al., 2000 |
| 7-day, Nitrogen fixation                          | Soil Microorganism | NOAEC = 12.7 mg a.e./kg   | NOAEC                 | Giesy et al., 2000 |
| 84-day, Degradation of cellulose, starch, protein | Soil Microorganism | NOAEC = 25 mg a.e./kg     | NOAEC                 | Giesy et al., 2000 |
| 84-day, Degradation of leaf litter                | Soil Microorganism | NOAEC = 25 mg a.e./kg     | NOAEC                 | Giesy et al., 2000 |

<sup>a</sup> a.e., glyphosate acid equivalents

<sup>b</sup> NOAEC unless specified. Effects may have been observed at higher levels, but they were not judged to be adverse (e.g., stimulatory effects).

#### 4.5.4 Soil Microorganism Toxicity to Glyphosate Herbicide Formulations

The results of chronic toxicity studies of Roundup in soil microbes are provided in table N-24. The No Observable Adverse Effect Concentration (NOAEC) endpoint was determined for various microbial activities, including dehydrogenase activity, immobilization of ammonium, nitrification, nitrogen fixation, urea hydrolysis, and nitrogen and carbon transformation. Microbial response to Roundup varied significantly. For example, the NOAEC for microbial nitrification ranged from 5 mg a.e./kg to 230 mg a.e./kg, and the NOAEC for urea hydrolysis ranged from 5 mg a.e./kg (1-day study) to 50 mg a.e./kg (42-day study).

**Table N-24. Soil Microorganism Toxicity to Glyphosate Herbicide Formulations**

| Study Type (% a.i)                                                           | Species            | Results                 | Endpoint <sup>a</sup>                                              | Reference          |
|------------------------------------------------------------------------------|--------------------|-------------------------|--------------------------------------------------------------------|--------------------|
| 28-day, Dehydrogenase activity (Roundup)                                     | Soil Microorganism | NOAEC = 24 mg a.e./kg   | NOAEC                                                              | Giesy et al., 2000 |
| 42-day, Immobilization of ammonium (Roundup)                                 | Soil Microorganism | NOAEC = 50 mg a.e./kg   | NOAEC                                                              | Giesy et al., 2000 |
| 7-21-day, Nitrification (Roundup)                                            | Soil Microorganism | NOAEC = 5.0 mg a.e./kg  | NOAEC                                                              | Giesy et al., 2000 |
| 25-day, Nitrification (Roundup)                                              | Soil Microorganism | NOAEC = 21.4 mg a.e./kg | NOAEC                                                              | Giesy et al., 2000 |
| 28-day, Nitrification (Roundup)                                              | Soil Microorganism | NOAEC = 24 mg a.e./kg   | NOAEC                                                              | Giesy et al., 2000 |
| 42-day, Nitrification (Roundup)                                              | Soil Microorganism | NOAEC = 50 mg a.e./kg   | NOAEC                                                              | Giesy et al., 2000 |
| 3-day, Nitrification (Roundup)                                               | Soil Microorganism | NOAEC = 230 mg a.e./kg  | NOAEC                                                              | Giesy et al., 2000 |
| 7-day, Nitrogen fixation (Roundup)                                           | Soil Microorganism | NOAEC = 12.7 mg a.e./kg | NOAEC                                                              | Giesy et al., 2000 |
| 1-day, Urea hydrolysis (Roundup)                                             | Soil Microorganism | NOAEC = 5.0 mg a.e./kg  | NOAEC                                                              | Giesy et al., 2000 |
| Urea hydrolysis, test duration not reported (Roundup)                        | Soil Microorganism | NOAEC = 11.5 mg a.e./kg | NOAEC                                                              | Giesy et al., 2000 |
| 42-day, Urea hydrolysis (Roundup)                                            | Soil Microorganism | NOAEC = 50 mg a.e./kg   | NOAEC                                                              | Giesy et al., 2000 |
| 28-day, Nitrogen and carbon transformation (Roundup Original MAX® Herbicide) | Soil Microorganism | 29.5 kg/ha              | <25% effect on nitrogen or carbon transformation processes in soil | Monsanto, 2006     |
| 28-day, Nitrogen and carbon transformation (Roundup WeatherMAX® Herbicide)   | Soil Microorganism | 40 L/ha                 | <25% effect on nitrogen or carbon transformation processes in soil | Monsanto, 2005     |

<sup>a</sup> NOAEC unless specified. Effects may have been observed at higher levels, but they were not judged to be adverse (e.g., stimulatory effects).

## 4.6 Amphibian Toxicity

The results of toxicity studies in amphibians from exposure to glyphosate and its formulations are discussed in sections 4.6.1 through 4.6.2 below.

### 4.6.1 Amphibian Toxicity to Glyphosate

Amphibians use a wide range of aquatic habitats for their breeding sites and could be exposed to glyphosate in surface water. This would most likely occur as a result of heavy rainfall after a recent application and subsequent dissipation into stream sediment (Lajmanovich, 2003). Acute toxicity of glyphosate in amphibians was assessed using 2-day and 4-day acute toxicity studies in tadpoles. Amphibians showed greater sensitivity to glyphosate tested as an acid; LC<sub>50</sub>s for

amphibians ranged from 78 to 121 mg a.e./L for glyphosate tested as acid and 343-466 mg a.e./L for glyphosate tested as IPA salt. The study results are presented in table N-25 below.

**Table N-25. Amphibian Toxicity to Glyphosate**

| Study Type (%a.i.)                   | Species                                         | Results                                                    | Endpoint | Reference          |
|--------------------------------------|-------------------------------------------------|------------------------------------------------------------|----------|--------------------|
| <b>Glyphosate tested as IPA salt</b> |                                                 |                                                            |          |                    |
| 2-day, Acute toxicity                | Tadpole ( <i>Litoria moorei</i> )               | LC <sub>50</sub> = > 343 mg a.e./L                         | Death    | Giesy et al., 2000 |
| 2-day, Acute toxicity                | Tadpole ( <i>Heleioporus eyrei</i> )            | LC <sub>50</sub> = > 373 mg a.e./L                         | Death    | Giesy et al., 2000 |
| 2-day, Acute toxicity                | Tadpole ( <i>Limnodynastes dorsalis</i> )       | LC <sub>50</sub> = > 400 mg a.e./L                         | Death    | Giesy et al., 2000 |
| 2-day, Acute toxicity                | Tadpole ( <i>Crinia insignifera</i> )           | LC <sub>50</sub> = > 466 mg a.e./L                         | Death    | Giesy et al., 2000 |
| <b>Glyphosate tested as acid</b>     |                                                 |                                                            |          |                    |
| 2-day, Acute toxicity                | Newly emerged tadpole ( <i>C. insignifera</i> ) | LC <sub>50</sub> = 83.6 mg a.e./L                          | Death    | Giesy et al., 2000 |
| 2-day, Acute toxicity                | Tadpole ( <i>L. moorei</i> )                    | LC <sub>50</sub> = 81.2 mg a.e./L                          | Death    | Giesy et al., 2000 |
| 2-day, Acute toxicity                | Tadpole ( <i>L. moorei</i> )                    | LC <sub>50</sub> = 121 mg a.e./L                           | Death    | Giesy et al., 2000 |
| 4-day, Acute toxicity                | Adult tadpole ( <i>C. insignifera</i> )         | LC <sub>50</sub> = 78 mg a.e./L<br>NOEC = 45 mg a.e./L     | Death    | Giesy et al., 2000 |
| 4-day, Acute toxicity                | Adult tadpole ( <i>L. moorei</i> )              | LC <sub>50</sub> = > 180 mg a.e./L<br>NOEC = 180 mg a.e./L | Death    | Giesy et al., 2000 |
| 4-day, Acute toxicity                | Tadpole ( <i>L. moorei</i> )                    | LC <sub>50</sub> = 111 mg a.e./L                           | Death    | Giesy et al., 2000 |

#### 4.6.2 Amphibian Toxicity to Glyphosate Herbicide Formulations

Acute toxicity of Roundup in amphibians was assessed using 2-day and 4-day acute toxicity studies in tadpoles. Table N-26 provides acute toxicity LC<sub>50</sub> values for the five tadpole species tested (*C. insignifera*, *H. eyrei*, *L. dorsalis*, *L. moorei*, and *X. laevis*). Amphibians' sensitivity to Roundup varied significantly, both within and across species. LC<sub>50</sub>s for amphibians ranged from 8.1 mg Roundup glyphosate equivalent (a.e.) (RU)/L for *L. moorei* and 175 mg RU/L for *H. eyrei*. In general, adult tadpoles demonstrated higher tolerances to Roundup than juveniles, with the exception of one study performed with *C. insignifera* newly emerged tadpoles (LC<sub>50</sub> 144 mg RU/L).

Amphibians exhibited greater sensitivity to Roundup formulations (LC<sub>50</sub> 8.1 to 175 mg RU/L) than to glyphosate tested as an acid or IPA salt (LC<sub>50</sub> 78 to 466 mg a.e./L). This could be due to the surfactant (POEA) used in agricultural formulations, which has been found to be more toxic to amphibians and other aquatic animals than the herbicide itself (Lajmanovich, 2003). Some researchers have suggested that Roundup (in combination with POEA) could cause extremely high rates of mortality to amphibians that could lead to eventual population declines (Relyea, 2005).

**Table N-26. Amphibian Toxicity to Glyphosate Herbicide Formulations**

| Study Type (% a.i.)             | Species                                         | Results                                                | Endpoint | Reference          |
|---------------------------------|-------------------------------------------------|--------------------------------------------------------|----------|--------------------|
| 2-day, Acute toxicity (Roundup) | Tadpole ( <i>C. insignifera</i> )               | LC <sub>50</sub> = 10 mg RU/L                          | Death    | Giesy et al., 2000 |
| 2-day, Acute toxicity (Roundup) | Tadpole ( <i>C. insignifera</i> )               | LC <sub>50</sub> = < 54.9 mg RU/L                      | Death    | Giesy et al., 2000 |
| 4-day, Acute toxicity (Roundup) | Adult tadpole ( <i>C. insignifera</i> )         | LC <sub>50</sub> = 96.8 mg RU/L<br>NOEC = 54 mg RU/L   | Death    | Giesy et al., 2000 |
| 2-day, Acute toxicity (Roundup) | Adult tadpole ( <i>C. insignifera</i> )         | LC <sub>50</sub> = 137 mg RU/L                         | Death    | Giesy et al., 2000 |
| 2-day, Acute toxicity (Roundup) | Newly emerged tadpole ( <i>C. insignifera</i> ) | LC <sub>50</sub> = 144 mg RU/L                         | Death    | Giesy et al., 2000 |
| 2-day, Acute toxicity (Roundup) | Tadpole ( <i>H. eyrei</i> )                     | LC <sub>50</sub> = 175 mg RU/L                         | Death    | Giesy et al., 2000 |
| 2-day, Acute toxicity (Roundup) | Tadpole ( <i>L. dorsalis</i> )                  | LC <sub>50</sub> = 8.3 mg RU/L                         | Death    | Giesy et al., 2000 |
| 2-day, Acute toxicity (Roundup) | Tadpole ( <i>L. moorei</i> )                    | LC <sub>50</sub> = 8.1 mg RU/L<br>NOEC = 1.6 mg RU/L   | Death    | Giesy et al., 2000 |
| 4-day, Acute toxicity (Roundup) | Tadpole ( <i>L. moorei</i> )                    | LC <sub>50</sub> = 18.7 mg RU/L<br>NOEC = 55 mg RU/L   | Death    | Giesy et al., 2000 |
| 2-day, Acute toxicity (Roundup) | Tadpole ( <i>L. moorei</i> )                    | LC <sub>50</sub> = 32.2 mg RU/L                        | Death    | Giesy et al., 2000 |
| 4-day, Acute toxicity (Roundup) | Adult tadpole ( <i>L. moorei</i> )              | LC <sub>50</sub> = > 165 mg RU/L<br>NOEC = 165 mg RU/L | Death    | Giesy et al., 2000 |
| 4-day, Acute toxicity (Roundup) | <i>Xenopus laevis</i> , embryo                  | LC <sub>50</sub> = 72 mg RU/L                          | Death    | Giesy et al., 2000 |

#### 4.6.3 California Red Legged Frog Toxicity to Glyphosate, Glyphosate Salts, and Glyphosate Formulations

In 2008, the EPA published a risk assessment to determine the effects of glyphosate, its salts, and glyphosate herbicide formulations on the California Red Legged Frog (CRLF)(<http://www.epa.gov/espp/litstatus/effects/redleg-frog/glyphosate/determination.pdf>). Use of glyphosate on alfalfa was one of the uses assessed in the risk assessment. We are incorporating this risk assessment by reference. From the EPA risk assessment:

“There are no direct effects on the aquatic-phase CRLF for any of the terrestrial or aquatic uses. The terrestrial-phase CRLF eating broadleaf plants, small insects and small herbivorous mammals on a dietary-basis may be at risk to direct effects following chronic exposure to glyphosate at application rates of 7.5 lb a.e./A [acre] and above (forestry, areas with impervious surfaces and rights of way). In addition, terrestrial phase amphibians may be at risk following acute exposure to one particular formulation (Registration No. 524-424), at application rates of 1.1 lbs formulation/A and above (ornamental lawns and turf and industrial outdoor uses). Indirect effects to the aquatic-phase CRLF, based on reduction in the prey base may occur with aquatic nonvascular

plants with aquatic weed management uses at an application rate of 3.75 lb a.e./A. Indirect effects to the terrestrial-phase CRLF, based on reduction in the prey base may occur with small insects at any registered rate, large insects at an application rate of 7.95 lb a.e./A (forestry uses), terrestrial phase amphibians following chronic exposure at application rates of 7.5 lb a.e./A and above and following acute exposure to one formulation at application rates of 1.1 lbs formulation/A and above and mammals following chronic exposure at application rates of 3.84 lbs a.e./A and above (i.e., many crops, forestry, rights of way and areas with impervious surfaces).

Indirect effects to both the aquatic- and terrestrial-phase CRLF, based on habitat effects may occur with aquatic non-vascular plants following aquatic weed management use and with aquatic emergent plants and terrestrial plants exposed via spray drift with aerial application at rates of 3.75 lbs /A and above and with ground applications at a rate of 7.95 lbs/A.”

Note that in all cases, the application rate is more than double the maximum single use (ground or aerial) application for GT alfalfa (1.55 lbs a.e./acre; ). The formulation that may have indirect toxic effects for CRLF is a formulation for ornamental planting and lawn/turf grasses, not for GT alfalfa uses.

#### 4.7 Aquatic Invertebrate Toxicity

Several acute and chronic toxicity tests were conducted on aquatic invertebrates for exposure to glyphosate and its formulations. A study was also conducted on the toxic effects of the metabolite AMPA on aquatic invertebrates. The toxicity study results are discussed in sections 4.7.1 through 4.7.4.

##### 4.7.1 Acute Aquatic Invertebrate Toxicity to Glyphosate

The acute toxicity of glyphosate to aquatic invertebrates is summarized in table N-27. The most sensitive species to glyphosate (96.7% a.i.) was *Chironomus plumosus* with a 48-hour EC<sub>50</sub> of 55 ppm (US EPA, 1993). The 48-hour EC<sub>50</sub> for *Daphnia magna* ranged from 780 mg/L (tested as an acid) to 930 mg/L (tested as the IPA salt), with a NOEC value of 560 mg/L (Giesy et al., 2000).



**Table N-27. Acute Aquatic Invertebrate Toxicity to Glyphosate**

| <b>Study Type (% a.i.)</b> | <b>Species</b>                  | <b>Result</b>                                                                            | <b>Endpoint</b> | <b>Reference</b>                |
|----------------------------|---------------------------------|------------------------------------------------------------------------------------------|-----------------|---------------------------------|
| Acute (96.7%)              | <i>Chironomus plumosus</i>      | LC <sub>50</sub> (95% CL) = 55 ppm (31-97), 48-hour                                      | Death           | US EPA, 1993                    |
| Acute                      | <i>Chironomus plumosus</i>      | EC <sub>50</sub> (95% CL) = 55 ppm (31-97), 48-hour                                      | Not reported    | USDA, 2003                      |
| Acute (83%)                | <i>Daphnia magna</i>            | LC <sub>50</sub> = 780 ppm, 48-hour, range not reported                                  | Death           | US EPA, 1993 <sup>a</sup>       |
| <i>Tested as acid:</i>     |                                 |                                                                                          |                 |                                 |
| Acute                      | <i>Ceriodaphnia dubia</i>       | LC <sub>50</sub> (95% CI) = 147 mg/L (141-153), 48-hour                                  | Death           | Tsui and Chu, 2003              |
| Acute                      | <i>Daphnia magna</i>            | Toxicity Value <sup>b</sup> = 780 mg/L, 48-hour range not reported<br>NOEC = 560 mg/L    | Not reported    | Giesy et al., 2000 <sup>a</sup> |
| Acute                      | <i>Pseudosuccinea columella</i> | Toxicity Value <sup>b</sup> = 98.9 mg/L, range and time frame exposure time not reported | Not reported    | Giesy et al., 2000              |
| <i>Tested as IPA salt:</i> |                                 |                                                                                          |                 |                                 |
| Acute                      | <i>Chironomus plumosus</i>      | Toxicity Value <sup>b</sup> = 55 mg/L, 48-hour, range not reported                       | Not reported    | Giesy et al., 2000              |
| Acute                      | <i>Chironomus riparius</i>      | Toxicity Value <sup>b</sup> = 5600 mg/L, 48-hour, range not reported                     | Not reported    | Giesy et al., 2000              |
| Acute; Sediment/water test | <i>Chironomus tetans</i>        | Toxicity Value <sup>b</sup> = >530 mg/L, 10 day, range not reported<br>NOEC = 265 mg/L   | Not reported    | Giesy et al., 2000              |
| Acute                      | <i>Ceriodaphnia dubia</i>       | LC <sub>50</sub> (95% CI) = 415 mg/L (339-508), 48-hour                                  | Death           | Tsui and Chu, 2003              |
| Acute                      | <i>Daphnia magna</i>            | Toxicity Value <sup>b</sup> = 930 mg/L, 48-hour, range not reported<br>NOEC = 320 mg/L   | Not reported    | Giesy et al., 2000              |
| Acute; Sediment/water test | <i>Hyalella azteca</i>          | Toxicity Value <sup>a</sup> = >530 mg/L, 10 day, range not reported<br>NOEC = 265 mg/L   | Not reported    | Giesy et al., 2000              |

#### 4.7.2 Acute Aquatic Invertebrate Toxicity to Glyphosate Herbicide Formulations

The acute toxicity of glyphosate formulations to aquatic invertebrates is summarized in table N-28. The most sensitive species to glyphosate formulations was *Daphnia magna* with a 48-hour EC<sub>50</sub> of 3.0 ppm (USDA, 2003). The 48-hour EC<sub>50</sub> for *Daphnia magna* ranged from 3.0 ppm to 160 mg/L (USDA, 2003; Monsanto, 2005, 2006, 2007b, 2007d). As evidenced by this data, glyphosate formulations are several orders of magnitude more toxic to *Daphnia magna* than technical glyphosate. The 48-hour EC<sub>50</sub> for *Chironomus plumosus* was 58.1 ppm (Giesy et al., 2000). Toxicity values (96-hour EC<sub>50</sub> or LC<sub>50</sub>) for *Gammarus pseudolimnaeus* ranged from 42 mg/L to 200 mg/L, with a NOEC value of 4.4 mg/L (Giesy et al., 2000).

**Table N-28. Acute Aquatic Invertebrate Toxicity to Glyphosate Herbicide Formulation**

| Study Type             | Formulation           | Species                                               | Result                                                                             | Endpoint     | Reference          |
|------------------------|-----------------------|-------------------------------------------------------|------------------------------------------------------------------------------------|--------------|--------------------|
| Acute Toxicity         | Roundup               | Fourth instar <i>Anopheles quadrimaculatus</i> larvae | LC <sub>50</sub> (95% CL) = 673.43 ppm (572.57-770.17), 24-hour                    | Death        | USDA, 2003         |
| Acute Toxicity         | Roundup               | <i>Chironomus plumosus</i>                            | Toxicity Value <sup>a</sup> = 58.1 mg/L <sup>b</sup> , 48-hour, range not reported | Not reported | Giesy et al., 2000 |
| Acute Toxicity         | Roundup               | <i>Ceriodaphnia dubia</i>                             | LC <sub>50</sub> (95% CL) = 5.39 mg/L (4.81-6.05), 48-hour                         | Death        | Tsui and Chu, 2003 |
| Acute Toxicity         | Roundup               | Fourth instar <i>Culex salinarius</i> larvae          | LC <sub>50</sub> (95% CL) = 1563.69 ppm (1262.00-2214.54), 24-hour                 | Death        | USDA, 2003         |
| Acute Toxicity         | Roundup               | <i>Daphnia magna</i>                                  | EC <sub>50</sub> (95% CL) = 3.0 ppm (2.6-3.4), 48-hour                             | Not reported | USDA, 2003         |
| Acute Toxicity, Static | Roundup Original MAX® | <i>Daphnia magna</i>                                  | EC <sub>50</sub> = 8.0 mg/L <sup>c</sup> , 48-hour                                 | Not reported | Monsanto, 2006     |
| Acute Toxicity, Static | Roundup WeatherMAX®   | <i>Daphnia magna</i>                                  | EC <sub>50</sub> = 8.0 mg/L <sup>c</sup> , 48-hour                                 | Not reported | Monsanto, 2005     |
| Acute Toxicity, Static | Roundup UltraMAX® II  | <i>Daphnia magna</i>                                  | EC <sub>50</sub> = 8.0 mg/L <sup>c</sup> , 48-hour                                 | Not reported | Monsanto, 2003     |
| Acute Toxicity         | Roundup               | <i>Daphnia magna</i>                                  | EC <sub>50</sub> = 9.7 mg/L <sup>b</sup> , 48-hour<br>NOEC = 1.9 mg/L <sup>d</sup> | Not reported | Giesy et al., 2000 |
| Acute Toxicity, Static | Honcho®               | <i>Daphnia magna</i>                                  | EC <sub>50</sub> = 11.0 mg/L <sup>c</sup> , 48-hour                                | Not reported | Monsanto, 2007b    |
| Acute Toxicity         | Roundup               | <i>Daphnia magna</i>                                  | Toxicity Value <sup>a</sup> = 12.9 mg/L <sup>b</sup> ; 48-hour<br>NOEC = 4.6 mg/L  | Not reported | Giesy et al., 2000 |
| Acute Toxicity         | Roundup               | <i>Daphnia magna</i>                                  | Toxicity Value <sup>a</sup> = 24 mg/L; 48-hour<br>NOEC = 7.8 mg/L                  | Not reported | Giesy et al., 2000 |
| Acute Toxicity, Static | Honcho® Plus          | <i>Daphnia magna</i>                                  | EC <sub>50</sub> = 160 mg/L, 48-hour                                               | Not reported | Monsanto, 2007d    |

| Study Type     | Formulation | Species                                          | Result                                                                                                      | Endpoint     | Reference          |
|----------------|-------------|--------------------------------------------------|-------------------------------------------------------------------------------------------------------------|--------------|--------------------|
| Acute Toxicity | Roundup     | <i>Daphnia pulex</i>                             | EC <sub>50</sub> (95% CL) = 3.2 ppm (3.0-3.4), 48-hour                                                      | Not reported | USDA, 2003         |
| Acute Toxicity | Roundup     | <i>Daphnia pulex</i>                             | EC <sub>50</sub> (95% CL) = 7.9 ppm (7.2-8.6), 48-hour                                                      | Not reported | USDA, 2003         |
| Acute Toxicity | Roundup     | <i>Daphnia pulex</i>                             | Toxicity Value <sup>a</sup> = 19 mg/L, 48-hour                                                              | Not reported | Giesy et al., 2000 |
| Acute Toxicity | Roundup     | <i>Daphnia pulex</i>                             | Toxicity Value <sup>a</sup> = 25.5 mg/L, 96-hour                                                            | Not reported | Giesy et al., 2000 |
| Acute Toxicity | Roundup     | <i>Daphnia</i> sp.                               | LC <sub>50</sub> = 5.3 ppm, 48-hour                                                                         | Death        | USDA, 2003         |
| Acute Toxicity | Roundup     | <i>Daphnia</i> sp.                               | LC <sub>50</sub> (95% CL) = 192 ppm (181-205), 48-hour                                                      | Death        | USDA, 2003         |
| Acute Toxicity | Roundup     | <i>Gammarus pseudolimnaeus</i>                   | Toxicity Value <sup>a</sup> = 42 mg/L; 48-hour<br>NOEC = 4.4 mg/L                                           | Not reported | Giesy et al., 2000 |
| Acute Toxicity | Roundup     | <i>Gammarus pseudolimnaeus</i>                   | LC <sub>50</sub> (95% CL) = 62 ppm (40-98), 48-hour;<br>LC <sub>50</sub> (95% CL) = 43 ppm (28-66), 96-hour | Death        | USDA, 2003         |
| Acute Toxicity | Roundup     | <i>Gammarus pseudolimnaeus</i>                   | Toxicity Value <sup>a</sup> = 138.7 mg/L <sup>b</sup> ; 96-hour                                             | Not reported | Giesy et al., 2000 |
| Acute Toxicity | Roundup     | <i>Gammarus pseudolimnaeus</i>                   | Toxicity Value <sup>a</sup> = 200 mg/L <sup>b</sup> ; 48-hour                                               | Not reported | Giesy et al., 2000 |
| Acute Toxicity | Roundup     | <i>Nitocra spinipes</i>                          | LC <sub>50</sub> (95% CL) = 22 ppm (17-29), 96-hour                                                         | Death        | USDA, 2003         |
| Acute Toxicity | Roundup     | <i>Orconectes nais</i>                           | Toxicity Value <sup>a</sup> = 7 mg/L, 96-hour                                                               | Not reported | Giesy et al., 2000 |
| Acute Toxicity | Roundup     | <i>Proambarus</i>                                | LC <sub>50</sub> = 96, 597 ppm, 48-hour<br>LC <sub>50</sub> = 64,002 ppm, 96-hour                           | Death        | USDA, 2003         |
| Acute Toxicity | Roundup     | <i>Procambarus clarkia</i>                       | LC <sub>50</sub> (95% CL) = 47.31 ppm (41.06-51.69); 96-hour                                                | Death        | USDA, 2003         |
| Acute Toxicity | Roundup     | <i>Pseudosuccinea columella</i>                  | Delayed effect on growth and development, egg-laying capacity and hatching; 3 generations; 0.1-10 mg/L      | Not reported | USDA, 2003         |
| Acute Toxicity | Roundup     | Fourth instar <i>Psurophora columbiae</i> larvae | LC <sub>50</sub> (95% CL) = 940.84 ppm (823.08-1067.12), 24-hour                                            | Death        | USDA, 2003         |
| Acute Toxicity | Roundup     | <i>Scapholeberis kingi</i>                       | Toxicity Value <sup>a</sup> = 61 mg/L, 3-hour, range not reported                                           | Not reported | Giesy et al., 2000 |

<sup>a</sup> Values were not specified as EC<sub>50</sub> or LC<sub>50</sub>.

<sup>b</sup> Value from data sources corrected to mg roundup/L

<sup>c</sup> Values are derived from a similar formulation

<sup>d</sup> Derived from an acute EC<sub>50</sub>/acute NOEC ratio of 5

#### 4.7.3 Acute Aquatic Invertebrate Toxicity to AMPA

The acute toxicity of AMPA to the freshwater flea – *Daphnia magna* is shown below in table N-29. The NOEC was 320 mg AMPA/L while the EC<sub>50</sub>/LC<sub>50</sub> was observed to be 690 mg/L.

**Table N-29. Acute Aquatic Invertebrate Toxicity to AMPA**

| Study Type (% a.i.) | Species              | Result                                                 | Endpoint     | References         |
|---------------------|----------------------|--------------------------------------------------------|--------------|--------------------|
| 2 day – Acute       | <i>Daphnia magna</i> | NOEC = 320 mg AMPA/L; LC <sub>50</sub> = 690 mg AMPA/L | Not reported | Giesy et al., 2000 |

#### 4.7.4 Chronic Aquatic Invertebrate Toxicity to Glyphosate

Several studies are available addressing the chronic toxicity of glyphosate to freshwater invertebrates (table N-30). A MATC of between 50 and 96 mg/L was determined for *Daphnia magna* in a flow-through study with glyphosate (99.7% a.i.) (US EPA, 1993). A flow-through study reported a 21-day NOEC of 100 mg/L (Giesy et al., 2000). A 4-week study in *Pseudosuccinea columella* observed increased protein concentrations of snails reared in 1.0 mg/L glyphosate compared to those reared in 0.1 mg/L (USDA, 2003). Another 4-week developmental study in *Pseudosuccinea columella* with glyphosate (93% a.i.) observed an increased quantity of free amino acid pool (USDA, 2003).

**Table N-30. Chronic Aquatic Invertebrate Toxicity to Glyphosate**

| Study Type (% a.i.)           | Species                         | Result                                                                                                                                                  | Endpoint                      | References         |
|-------------------------------|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|--------------------|
| Chronic, flow-through (99.7%) | <i>Daphnia magna</i>            | MATC = > 50 - <96 mg/L, time frame exposure time not reported                                                                                           | Reduced reproductive capacity | US EPA, 1993       |
|                               | <i>Pseudosuccinea columella</i> | Increased protein concentration of snails reared in 1.0 mg/L compared to those reared in 0.1 mg/L; exact mechanism for response not determined; 4 weeks | Biochemical alteration        | USDA, 2003         |
| Developmental (93%)           | <i>Pseudosuccinea columella</i> | Increased quantity of free amino acid pool; 4 weeks                                                                                                     | Not reported                  | USDA, 2003         |
| <i>Tested as acid:</i>        |                                 |                                                                                                                                                         |                               |                    |
| Chronic, flow-through         | <i>Daphnia magna</i>            | NOEC = 50 mg a.e./L, 21-day, range not reported                                                                                                         | Not reported                  | Giesy et al., 2000 |
| Chronic, static               | <i>Daphnia magna</i>            | NOEC = 100 mg a.e./L, 21-day, range not reported                                                                                                        | Not reported                  | Giesy et al., 2000 |

#### 4.7.5 Chronic Aquatic Invertebrate Toxicity to Glyphosate Herbicide Formulations

The chronic toxicity of glyphosate formulations to aquatic invertebrates is summarized in table N-31. A 21-day study identified a NOEC of 3.2 mg/L for *Daphnia magna* (Giesy, et al., 2000). In accordance with acute toxicity observations, formulations of glyphosate were more toxic to *Daphnia magna* than technical glyphosate. A chronic toxicity study in *tubifex tubifex* identified a NOEC of greater than 89 mg/L (Giesy, et al., 2000).

**Table N-31. Chronic Aquatic Invertebrate Toxicity to Glyphosate Herbicide Formulation**

| Study Type       | Formulation | Species                | Result                  | Reference           |
|------------------|-------------|------------------------|-------------------------|---------------------|
| Chronic toxicity | Roundup     | <i>Daphnia magna</i>   | NOEC= 3.2 mg/L, 21 days | Giesy, et al., 2000 |
| Chronic toxicity | Roundup     | <i>Tubifex tubifex</i> | NOEC= >89 mg/L          | Giesy, et al., 2000 |

## 4.8 Fish Toxicity

Several acute and chronic toxicity tests were conducted on fish for exposure to glyphosate and its formulations. The toxicity study results are discussed in sections 4.8.1 through 4.8.5.

### 4.8.1 Acute Fish Toxicity to Glyphosate

A large number of studies have been performed in a variety of species of fish to determine the acute toxicity of glyphosate. The acute toxicity of glyphosate to freshwater fish is summarized in table N-32. Studies conducted on saltwater/estuarine fish were not reported. The most sensitive species to glyphosate is rainbow trout (fry), with a 96-hour LC<sub>50</sub> of 7.9 parts per million (ppm) (USDA, 2003). The 96-hour LC<sub>50</sub> of glyphosate to rainbow trout ranges from 7.9 ppm glyphosate (percent active ingredient [a.i.] unknown) to 25,657 mg/L glyphosate (38% a.i.) (USDA, 2003). This large range is most likely indicative of different study conditions. Sockeye salmon was observed to have an 96-hour LC<sub>50</sub> ranging from 8.1 ppm (fingerling) to 8.7 ppm (fry), and Coho salmon was observed to have an 96-hour LC<sub>50</sub> ranging from 12.8 ppm (fry) to 36 mg/L (glyphosate tested as an acid) (USDA, 2003).

For bluegill sunfish, a 96-hour Toxic Limit (TL)<sub>50</sub> of 24 ppm was reported for a dynamic study with glyphosate (96.5% a.i.) (USDA, 2003). Reported 96-hour LC<sub>50</sub> values ranged from 120 ppm to >1000 mg/L (tested as IPA salt) (USDA, 2003; Giesy et al., 2000). The 96-hour LC<sub>50</sub> value for channel catfish was 130 mg/L (tested as IPA salt) (Giesy et al., 2000). The 96-hour LC<sub>50</sub> for fathead minnow ranged from 84.9 mg/L (87.3% a.i.) to > 648 mg/L (tested as the IPA salt) (US EPA, 1993; Giesy et al., 2000). Salmonids are more sensitive to glyphosate than other species of fish.

**Table N-32. Acute Freshwater Fish Toxicity to Glyphosate**

| Study Type<br>(% a.i. if provided) | Species              | Result                                                    | Endpoint     | Reference               |
|------------------------------------|----------------------|-----------------------------------------------------------|--------------|-------------------------|
| Acute, Static                      | Rainbow Trout (fry)  | LC <sub>50</sub> = 7.8 ppm, 96-hour, range not reported   | Death        | USDA, 2003              |
| Acute, Static                      | Sockeye (fingerling) | LC <sub>50</sub> = 8.1 ppm, 96-hour, range not reported   | Death        | USDA, 2003              |
| Acute, Static                      | Sockeye (fingerling) | LC <sub>50</sub> = 8.4 ppm, 96-hour, range not reported   | Death        | USDA, 2003              |
| Acute, Static                      | Rainbow Trout (fry)  | LC <sub>50</sub> = 8.5 ppm, 96-hour, range not reported   | Death        | USDA, 2003              |
| Acute, Static                      | Sockeye (fry)        | LC <sub>50</sub> = 8.7 ppm, 96-hour, range not reported   | Death        | USDA, 2003              |
| Acute, Static                      | Rainbow Trout        | LC <sub>50</sub> = 10.42 ppm, 96-hour, range not reported | Death        | USDA, 2003              |
| Acute, Static                      | Coho Salmon (fry)    | LC <sub>50</sub> = 12.8 ppm, 96-hour, range not reported  | Death        | USDA, 2003              |
| Acute                              | Bleak                | LC <sub>50</sub> = 16 ppm (15-18), 96-hour                | Death        | USDA, 2003 <sup>b</sup> |
| Acute, Dynamic                     | Bluegill             | TL <sub>50</sub> = 24 ppm, 96-hour, range not reported    | Not reported | USDA, 2003              |

| Study Type<br>(% a.i. if provided) | Species                | Result                                                                                                                | Endpoint     | Reference               |
|------------------------------------|------------------------|-----------------------------------------------------------------------------------------------------------------------|--------------|-------------------------|
| Acute (96.5%)                      | Bluegill Sunfish       | LC <sub>50</sub> = > 24 mg/L, 48-hour,<br>range not provided                                                          | Death        | US EPA, 1993            |
| Acute                              | Rainbow Trout          | TL <sub>50</sub> = 38 ppm, 96-hour, range<br>not reported                                                             | Not reported | USDA, 2003              |
| Acute                              | Rainbow Trout<br>(fry) | LC <sub>50</sub> = 50 ppm, 96-hour, range<br>not reported                                                             | Death        | USDA, 2003              |
| Acute                              | Bluegill               | TL <sub>50</sub> = 78 ppm, 96-hour, range<br>not reported                                                             | Not reported | USDA, 2003              |
| Acute (87.3%)                      | Fathead Minnow         | LC <sub>50</sub> (95% CL) = 84.9 mg/L<br>(72.9-99.3), 48-hour                                                         | Death        | US EPA, 1993            |
| Acute, Static (96.7%)              | Fathead Minnow         | LC <sub>50</sub> (95% CL) = 97 mg/L (79-<br>120), 48-hour                                                             | Death        | US EPA, 1993            |
| Acute, Pulse<br>Exposure (95%)     | Flagfish               | LC <sub>20</sub> = 29.6 ppm, 96-hour,<br>range not reported                                                           | Death        | USDA, 2003              |
| Acute (83%)                        | Rainbow Trout          | LC <sub>50</sub> (95% CL) = 86 mg/L (70-<br>106), 48-hour                                                             | Death        | US EPA, 1993            |
| Acute                              | Trout                  | LC <sub>50</sub> = 86 ppm, 96-hour, range<br>not reported                                                             | Death        | USDA, 2003              |
| Acute                              | Carp                   | LC <sub>50</sub> = 115 ppm, 96-hour,<br>range not reported                                                            | Death        | USDA, 2003              |
| Acute, Static                      | Carp                   | TL <sub>50</sub> = 115 ppm<br>TL <sub>1</sub> = 125 ppm<br>TL <sub>99</sub> = 105 ppm<br>96-hour, range not reported  | Not reported | USDA, 2003              |
| Acute, Static                      | Carp                   | TL <sub>50</sub> = 119 ppm<br>TL <sub>1</sub> = 146 ppm<br>TL <sub>99</sub> = 96.7 ppm<br>48-hour, range not reported | Not reported | USDA, 2003              |
| Acute                              | Bluegill               | LC <sub>50</sub> = 120 ppm, 96-hour,<br>range not reported                                                            | Death        | USDA, 2003              |
| Acute (83%)                        | Bluegill Sunfish       | LC <sub>50</sub> (95% CL) = 120 mg/L<br>(111-130), 48-hour                                                            | Death        | US EPA, 1993            |
| Acute, Static (96.7%)              | Channel Catfish        | LC <sub>50</sub> (95% CL) = 130 mg/L<br>(110-160), 48-hour                                                            | Death        | US EPA, 1993            |
| Acute, Static (96.7%)              | Bluegill Sunfish       | LC <sub>50</sub> (95% CL) = 140 mg/L<br>(110-160), 48-hour                                                            | Death        | US EPA, 1993            |
| Acute, Static (96.7%)              | Rainbow Trout          | LC <sub>50</sub> (95% CL) = 140 mg/L<br>(120-170), 48-hour                                                            | Death        | US EPA, 1993            |
| Acute                              | Harlequin fish         | LC <sub>50</sub> = 168 ppm, 96-hour,<br>range not reported                                                            | Death        | USDA, 2003 <sup>e</sup> |
| Acute, Semi-Static<br>(62%)        | Carp                   | LC <sub>50</sub> = 620 ppm, 96-hour,<br>range not reported                                                            | Death        | USDA, 2003              |
| Acute, Semi-Static<br>(62%)        | Carp                   | LC <sub>50</sub> = 645 ppm, 48-hour,<br>range not reported                                                            | Death        | USDA, 2003              |
| Acute, Static (54.9%)              | Rainbow trout          | LC <sub>50</sub> = 7,620 mg/L, 96-hour,<br>range not reported<br>NOEC = 6,250 mg/L                                    | Death        | USDA, 2003              |
| Acute, Static (54.9%)              | Goldfish               | LC <sub>50</sub> = 7,816 mg/L, 96-hour,<br>range not reported<br>NOEC = 1,500 mg/L                                    | Death        | USDA, 2003              |
| Acute, Static (36%)                | Rainbow trout          | LC <sub>50</sub> = 25,605 mg/L, 96-hour,<br>range not reported<br>NOEC = 8,000 mg/L                                   | Death        | USDA, 2003              |
| Acute, Static (38%)                | Rainbow Trout          | LC <sub>50</sub> = 25,657 mg/L, 96-hour,<br>range not reported                                                        | Death        | USDA, 2003              |

| Study Type<br>(% a.i. if provided) | Species          | Result                                                      | Endpoint | Reference                       |
|------------------------------------|------------------|-------------------------------------------------------------|----------|---------------------------------|
| <i>Tested as acid:</i>             |                  |                                                             |          |                                 |
| Acute Toxicity                     | Chum salmon      | LC <sub>50</sub> = 22 mg/L, 148 mg/L <sup>a</sup> , 96-hour | Death    | Giesy et al., 2000              |
| Acute Toxicity                     | Rainbow trout    | LC <sub>50</sub> = 22 mg/L, 197 mg/L <sup>a</sup> , 96-hour | Death    | Giesy et al., 2000              |
| Acute Toxicity                     | Pink salmon      | LC <sub>50</sub> = 23 mg/L, 190 mg/L <sup>a</sup> , 96-hour | Death    | Giesy et al., 2000              |
| Acute                              | Bluegill sunfish | LC <sub>50</sub> = >24 mg/L, 96-hour<br>NOEC = 24 mg/L      | Death    | Giesy et al., 2000 <sup>b</sup> |
| Acute Toxicity                     | Chinook salmon   | LC <sub>50</sub> = 30 mg/L, 211 mg/L <sup>a</sup> , 96-hour | Death    | Giesy et al., 2000              |
| Acute Toxicity                     | Flagfish         | LC <sub>50</sub> = >30 mg/L, 96-hour                        | Death    | Giesy et al., 2000              |
| Acute Toxicity                     | Coho salmon      | LC <sub>50</sub> = 36 mg/L, 174 mg/L <sup>a</sup> , 96-hour | Death    | Giesy et al., 2000              |
| Acute                              | Bluegill sunfish | LC <sub>50</sub> = 120 mg/L, 96-hour<br>NOEC = 100 mg/L     | Death    | Giesy et al., 2000              |
| Acute Toxicity                     | Rainbow trout    | LC <sub>50</sub> = 86 mg/L, 96-hour<br>NOEC = 42 mg/L       | Death    | Giesy et al., 2000              |
| Acute Toxicity                     | Harlequin fish   | LC <sub>50</sub> = 168 mg/L, 96-hour<br>NOEC = <100         | Death    | Giesy et al., 2000 <sup>c</sup> |
| Acute Toxicity                     | Rainbow trout    | LC <sub>50</sub> = >1000 mg/L, 96-hour<br>NOEC = 1000 mg/L  | Death    | USDA, 2003                      |
| <i>Tested as IPA salt:</i>         |                  |                                                             |          |                                 |
| Acute                              | Fathead minnow   | LC <sub>50</sub> = 97 mg/L, 96-hour                         | Death    | Giesy et al., 2000              |
| Acute                              | Bluegill sunfish | LC <sub>50</sub> = 140-220 mg/L, 96-hour                    | Death    | Giesy et al., 2000              |
| Acute                              | Bluegill sunfish | LC <sub>50</sub> = >1000 mg/L, 96-hour<br>NOEC = 560 mg/L   | Death    | Giesy et al., 2000              |
| Acute                              | Channel catfish  | LC <sub>50</sub> = 130 mg/L, 96-hour                        | Death    | Giesy et al., 2000              |
| Acute                              | Rainbow trout    | LC <sub>50</sub> = 140-240 mg/L, 96-hour                    | Death    | Giesy et al., 2000              |
| Acute                              | Fathead minnow   | LC <sub>50</sub> = >648 mg/L, 96-hour<br>NOEC = 648 mg/L    | Death    | Giesy et al., 2000              |
| Acute                              | Plains minnow    | LC <sub>50</sub> = >648 mg/L, 96-hour<br>NOEC = 648 mg/L    | Death    | Giesy et al., 2000              |
| Acute                              | Bluegill sunfish | LC <sub>50</sub> = >1000 mg/L, 96-hour<br>NOEC = 560 mg/L   | Death    | Giesy et al., 2000              |
| Acute                              | Rainbow trout    | LC <sub>50</sub> = >1000 mg/L, 96-hour<br>NOEC = 1000 mg/L  | Death    | Giesy et al., 2000              |

<sup>a</sup> Values for soft (creek) and hard (lake) water, respectively

<sup>b</sup> Linden E. et al. (1979) as cited in USDA, 2003 and Bionomics (1973c) as cited in Giesy et al., 2000 are believed to reference identical studies, but this can not be confirmed with available data. Therefore, both studies are listed.

<sup>c</sup> Monsanto Co. (1982a) as cited in USDA, 2003 and HRC (1977) as cited in Giesy et al., 2000 are believed to reference identical studies, but this can not be confirmed with available data. Therefore, both studies are listed.

#### 4.8.2 Acute Fish Toxicity to Glyphosate Herbicide Formulations

Many studies have also been performed in a variety of species of fish to determine the acute toxicity of glyphosate formulations. This ecotoxicity risk assessment was limited to glyphosate formulations suggested for use on GT alfalfa. The acute toxicity of glyphosate to freshwater fish is summarized in table N-33. Studies conducted on saltwater fish were not reported.

In general, the glyphosate formulations were more toxic to fish than technical glyphosate. The most sensitive species to the formulations considered was rainbow trout with an 96-hour LC<sub>50</sub> of 3.13 mg/L when treated with formulations similar to Roundup UltraMAX II® and Roundup WeatherMAX® (Monsanto, 2004 and 2005). Comparatively, the 96-hour LC<sub>50</sub> for rainbow trout treated with glyphosate was 7.9 ppm (which equates to 7.9 mg/L). The 96-hour LC<sub>50</sub> for rainbow trout treated with glyphosate formulations ranged from 3.13 mg/L to 52 mg/L (Monsanto, 2005, 2006, 2007b, 2007d; Giesy et al., 2000). Interestingly, salmon species were less sensitive to glyphosate formulations than to glyphosate. When treated with glyphosate formulations, sockeye salmon was observed to have an 96-hour LC<sub>50</sub> of 26.7 mg/L, and Coho salmon was observed to have an 96-hour LC<sub>50</sub> ranging from 13 ppm mg/L to 42 mg/L (Giesy et al., 2000).

For bluegill sunfish, reported 96-hour LC<sub>50</sub> values ranged from 5.2 mg/L to 34 mg/L (Monsanto, 2005, 2006, 2007b, 2007d; Giesy et al., 2000). The 96-hour LC<sub>50</sub> value for channel catfish ranged from 10.6 mg/L (fry) to 42 mg/L (adult) (Giesy et al., 2000). The 96-hour LC<sub>50</sub> for fathead minnow ranged from 7.4 mg/L to 23 mg/L. In bluegill sunfish, channel catfish, and fathead minnow, formulations of glyphosate are much more toxic than technical grade glyphosate (Giesy et al., 2000). The increased toxicity is due to the presence of a surfactant in glyphosate formulations.

**Table N-33. Acute Freshwater Fish Toxicity to Glyphosate Herbicide Formulation**

| Study Type                   | Formulation           | Species                   | Result                                                                              | Endpoint | Reference          |
|------------------------------|-----------------------|---------------------------|-------------------------------------------------------------------------------------|----------|--------------------|
| Acute Toxicity, Semi-static  | Roundup WeatherMAX®   | Rainbow Trout             | LC <sub>50</sub> = 3.13 mg/L <sup>a</sup> , 96-hour                                 | Death    | Monsanto, 2005     |
| Acute Toxicity, Semi-static  | Roundup UltraMAX® II  | Rainbow Trout             | LC <sub>50</sub> = 3.13 mg/L <sup>a</sup> , 96-hour                                 | Death    | Monsanto, 2003     |
| Acute Toxicity               | Roundup               | Rainbow trout, fingerling | LC <sub>50</sub> = 4.2 – 27 mg/L <sup>b</sup> , 96-hour<br>NOEC = 0.84 <sup>d</sup> | Death    | Giesy et al., 2000 |
| Acute Toxicity, Static       | Roundup Original MAX® | Bluegill sunfish          | LC <sub>50</sub> = 5.2 mg/L <sup>a</sup> , 96-hour                                  | Death    | Monsanto, 2006     |
| Acute Toxicity, Static       | Roundup Original MAX® | Common carp               | LC <sub>50</sub> = 4.0 mg/L <sup>a</sup> , 96-hour                                  | Death    | Monsanto, 2005     |
| Acute Toxicity, Flow through | Honcho®               | Bluegill sunfish          | LC <sub>50</sub> = 5.8 mg/L <sup>a</sup> , 96-hour                                  | Death    | Monsanto, 2007b.   |
| Acute Toxicity               | Roundup               | Bluegill Sunfish          | LC <sub>50</sub> = 5.8 mg/L, 96-hour<br>NOEC = 2.2 mg/L                             | Death    | Giesy et al., 2000 |
| Acute Toxicity               | Roundup               | Fathead minnow            | LC <sub>50</sub> = 7.4 mg/L <sup>b</sup> , 96-hour                                  | Death    | Giesy et al., 2000 |
| Acute Toxicity               | Roundup               | Carp                      | LC <sub>50</sub> = 10 mg/L, 96-hour<br>NOEC = 5.6 mg/L                              | Death    | Giesy et al., 2000 |
| Acute Toxicity, Flow through | Honcho®               | Rainbow Trout             | LC <sub>50</sub> = 8.2 mg/L <sup>a</sup> , 96-hour                                  | Death    | Monsanto 2007b     |



| Study Type             | Formulation  | Species                       | Result                                                                             | Endpoint | Reference          |
|------------------------|--------------|-------------------------------|------------------------------------------------------------------------------------|----------|--------------------|
| Acute Toxicity         | Roundup      | Rainbow Trout                 | LC <sub>50</sub> = 8.2 mg/L, 96-hour<br>NOEC = 6.4 mg/L                            | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Channel catfish, fry          | LC <sub>50</sub> = 10.6 mg/L <sup>b</sup> , 96-hour                                | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Tilapia                       | LC <sub>50</sub> = 13 mg/L, time frame exposure time not reported                  | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Mosquito fish                 | LC <sub>50</sub> = 15 mg/L, 96-hour                                                | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Carp                          | LC <sub>50</sub> = 15 mg/L, 96-hour                                                | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Rainbow Trout                 | LC <sub>50</sub> = 15 mg/L, 14 mg/L <sup>c</sup> , 96-hour                         | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Rainbow Trout, Natural Waters | LC <sub>50</sub> = 15 mg/L, 96-hour                                                | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Bluegill Sunfish              | LC <sub>50</sub> = 16.1 mg/L <sup>b</sup> , 96-hour                                | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Chum Salmon                   | LC <sub>50</sub> = 19 mg/L, 11 mg/L <sup>c</sup> , 96-hour                         | Death    | Giesy et al., 2000 |
| Acute Toxicity, Static | Honcho® Plus | Bluegill sunfish              | LC <sub>50</sub> = 24 mg/L, 96-hour                                                | Death    | Monsanto, 2007d    |
| Acute Toxicity         | Roundup      | Carp                          | LC <sub>50</sub> = 26 mg/L, 96-hour                                                | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Chinook Salmon                | LC <sub>50</sub> = 27 mg/L, 17 mg/L <sup>c</sup> , 96-hour                         | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Chinook Salmon                | LC <sub>50</sub> = 20 mg/L, 96-hour                                                | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Coho Salmon                   | LC <sub>50</sub> = 22 mg/L, 96-hour                                                | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Rainbow Trout                 | LC <sub>50</sub> = 22 mg/L, 96-hour<br>NOEC = 8.0 mg/L                             | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Fathead minnow                | LC <sub>50</sub> = 23 mg/L, 96-hour<br>NOEC = 13.6 mg/L                            | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Sockeye salmon                | LC <sub>50</sub> = 26.7 mg/L, 96-hour                                              | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Coho Salmon                   | LC <sub>50</sub> = 27 mg/L, 13 mg/L <sup>c</sup> , 96-hour                         | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Rainbow Trout                 | LC <sub>50</sub> = 27 mg/L, 96-hour<br>NOEC = 6.75 mg/L                            | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Rainbow Trout                 | LC <sub>50</sub> = 27 mg/L <sup>b</sup> , 96-hour<br>NOEC = 21.4 mg/L <sup>b</sup> | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Pink Salmon                   | LC <sub>50</sub> = 31 mg/L, 14 mg/L <sup>c</sup> , 96-hour                         | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Rainbow Trout                 | LC <sub>50</sub> = 33.6 mg/L <sup>b</sup> , 96-hour                                | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Bluegill Sunfish              | LC <sub>50</sub> = 34 mg/L <sup>b</sup> , 96-hour<br>NOEC = 21 mg/L                | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Channel catfish               | LC <sub>50</sub> = 39 mg/L, 96-hour<br>NOEC = 23 mg/L                              | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Channel catfish, adult        | LC <sub>50</sub> = 42.0 mg/L <sup>b</sup> , 96-hour                                | Death    | Giesy et al., 2000 |
| Acute Toxicity         | Roundup      | Coho Salmon, fry              | LC <sub>50</sub> = 42 mg/L, 96-hour                                                | Death    | Giesy et al., 2000 |
| Acute Toxicity, Static | Honcho® Plus | Rainbow Trout                 | LC <sub>50</sub> = 42 mg/L, 96-hour                                                | Death    | Monsanto, 2007d    |
| Acute Toxicity         | Roundup      | Rainbow Trout, Natural Waters | LC <sub>50</sub> = 52 mg/L, 96-hour                                                | Death    | Giesy et al., 2000 |

<sup>a</sup> Values are derived from a similar formulation

<sup>b</sup> Value from data sources corrected to mg roundup/L

<sup>c</sup> Values for soft (creek) and hard (lake) water, respectively

<sup>d</sup> Derived from an acute LC<sub>50</sub>/acute NOEC ratio of 5

#### 4.8.3 Acute Fish Toxicity to AMPA

The acute fish toxicity of AMPA is summarized in table N-34 below. The 4-day LC<sub>50</sub> value was established to be 520 mg AMPA/L while the NOEC was 33 mg AMPA/L.

**Table N-34. Acute Fish Toxicity to AMPA**

| Study Type<br>(% a.i. if provided) | Species       | Result                                              | Endpoint     | Reference          |
|------------------------------------|---------------|-----------------------------------------------------|--------------|--------------------|
| 4-day                              | Rainbow trout | NOEC = 33 mg AMPA/L;<br>LC <sub>50</sub> = 520 mg/L | Not reported | Giesy et al., 2000 |

#### 4.8.4 Chronic Fish Toxicity to Glyphosate

The chronic toxicity of glyphosate to fathead minnow and rainbow trout is summarized in table N-35. Chronic toxicity values for saltwater fish were not reported. The Maximum Allowable Toxicant Concentration (MATC) for fathead minnow was determined to be greater than 25.7 mg/L glyphosate (87.3% a.i.) (US EPA, 1993). This study was a full life-cycle toxicity study, and fish were able to reproduce normally at the identified MATC. A 21-day chronic study in rainbow trout identified a NOEC of 52 mg/L (Giesy, et al., 2000).

**Table N-35. Chronic Fish Toxicity to Glyphosate**

| Study Type<br>(% a.i. if provided) | Species        | Result                                           | Endpoint                                        | Reference          |
|------------------------------------|----------------|--------------------------------------------------|-------------------------------------------------|--------------------|
| Chronic (87.3%), life-cycle        | Fathead Minnow | MATC > 25.7 mg/L                                 | range and time frame exposure time not reported | US EPA, 1993       |
| <i>Tested as acid:</i>             |                |                                                  |                                                 |                    |
| Chronic                            | Fathead Minnow | NOEC = 26 mg a.e./L, 255-day, range not reported | Survival, growth, or reproduction               | Giesy et al., 2000 |
| Chronic, flow-through              | Rainbow trout  | NOEC = 52 mg a.e./L, 21-day, range not reported  | Not Reported                                    | Giesy et al., 2000 |

MATC= Maximum acceptable toxicant concentration

#### 4.8.5 Chronic Fish Toxicity to Glyphosate Herbicide Formulations

A single study is available assessing the toxicity of glyphosate formulations to freshwater fish. A 21-day chronic toxicity study with Roundup identified a NOEC of 2.4 mg/L for rainbow trout. Details of this study are presented in table N-36. Data addressing the toxicity of glyphosate formulations to saltwater fish was not reported.

**Table N-36. Chronic Fish Toxicity to Glyphosate Herbicide Formulation**

| Study Type | Formulation | Species       | Result                  | Reference          |
|------------|-------------|---------------|-------------------------|--------------------|
| Chronic    | Roundup     | Rainbow trout | NOEC = 2.4 mg/L, 21-day | Giesy et al., 2000 |

## 4.9 Saltwater and Marine Species Toxicity

Several acute toxicity tests were conducted on saltwater and marine organisms for exposure to glyphosate and its formulations. Per the US EPA's 1993 RED for Glyphosate, "since there is such an extensive data set for this chemical, the Agency can determine that glyphosate demonstrates low toxicity to fish and oyster species, and therefore is waiving the marine fish and oyster acute toxicity studies on the formulated product". The toxicity study results are discussed in sections 4.9.1.1 through 4.9.3.1.

### 4.9.1 Acute Saltwater and Marine Species Toxicity to Glyphosate

The acute toxicity of glyphosate to marine and estuarine organisms is summarized in table N-37. The most sensitive marine species to glyphosate was *Acartia tonsa* with a 48-hour LC<sub>50</sub> of 35.3 mg/L (tested as acid) (Tsui and Chu, 2003). The grass shrimp was reported to have a 96-hour LC<sub>50</sub> of 281 ppm (US EPA, 1993). The 48-hour TL<sub>50</sub> for Atlantic Oyster was determined to be > 10 mg/L (US EPA, 1993). The 48-hour TL<sub>50</sub> for Fiddler crab was determined to be 935 ppm (US EPA, 1993).

**Table N-37. Acute Saltwater and Marine Species Toxicity to Glyphosate**

| Study Type<br>(% a.i. if<br>provided) | Species                            | Result                                                                                  | Endpoint     | Reference                       |
|---------------------------------------|------------------------------------|-----------------------------------------------------------------------------------------|--------------|---------------------------------|
| Acute (96.7%)                         | Atlantic oyster                    | TL <sub>50</sub> = > 10 mg/L, 48-hour, range not reported                               | Death        | US EPA, 1993 <sup>a</sup>       |
| Acute (96.7%)                         | Grass shrimp                       | LC <sub>50</sub> = 281 ppm (207-381), 96-hour                                           | Death        | US EPA, 1993 <sup>b</sup>       |
| Acute (96.7%)                         | Fiddler crab                       | LC <sub>50</sub> = 934 ppm (555-1570), 96-hour                                          | Death        | US EPA, 1993 <sup>b</sup>       |
| <i>Tested as acid:</i>                |                                    |                                                                                         |              |                                 |
| Acute                                 | <i>Acartia tonsa</i>               | LC <sub>50</sub> (95% CI) = 35.3 mg/L (30.9-40.3); 48-hour                              | Death        | Tsui and Chu, 2003              |
| Acute                                 | <i>Cassostrea virginica</i> , eggs | Toxicity Value <sup>c</sup> = >10 mg/L, 48-hour, range not reported<br>NOEC = 10 mg/L   | Not Reported | Giesy et al., 2000 <sup>a</sup> |
| Acute                                 | <i>Mysidopsis bahia</i>            | Toxicity Value <sup>c</sup> = >1000 mg/L, 4 day, range not reported                     | Not Reported | Giesy et al., 2000              |
| Acute                                 | <i>Palaemonetes vulgaris</i>       | Toxicity Value <sup>c</sup> = 281 mg/L, 4 day, range not reported<br>NOEC = 210 mg/L    | Not Reported | Giesy et al., 2000 <sup>b</sup> |
| Acute                                 | <i>Tripneustes esculentus</i>      | Toxicity Value <sup>c</sup> = >1000 mg/L, 4 day, range not reported<br>NOEC = 1000 mg/L | Not Reported | Giesy et al., 2000              |
| Acute                                 | <i>Uca pugilator</i>               | Toxicity Value <sup>c</sup> = 934 mg/L, 4 day, range not reported<br>NOEC = 650 mg/L    | Not Reported | Giesy et al., 2000 <sup>b</sup> |
| <i>Tested as IPA salt:</i>            |                                    |                                                                                         |              |                                 |
| Acute                                 | <i>Acartia tonsa</i>               | LC <sub>50</sub> (95% CI) = 49.3 mg/L (38.4-63.1); 48-hour                              | Death        | Tsui and Chu, 2003              |

<sup>a</sup> Bentley, R. (1973b) as cited in US EPA, 1993 and Bionomics (1973a) as cited in Giesy et al., 2000 are believed to reference identical studies, but this can not be confirmed with available data. Therefore, both studies are listed.

<sup>b</sup> Bentley, R. (1973a) as cited in US EPA, 1993 and Bionomics (1973b) as cited in Giesy et al., 2000 are believed to reference identical studies, but this can not be confirmed with available data. Therefore, both studies are listed.

<sup>c</sup> Values were not specified as EC<sub>50</sub> or LC<sub>50</sub>.

#### 4.9.2 Acute Saltwater and Marine Species Toxicity to Glyphosate Herbicide Toxicity

One study is available addressing the toxicity of Roundup to *Acartia tonsa*. A 48-hour LC<sub>50</sub> of 1.77 mg/L was determined for *Acartia tonsa* treated with Roundup. This study is summarized in table N-38.

**Table N-38. Acute Saltwater and Marine Species Toxicity to Glyphosate Herbicide Formulation**

| Study Type | Species              | Result                                                     | Endpoint | Reference          |
|------------|----------------------|------------------------------------------------------------|----------|--------------------|
| Acute      | <i>Acartia tonsa</i> | LC <sub>50</sub> (95% CI) = 1.77 mg/L (1.33-2.34); 48-hour | Death    | Tsui and Chu, 2003 |

#### 4.9.3 Chronic Saltwater and Marine Species Toxicity to Glyphosate and Glyphosate Herbicide Toxicity

No studies were identified that investigated chronic toxicity in saltwater or marine species.

### 4.10 Risk Assessment and Characterization

Risk characterization integrates the results of the exposure and ecotoxicity data to evaluate the likelihood of adverse ecological effects. The means of this integration is called the quotient method. Risk quotients (RQs) are calculated by dividing exposure estimates by acute and chronic ecotoxicity values ( $RQ = \text{Exposure}/\text{Toxicity}$ ).

RQs are then compared to the US EPA's levels of concern (LOCs) presented in table N-39 below. These LOCs are used by US EPA's Office of Pesticide Programs to analyze potential risk to nontarget organisms and the need to consider regulatory action. The criteria indicate that a pesticide used as directed has the potential to cause adverse effects on nontarget organisms. LOCs currently address the following risk presumption categories: (1) **acute** – potential for acute risk to non-target organisms which may warrant regulatory action in addition to restricted use classification, (2) **acute restricted use** – the potential for acute risk to non-target organisms, but may be mitigated through restricted use classification, (3) **acute endangered species** – endangered species may be adversely affected by use, (4) **chronic risk** – the potential for chronic risk may warrant regulatory action, endangered species may potentially be affected through chronic exposure, (5) **non-endangered plant risk** – potential for effects in non-target plants, and (6) **endangered plant risk** – potential for effects in endangered plants. Currently, US EPA does not perform assessments for chronic risk to plants, acute or chronic risks to nontarget insects, or chronic risk from granular/bait formulations to birds or mammals.

The ecotoxicity test values (measurement endpoints) used in the acute and chronic risk quotients are derived from required studies. Examples of ecotoxicity values derived from short-term laboratory studies that assess acute effects are: (1) LC<sub>50</sub> (fish and birds), (2) LD<sub>50</sub> (birds and mammals), (3) concentration that causes an effect in 50 percent of the test animals (EC<sub>50</sub>) (aquatic plants and aquatic invertebrates), and (4) concentration that causes an effect in 25 percent of the test animals concentration (EC<sub>25</sub>) (terrestrial plants). Examples of toxicity test effect levels derived from the results of long-term laboratory studies that assess chronic effects

are: (1) lowest observed adverse effect concentration (LOAEC) (birds, fish, and aquatic invertebrates) and (2) no observed adverse effect concentration (NOAEC) (birds, fish and aquatic invertebrates). For birds and mammals, the NOAEC generally is used as the ecotoxicity test value in assessing chronic effects, although other values may be used when justified. However, the NOAEC is used if the measurement endpoint is production of offspring or survival.

**Table N-39. Risk Presumption Categories**

| <b>Risk Presumption for Terrestrial Animals</b>                                                                                         | <b>LOC</b> |
|-----------------------------------------------------------------------------------------------------------------------------------------|------------|
| Acute: Potential for acute risk for all non-target organisms                                                                            | >0.5       |
| Acute Restricted Use: Potential for acute risk for all non-target organisms, but may be mitigated through restricted use classification | >0.2       |
| Acute Endangered Species: Endangered species may be adversely affected by use                                                           | >0.1       |
| Chronic Risk: Potential for chronic risk may warrant regulatory action                                                                  | >1         |
| <b>Risk Presumption for Aquatic Organisms</b>                                                                                           | <b>LOC</b> |
| Acute: Potential for acute risk for all non-target organisms                                                                            | >0.5       |
| Acute Restricted Use: Potential for acute risk for all non-target organisms, but may be mitigated through restricted use classification | >0.1       |
| Acute Endangered Species: Endangered species may be adversely affected by use                                                           | >0.05      |
| Chronic Risk: Potential for chronic risk may warrant regulatory action                                                                  | >1         |
| <b>Risk Presumption for Terrestrial and Aquatic Plants</b>                                                                              | <b>LOC</b> |
| Potential for risk for all non-endangered and endangered plants                                                                         | >1         |

#### *4.10.1 Exposure and Risk to Nontarget Terrestrial Animals*

Exposure to nontarget terrestrial organisms was estimated using the Tier 1 T-REX (Terrestrial Residue EXposure) simulation model (version 1.2.3) based on the maximum proposed application rate, re-application interval, and the default foliar dissipation half-life of 35 days at a rate of 1.99 lb ai/acre, applied four times at 30 day intervals. Residues on various terrestrial food items ranged from 60.53 to 968.42 mg/kg diet (US EPA, 2005).

##### **4.10.1.1 Terrestrial Exposure Modeling and Risk Characterization**

This spreadsheet-based model calculates the residues on avian and mammalian food items along with the dissipation rate of a chemical applied to foliar surfaces (for single or multiple applications) in order to estimate acute and reproductive risk quotients(US EPA, 2005). The methods used by T-REX to estimate risk from consumption of selected contaminated food items is described below. For this analysis, T-REX calculates estimated environmental concentrations (EECs) and risk quotients based on both the upper bound and mean residue concentrations as presented by Hoerger and Kenaga (1972) and modified by Fletcher et al. (1994). Based on the estimated dietary residue concentrations from the upper bound and mean Kenaga values, T-REX calculates the associated doses for various size classes of birds and mammals. Both the dietary

concentration (mg/kg-dietary item) and the resulting estimated doses (mg/kg-bw) may be used for risk estimation. The EECs for terrestrial exposure were derived from the Kenaga nomograph based on a large set of field residue data. The EECs presented in table N-40 were calculated by the TREX Version 1.2.3 model and the corresponding avian acute and chronic RQs presented in tables N-40 and N-42 are based on the most sensitive subacute dietary LC<sub>50</sub>, single oral dose LD<sub>50</sub>, and NOAEC for birds.

**Table N-40. Dietary-based EECs Upper Bound Kenaga Values from TREX model**

| Food source                     | Estimate concentration glyphosate (ppm) |
|---------------------------------|-----------------------------------------|
| Short Grass                     | 968.42                                  |
| Tall Grass                      | 443.86                                  |
| Broadleaf plants/Small Insects  | 544.74                                  |
| Fruits/pods/seeds/Large insects | 60.53                                   |

Acute avian risk is assessed both by comparing the dietary LC<sub>50</sub> with residues on avian food items and by comparing the acute oral LD<sub>50</sub> with estimated daily doses calculated from residues on avian food items. Calculations for oral dose risk quotients are based on a Northern bobwhite quail oral acute LD<sub>50</sub> of >2000 mg glyphosate/kg body weight. Calculations for acute dietary-based risk quotients are based on a bobwhite quail subacute dietary LC<sub>50</sub> of 4640 mg/kg diet. There were no statistically significant results in the bobwhite quail reproductive toxicity and resulted in a chronic NOAEC of > 1000 mg/kg diet. These endpoints are not adjusted for body weight.

**Table N-41. Avian Dose-based RQs from TREX model**

| Dose-based RQs<br>(Dose-based EEC/adjusted LD <sub>50</sub> ) | Avian Acute RQs |       |        |
|---------------------------------------------------------------|-----------------|-------|--------|
|                                                               | 20 g            | 100 g | 1000 g |
| Short Grass                                                   | 0.77            | 0.34  | 0.11   |
| Tall Grass                                                    | 0.35            | 0.16  | 0.05   |
| Broadleaf plants/sm insects                                   | 0.43            | 0.19  | 0.06   |
| Fruits/pods/seeds/lg insects                                  | 0.05            | 0.02  | 0.01   |

RQs were calculated, and where the resulting quotient is lower than the LOCs, thus the acute risk is minimal for those scenarios, routes of exposure and food items. In cases where the RQs exceed an LOC, they are not presented because there is no definitive lethal dose. In those cases, the estimated oral dose is compared with the dose level at which no mortality occurred. If the estimated field oral dose does not exceed the laboratory derived dose of no mortality effect, it is concluded that potential for acute risk is minimal. If the estimated field dose exceeds the laboratory dose of no mortality effect, the conclusion is left as uncertain because acute risk cannot be ruled out, nor can it be concluded as likely. Oral dose-based scenarios are calculated by dividing the consumption-weighted equivalent dose by the body weight-adjusted LD<sub>50</sub>. The acute RQs for birds based on single-oral dose oral studies are summarized in table N-41.

**Table N-42. Avian Dietary-based RQs from TREX model**

| Dietary-based RQs<br>(Dietary-based EEC/LC50 or NOAEC) | RQs   |         |
|--------------------------------------------------------|-------|---------|
|                                                        | Acute | Chronic |
| Short Grass                                            | 0.21  | 0.97    |
| Tall Grass                                             | 0.10  | 0.44    |
| Broadleaf plants/Small Insects                         | 0.12  | 0.54    |
| Fruits/pods/seeds/Large insects                        | 0.01  | 0.06    |

These peak EECs resulted in no LOC exceedences, except for the birds whose diet consists of broad leaf plants and small insects; however this exceedence is minor with a RQ of 0.12, which is slightly greater than the LOC (>0.1) for Acute Endangered Species: Endangered species may be adversely affected by use. The EEC is based on worst case scenario and very minor; therefore, it is not considered a risk. Consumption-weighted doses for mammals based on weight class at four applications of 1.99 lb ai/acre with 35 day foliar half-life resulted in the risk quotients presented in tables N-43 and N-44.

**Table N-43. Mammalian Dose-Based Risk Quotients (RQ) from TREX model**

| Dose-based RQs<br>(Dose-based EEC/LD50 or NOAEL) | 15 g mammal |         | 35 g mammal |         | 1000 g mammal |         |
|--------------------------------------------------|-------------|---------|-------------|---------|---------------|---------|
|                                                  | Acute       | Chronic | Acute       | Chronic | Acute         | Chronic |
| Short Grass                                      | 0.10        | 2.40    | 0.08        | 2.05    | 0.04          | 1.10    |
| Tall Grass                                       | 0.04        | 1.10    | 0.04        | 0.94    | 0.02          | 0.50    |
| Broadleaf plants/small insects                   | 0.05        | 1.35    | 0.05        | 1.15    | 0.03          | 0.62    |
| Fruits/pods/large insects                        | 0.01        | 0.15    | 0.01        | 0.13    | 0.00          | 0.07    |
| Seeds (granivore)                                | 0.00        | 0.03    | 0.00        | 0.03    | 0.00          | 0.02    |

Calculations for both oral dose-based and dietary-based risk quotients were based on an acute laboratory rat LD<sub>50</sub> value of >4320 mg/kg bw and a 2-generation chronic reproductive effect NOAEC of 175 mg/kg bw. For chronic oral dose-based RQ calculations, the NOAEC (3500 mg/kg diet) was converted to a NOAEL (175 mg/kg body weight) based on a standard FDA lab rat conversion (US EPA, 2006a).

**Table N-44. Mammalian Dietary-Based Risk Quotients (RQ) from TREX model**

| Dietary-based RQs<br>(Dietary-based EEC/LC50 or NOAEC) | Mammal RQs |         |
|--------------------------------------------------------|------------|---------|
|                                                        | Acute      | Chronic |
| Short Grass                                            | <0.1       | 0.28    |
| Tall Grass                                             | <0.1       | 0.13    |
| Broadleaf plants/small insects                         | <0.1       | 0.16    |
| Fruits/pods/seeds/large insects                        | <0.1       | 0.02    |

Risk to non-target insects is expected to be low; the honey bee LD<sub>50</sub> is very high >100 µg/honeybee; therefore, glyphosate is not considered a risk to honeybee and other non-target arthropods.

#### 4.10.2 Exposure and Risk to Aquatic Organisms

Exposure to aquatic species was estimated using GENEEC (GENeric Estimated Exposure Concentration) Version 2.0 (US EPA, 2001b) as the Tier I simulation model. GENEEC is a Tier 1 simulation model that estimates the peak value which occurs on the day of a single large rainstorm event as well as multiple day averages over periods of 4, 21, 60 and 90 days. The magnitude of the peak concentration is the result of how fast the chemical dissipates (degradation; partitioning) in the field. The multiple day average over periods of four to 90 days reflect the dissipation (such as degradation and partitioning) of the chemical that takes place in the water body. These peak and average concentrations are then compared with the appropriate toxicity tests for aquatic plants and animals.

The peak concentration of glyphosate in a pond receiving runoff from a drainage basin treated 100 percent with glyphosate would be 15.66 µg/L (ppb) for Honcho® at the highest application rate. This does not exceed any LOCs, and longer term exposures would be lower; therefore risk is presumed to be below thresholds of concern. The input parameters for and the results of this model are presented in the following section.

##### 4.10.2.1 Aquatic Exposure Modeling

GENEEC Version 2.0 (US EPA, 2001b) was used to estimate the EECs in surface water in order to assess exposure in aquatic ecosystems.

These estimated environmental concentrations were based on the application rates proposed in the labels for uses on tolerant, gene modified alfalfa. It was assumed that glyphosate was applied in four sequential applications; at least 7 days apart to an annual total maximum of 7.98 lbs glyphosate equivalent per acre and that each single application is assumed to be 1.99 lbs glyphosate equivalents per acre.

Environmental fate input parameters were selected in accordance with EFED's "Guidance for Selecting Input Parameters in Modeling the Environmental Fate and Transport of Pesticides, Version II" (February 28, 2002; [http://www.epa.gov/oppefed1/models/water/input\\_guidance2\\_28\\_02.htm](http://www.epa.gov/oppefed1/models/water/input_guidance2_28_02.htm)) and are presented below.

Environmental Fate Input Parameters:

- Solubility in water (mg/L): 12,000
- Soil Organic Carbon Partition Coefficient ( $K_d$ ): 62<sup>48</sup>
- Aerobic soil metabolism half-life (days): 2<sup>49</sup>
- Non wetted ground high boom fine spray application with 0 ft no spray zone, and 0 in depth incorporation
- Aerobic aquatic metabolism half-life (days): 7<sup>50</sup>
- Photolytic half-life (days): 0

<sup>48</sup> The values for  $K_d$  were the lowest values determined from a non-sandy soil, for Drummer silty clay loam (US EPA, 1993)

<sup>49</sup> The value of aerobic soil metabolism half-life for glyphosate equivalents is based on data from US EPA, 1993.

<sup>50</sup> The value of aerobic aquatic metabolism half-life for glyphosate equivalents is based on data from US EPA, 1993.



- Hydrolytic half-life (days): 0

RUN No. 1 FOR glyphosate ON RR alfalfa \* INPUT VALUES \*

-----  
 RATE (#/AC) No.APPS & SOIL SOLUBIL APPL TYPE NO-SPRAY INCORP  
 ONE(MULT) INTERVAL Kd (PPM) (%DRIFT) ZONE(FT) (IN)  
 -----

1.990( 2.183) 4 7 62.0 12000.0 GRHIFI( 6.6) .0 .0

FIELD AND STANDARD POND HALFLIFE VALUES (DAYS)

-----  
 METABOLIC DAYS UNTIL HYDROLYSIS PHOTOLYSIS METABOLIC  
 COMBINED

(FIELD) RAIN/RUNOFF (POND) (POND-EFF) (POND) (POND)

-----  
 2.00 2 N/A .00- .00 7.00 7.00  
 -----

GENERIC EECs (IN MICROGRAMS/LITER (PPB)) Version 2.0 Aug 1, 2001

-----  
 PEAK MAX 4 DAY MAX 21 DAY MAX 60 DAY MAX 90 DAY  
 GEEC AVG GEEC AVG GEEC AVG GEEC AVG GEEC  
 -----

15.66 14.58 9.00 4.11 2.79

#### Aquatic Risk Characterization

Risk presumptions and the corresponding acute and chronic RQs and LOCs are tabulated in tables N-45 and N-46. The values in these tables are based on results of submitted studies and data from peer-reviewed literature, as indicated by the notes following each table. None of the acute or chronic RQs for glyphosate exceeded LOCs for any of the most sensitive aquatic species tested.

**Table N-45. Acute Risk Quotients for Glyphosate and Most Sensitive Species**

| Species                               | EEC<br>(µg/L) <sup>a</sup> | Toxicity<br>(µg/L)  | Acute RQ | Acute LOCs<br>Exceeded |
|---------------------------------------|----------------------------|---------------------|----------|------------------------|
| <b>Amphibians</b>                     |                            |                     |          |                        |
| <i>Crinia insignifera</i> tadpoles    | 15.66                      | 78,000 <sup>b</sup> | 0.0002   | None                   |
| <b>Freshwater Fish</b>                |                            |                     |          |                        |
| Rainbow Trout                         | 15.66                      | 7,800 <sup>c</sup>  | 0.002    | None                   |
| <b>Freshwater Invertebrates</b>       |                            |                     |          |                        |
| <i>Chironomus plumosus</i>            | 15.66                      | 55,000 <sup>d</sup> | 0.0003   | None                   |
| <b>Marine and Estuarine Organisms</b> |                            |                     |          |                        |
| <i>Acartia tonsa</i>                  | 15.66                      | 35,300 <sup>e</sup> | 0.0004   | None                   |
| <b>Freshwater Algae</b>               |                            |                     |          |                        |
| <i>Skeletonema costatum</i>           | 15.66                      | 850 <sup>d</sup>    | 0.018    | None                   |

<sup>a</sup> GENEEC Version 2.0 (US EPA, 2001)

<sup>b</sup> Giesy et al., 2000

<sup>c</sup> USDA, 2003

<sup>d</sup> US EPA, 1993

<sup>e</sup> Tsui and Chu, 2003

**Table N-46. Chronic Risk Quotients for Glyphosate and Most Sensitive Species**

| Species                              | EEC<br>(µg/L) <sup>a</sup> | Toxicity<br>(µg/L) <sup>b</sup> | Acute RQ | Chronic LOC<br>Exceeded? |
|--------------------------------------|----------------------------|---------------------------------|----------|--------------------------|
| <b>Freshwater Fish</b>               |                            |                                 |          |                          |
| Fathead Minnow                       | 15.66                      | 25,700                          | 0.0006   | None                     |
| <b>Freshwater Invertebrates</b>      |                            |                                 |          |                          |
| <i>Daphnia magna</i>                 | 15.66                      | 50,000                          | 0.0003   | None                     |
| <b>Marine and Estuarine Organism</b> |                            |                                 |          |                          |
| <i>Acartia tonsa</i>                 | 15.66                      | 1,770 <sup>c</sup>              | 0.0011   | None                     |
| <b>Freshwater Algae</b>              |                            |                                 |          |                          |
| <i>Lemna gibba</i>                   | 15.66                      | 16,600 <sup>c</sup>             | 0.0009   | None                     |

<sup>a</sup> GEENC Version 2.0 (US EPA, 2001)

<sup>b</sup> US EPA, 1993

<sup>c</sup> Giesy et al., 2000

<sup>e</sup> Tsui and Chu, 2003

#### 4.11 Summary of Findings

In general, glyphosate has a low toxicity to animals; however, the end use herbicide formulations, in some cases, are more toxic. The data suggest certain surfactants in glyphosate formulations result in a higher toxicity to amphibians, aquatic invertebrates, and fish. The dose-response assessment for fish is substantially complicated by information indicating that some fish species such as salmonids are more sensitive to glyphosate than other species. Glyphosate appears to be about equally toxic to both algae and aquatic macrophytes.

For GT alfalfa use, exposure does not result in risk exceeding LOCs; however, the end use herbicide concentration could not be determined and without an estimate of environmental concentrations, quantitative risk values cannot be calculated. The 2008 risk assessment published by the EPA for the effects of glyphosate, its salts, and glyphosate herbicide formulations found indirect effects on the CRLF at application rates more than twice the application rate of glyphosate on GT alfalfa.

## 5.0 Alfalfa Other Pesticide Ecotoxicity data

### 5.1 Alfalfa Pesticide Comparative Ecotoxicity

**Table N-47. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data - Aquatic**

| Herbicide                                                                                                                         | Test and Species Tested                                                                              | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>            | Effect/Conclusion                                                                           | Reference                                                                                                                                                                                                                                                                                                                                                                             |
|-----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|---------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Amphibians</b> <sup>51</sup>                                                                                                   |                                                                                                      |                                                           |                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                       |
| No data was available from the EPA RED documents or MSDS on the soil microorganism toxicity for the 20 herbicides used in alfalfa |                                                                                                      |                                                           |                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Freshwater Fish</b>                                                                                                            |                                                                                                      |                                                           |                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                       |
| Glyphosate                                                                                                                        | Acute Toxicity – Cold Water<br>Rainbow trout ( <i>Oncorhynchus mykiss</i> )                          | 48-hr LC <sub>50</sub> = 140<br>mg/L (120-170, 95%<br>CL) | Slightly non-toxic to<br>Practically Non-Toxic to<br>both cold water and<br>warm water fish | US EPA, 1993<br>MRID 00136339. Thompson, C.; Mcallister, W.<br>(1978) Acute Toxicity of Technical Glyphosate (AB-<br>78-165) to Rainbow Trout ( <i>Salmo gairdneri</i> ).<br>(Unpublished study received Dec 5, 1978 under<br>524-308; prepared by Analytical Bio Chemistry<br>Laboratories, Inc., submitted by Monsanto Co.,<br>Washington, DC; CDL:097661-B)                        |
|                                                                                                                                   | Acute Toxicity – Warm Water<br>Bluegill sunfish ( <i>Lepomis<br/>macrochirus</i> )                   | 48-hr LC <sub>50</sub> = 140<br>mg/L (110-160, 95%<br>CL) |                                                                                             | US EPA, 1993<br>MRID 00108205. McAllister, W.; Forbis, A. (1978)<br>Acute Toxicity of Technical Glyphosate to Bluegill<br>Sunfish ( <i>Lepomis macrochirus</i> ): Static Acute<br>Bioassay Report. (Unpublished study received Jul<br>14, 1978 under 524-308; prepared by Analytical Bio<br>Chemistry Laboratories, Inc., submitted by<br>Monsanto Co., Washington, DC; CDL:234395-B) |
|                                                                                                                                   | Chronic Toxicity to Freshwater Fish<br>Fathead Minnow ( <i>Pimephales<br/>promelas</i> , Rafinesque) | MATC > 25.7 mg/L                                          | No effects at or below<br>this level                                                        | US EPA, 1993<br>MRID 00108171. EG & G, Bionomics (1975)<br>Chronic Toxicity of Glyphosate to the Fathead<br>Minnow ( <i>Pimephales promelas</i> , Rafinesque).<br>(Unpublished study received Dec 27, 1978 under<br>524-308; submitted by Monsanto Co., Washington,<br>DC; CDL:097759-B)                                                                                              |
| 2,4-D                                                                                                                             | Acute Toxicity to Freshwater Fish<br>Bluegill sunfish ( <i>Lepomis<br/>macrochirus</i> )             | LC <sub>50</sub> = 263 mg ae/L                            | Practically Non-Toxic                                                                       | US EPA, 2005a<br>MRID 41158301. Alexander, H.; Mayes, M.;<br>Gersich, F. (1983) The Acute Toxicity of (2,4-<br>Dichlorophenoxy)acetic Acid to Representative<br>Aquatic Organisms: Project Study ID: ES-DR-0002-<br>2297-4. Unpublished study prepared by Dow<br>Chemical U.S.A. 26 p.                                                                                                |

<sup>51</sup> See also the 2008 risk assessment for the California Red Legged Frog published by the EPA (<http://www.epa.gov/espp/litstatus/effects/redleg-frog/index.html#glyphosate>)

| Herbicide  | Test and Species Tested                                                                        | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>              | Effect/Conclusion                                                                   | Reference                                                                                                                                                                                                                                                                                                                                                                                                |
|------------|------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            | Chronic Toxicity to Freshwater Fish<br>Fathead Minnow ( <i>Pimephales promelas</i> Rafinesque) | NOEC = 63.4 mg<br>ae/L                                      | NOEC based on length<br>and larval survival from<br>the early life stage<br>studies | US EPA, 2005<br>MRID 41737304. Mayes, M.; Gorzinski, S.; Potter,<br>R.; et al. (1990) 2,4-Dichloro- phenoxyaceticAcid:<br>Evaluation of the Toxicity to Early Life Stages of the<br>Fathead Minnow, Pimephales promelas<br>Rafinesque: Lab Project Number: ES-DR-0002-<br>2297-10. Unpublished study pre- pared by The<br>Dow Chemical Co. 48 p.                                                         |
| 2,4-DB     | Acute Toxicity to Freshwater Fish<br>Rainbow trout ( <i>Oncorhynchus mykiss</i> )              | 96-hr LC <sub>50</sub> = 2.4 mg<br>a.i./L                   | Moderately Toxic                                                                    | US EPA, 2005b<br>MRID 00116622. Johnson, W.; Finley, M. (1980)<br>Handbook of Acute Toxicity of Chemicals to Fish<br>and Aquatic Invertebrates. By U.S. Fish and<br>Wildlife Service, Columbia National Fisheries<br>Research Laboratory. Washington, DC:USFWS.<br>(Resource publication 137, pages 59, 60 only;<br>published study; CDL:248614-Q).                                                      |
| Benefin    | Acute Toxicity to Freshwater Fish<br>Bluegill sunfish ( <i>Lepomis macrochirus</i> )           | 96-hr LC <sub>50</sub> = 3.17<br>ppb a.i.                   | Very Highly Toxic                                                                   | US EPA, 2004<br>MRID 00026955. Kehr, C.C.; West, H.C.;<br>Hamelink, J.L.; et al. (1978) The Toxicity of Benefin<br>in Bluegills (?~Lepomis Macrochirus~?): A Twenty-<br>Eight Day Continuous Flow-Through Study: Study<br>No. 2057-77. (Unpublished study received Jun 29,<br>1978 under 1471-71; submitted by Elanco Products<br>Co., Div. of Eli Lilly and Co., Indiana- polis, Ind.;<br>CDL:234214-C) |
|            | Chronic Toxicity to Freshwater Fish<br>Rainbow trout ( <i>Oncorhynchus mykiss</i> )            | NOAEL = 0.0019<br>ppm a.i.<br><br>LOAEL = 0.005<br>ppm a.i. | May affect fish and<br>larval length and<br>survival                                | US EPA, 2004<br>MRID 41613805. Cocke, P.; Gunnoe, M.; Koenig,<br>G. (1990) The Toxicity of Benefin to Rainbow Trout<br>( <i>Salmo gairdneri</i> ) in a 49-Day Early Life-Stage<br>Study: Lab Project Number: F00690. Unpublished<br>study prepared by Lilly Research Laboratories. 88<br>p.                                                                                                              |
| Bromoxynil | Acute Toxicity to Freshwater Fish<br>Rainbow trout ( <i>Oncorhynchus mykiss</i> )              | LC <sub>50</sub> = 2100 ppb a.i.<br>(phenol)                | Moderately Toxic                                                                    | US EPA, 1998a<br>MRID 00155072. Surprenant, D. (1985) Acute<br>Toxicity of Bromoxynil Phenol to Rainbow Trout<br>( <i>Salmo gairdneri</i> ): Study #565.0285.6110.103:<br>Report #BW-85-10-1855. Unpublished study<br>prepared by Springborn Bionomics, Inc. 15 p.                                                                                                                                       |
|            | Acute Toxicity to Freshwater Fish<br>Bluegill sunfish ( <i>Lepomis</i> )                       | LC <sub>50</sub> = 4000 ppb a.i.<br>(phenol)                | Moderately Toxic                                                                    | US EPA, 1998a<br>MRID 43059601. Bettencourt, M. (1993)                                                                                                                                                                                                                                                                                                                                                   |

| Herbicide  | Test and Species Tested                                                           | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>    | Effect/Conclusion                                                                | Reference                                                                                                                                                                                                                                                                                                                                                                                        |
|------------|-----------------------------------------------------------------------------------|---------------------------------------------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            | <i>macrochirus</i> )                                                              |                                                   |                                                                                  | Bromoxynil Heptanoate-Acute Toxicity to Bluegill Sunfish ( <i>Lepomis macrochirus</i> ) Under Flow-Through Conditions: Lab Project Number: 93-10-5006: 10566.0693. 6303.105. Unpublished study prepared by Springborn Labs., Inc., Environmental Sciences Div. 72 p.                                                                                                                             |
|            | Chronic Toxicity to Freshwater Fish Fathead Minnow ( <i>Pimephales promelas</i> ) | NOAEL = 18 ppb<br>LOAEL = 39 ppb<br>MATC = 26 ppb | Very Highly Toxic, decreased larval growth, survival and embryo hatching success | US EPA, 1998a<br>MRID 41928301. Sousa, J. (1991) Bromoxynil Octanoate: Toxicity to Fathead Minnow ( <i>Pimephales promelas</i> ) Embryos and Larvae: Final Report: Lab Project Number: 10566. 0990. 6167. 120: 91-4-3719. Unpublished study prepared by Springborn Laboratories, Inc. 68 p.                                                                                                      |
| Clethodim  | Acute Toxicity to Freshwater Fish Bluegill sunfish ( <i>Lepomis macrochirus</i> ) | 96-hr LC <sub>50</sub> >1000 mg/L                 | Practically Non-Toxic                                                            | MSDS, 2007                                                                                                                                                                                                                                                                                                                                                                                       |
| Clopyralid | No Data Available                                                                 |                                                   |                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                  |
| Diuron     | Acute Toxicity to Freshwater Fish Cutthroat trout ( <i>Oncerynchus clarki</i> )   | 96-hr LC <sub>50</sub> = 0.71 ppm                 | Highly Toxic                                                                     | US EPA, 2003<br>MRID 40098001. Mayer, F.; Ellersieck, M. (1986) Manual of Acute Toxicity: Inter- pretation and Data Base for 410 Chemicals and 66 Species of Freshwater Animals. US Fish & Wildlife Service, Resource Publication 160. 579p.                                                                                                                                                     |
|            | Chronic Toxicity to Freshwater Fish Fathead Minnow ( <i>Pimephales promelas</i> ) | NOEC = 0.026 ppm<br>LOEC = 0.062 ppm              | Affects survival                                                                 | US EPA, 2003<br>MRID 00141636. Call, D.; Brooke, L.; Kent, R. (1983) Toxicity, bioconcentration, and metabolism of five herbicides in freshwater fish. Prepared by Univ. of Wisconsin, Center for Lake Superior Environmental studies for the Environmental Protection Agency; available from the National Technical Information Service. 113 p.                                                 |
| EPTC       | Acute Toxicity to Freshwater Fish                                                 | 96-hr LC <sub>50</sub> = 14-27 ppm                | Slightly Toxic                                                                   | US EPA, 1999                                                                                                                                                                                                                                                                                                                                                                                     |
| Hexazinone | Acute Toxicity to Freshwater Fish Fathead Minnow ( <i>Pimephales promelas</i> )   | LC <sub>50</sub> = 274 ppm                        | Practically Non-Toxic                                                            | US EPA, 1994<br>MRID 00104980. Sleight, B. (1973) Acute Toxicity of H-7759, MR-581 to Bluegill ( <i>Lepomis macrochirus</i> ), Rainbow Trout ( <i>Salmo gairdneri</i> ) and Fathead Minnow ( <i>Pimephales promelas</i> ). (Unpublished study received Dec 5, 1973 under 352-EX-85; prepared by Bionomics, Inc., submitted by E.I. du Pont de Nemours & Co., Inc., Wilmington, DE; CDL:223386-L) |

| Herbicide   | Test and Species Tested                                                              | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>           | Effect/Conclusion                      | Reference                                                                                                                                                                                                                                                                                                                                                                             |
|-------------|--------------------------------------------------------------------------------------|----------------------------------------------------------|----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             | Chronic Toxicity to Freshwater Fish                                                  | NOEL = 17 mg/L<br>LOEL = 35.5 mg/L<br>MATC = 24.6 ppm    | Fish length was affected               | US EPA, 1994<br>MRID 41406001. Pierson, K. (1990) Effects of IN A3674-207 on the Embryos and Larvae of Fathead Minnows ( <i>Pimephales promelas</i> ): Lab Project Number HLR 656-89: MR-8705-001. Unpublished study prepared by E. I. du Pont de Nemours and Co., Inc. 221 p.                                                                                                        |
| Imazamox    | Acute Toxicity to Freshwater Fish<br>Bluegill sunfish ( <i>Lepomis macrochirus</i> ) | LC <sub>50</sub> >119 mg/L                               | Practically Non-Toxic                  | US EPA, 1997a.<br>Imazamox – Pesticide Fact Sheet.                                                                                                                                                                                                                                                                                                                                    |
| Imazethapyr | No Data Available                                                                    |                                                          |                                        |                                                                                                                                                                                                                                                                                                                                                                                       |
| Metribuzin  | Acute Toxicity to Freshwater Fish<br>Rainbow trout ( <i>Oncorhynchus mykiss</i> )    | LC <sub>50</sub> = 76.77 ppm                             | Slightly Toxic                         | US EPA, 1998b<br>EPA Accession No. 255025                                                                                                                                                                                                                                                                                                                                             |
|             | Acute Toxicity to Freshwater Fish<br>Bluegill sunfish ( <i>Lepomis macrochirus</i> ) | LC <sub>50</sub> = 75.96 ppm                             | Slightly Toxic                         |                                                                                                                                                                                                                                                                                                                                                                                       |
|             | Chronic Toxicity to Freshwater Fish<br>Rainbow trout ( <i>Oncorhynchus mykiss</i> )  | NOEC = 3.0 ppm                                           | Growth affected                        | US EPA, 1998b<br>MRID 42447801. Gagliano, G.; Roney, D. (1992) Early Life Stage Toxicity of Sencor Technical to the Rainbow Trout ( <i>Oncorhynchus mykiss</i> ) under Flow-through Conditions: Lab Project Number: 103249:SE842201. Unpublished study prepared by Miles, Inc. 87 p.                                                                                                  |
| Norfluzon   | Acute Toxicity to Freshwater Fish<br>Rainbow trout ( <i>Oncorhynchus mykiss</i> )    | LC <sub>50</sub> = 8.1 ppm                               | Moderately Toxic                       | US EPA, 1996a<br>MRID 00087863. Stoll, R.E.; LeBlanc, G.A.; Sousa, J.V. (1981) Acute LC50 Toxicity Study in Rainbow Trout on Norflurazon: EG&G Bionomics No. BK-31-7-899; Sandoz Project T-1637. (Unpublished study received Dec. 18, 1981, under 11273-10; prepared in cooperation with EG&G Bionomics, submitted by Sandoz, Inc. Crop Protection, San Diego, Calif.; CDL:246433-A). |
|             | Chronic Toxicity to Freshwater Fish<br>Rainbow trout ( <i>Oncorhynchus mykiss</i> )  | NOEC = 0.77 ppm<br>LOEC = 1.5 ppm<br>MATC >0.77 <1.5 ppm | Survival and growth of larvae affected | US EPA, 1996a<br>MRID 00118048. LeBlanc, G. (1982) Early Life Stage Toxicity Study in the Rainbow Trout on Norflurazon: Report #BW-82-5-1165: Sandoz Project T-1733. (Unpublished study received Nov 15, 1982 under 11273-13; prepared by EG&G Bionomics, submitted by Sandoz, Inc., Crop Protection, San Diego, CA; CDL:248829-A).                                                   |

| Herbicide   | Test and Species Tested                                                                                | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>        | Effect/Conclusion           | Reference                                                                                                                                                                                                                                                                                                                                                       |
|-------------|--------------------------------------------------------------------------------------------------------|-------------------------------------------------------|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Paraquat    | Acute Toxicity to Freshwater Fish<br>Bluegill sunfish ( <i>Lepomis macrochirus</i> )                   | LC <sub>50</sub> = 13 ppm                             | Slightly Toxic              | US EPA, 1997b<br>MRID 40098001. Mayer Jr., F.; Ellersieck, M. (1986) - Manual of Acute Toxicity: Interpretation and Database for 410 Chemicals in 66 Species of Freshwater Animals. U.S. Department of Interior, Fish and Wildlife Service. Resource publication 160.                                                                                           |
| Picloram    | Acute Toxicity to Freshwater Fish<br>Rainbow trout ( <i>Oncorhynchus mykiss</i> )                      | LC <sub>50</sub> = 5.5 mg/L                           | Moderately Toxic            | US EPA, 1995<br>MRID 00112016. Batchelder, T. (1974) Acute Fish Toxicity of Picloram--(Dry Tordon Acid). (Unpublished study received Sep 10, 1976 under 464-541; submitted by Dow Chemical U.S.A., Midland, MI; CDL:226137-C)                                                                                                                                   |
| Pronamide   | Aquatic Toxicity                                                                                       | LC <sub>50</sub> or EC <sub>50</sub> = 0.1-1.0 mg/L   | Highly Toxic                | MSDS, 2006                                                                                                                                                                                                                                                                                                                                                      |
| Sethoxydim  | No Data Available                                                                                      |                                                       |                             |                                                                                                                                                                                                                                                                                                                                                                 |
| Terbacil    | Acute Toxicity to Freshwater Fish<br>Rainbow trout ( <i>Oncorhynchus mykiss</i> )                      | 96-hr LC <sub>50</sub> = 46.2 ppm                     | Slightly Toxic              | US EPA, 1998c<br>MRID 00390017                                                                                                                                                                                                                                                                                                                                  |
| Trifluralin | Acute Toxicity to Freshwater Fish – Cold Water<br>Rainbow trout ( <i>Oncorhynchus mykiss</i> )         | LC <sub>50</sub> = 41 ppb                             | Very Highly Toxic           | US EPA, 1996c<br>MRID 40094602. Johnson, W.; Finley, M. (1980) Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates: Resource Publication 137. U.S. Fish and Wildlife Service, Washington, D.C. 106 p.                                                                                                                                     |
|             | Acute Toxicity to Freshwater Fish – Warm Water<br>Bluegill sunfish ( <i>Lepomis macrochirus</i> )      | LC <sub>50</sub> = 58 ppb                             |                             |                                                                                                                                                                                                                                                                                                                                                                 |
|             | Chronic Toxicity to Freshwater Fish – Early Life Stage<br>Rainbow trout ( <i>Oncorhynchus mykiss</i> ) | NOEC = 1.14 ppb<br>LOEC = 2.18 ppb<br>MATC = 1.58 ppb | Larval fish length affected | US EPA, 1996c<br>MRID 41386202. Adams, E.; Cocke, P. and Gunnoe, M. (1990) The Toxicity of Trifluralin to Rainbow Trout ( <i>Salmo gairdneri</i> ) in a 48-Day Early Lifestage Study: Lab Project Number: FO2489. Unpublished study prepared by Lilly Research Laboratories. 86 p.                                                                              |
|             | Chronic Toxicity to Freshwater Fish – Life Cycle<br>Fathead Minnow ( <i>Pimephales promelas</i> )      | NOEC = 1.9 ppb<br>LOEC = 5.1 ppb<br>MATC = 3.5 ppb    | Not reported                | US EPA, 1996c<br>MRID 05008271. 05008271 Macek, K.J.; Lindberg, M.A.; Sauter, S.; Buxton, K.S.; Costa, P.A. (1976) Toxicity of Four Pesticides to Water Fleas and Fathead Minnows. Duluth, Minn.: U.S. Environmental Protection Agency, Environmental Research Laboratory. (EPA report no. EPA-600/3-76-099; available from: NTIS, Springfield, VA; PB-262 912) |

| Herbicide             | Test and Species Tested                                                                                             | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>                | Effect/Conclusion                                                                       | Reference                                                                                                                                                                                                                                                                                                    |
|-----------------------|---------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|-----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Aquatic Plants</b> |                                                                                                                     |                                                               |                                                                                         |                                                                                                                                                                                                                                                                                                              |
| Glyphosate            | Aquatic Plant Toxicity<br><i>Skeletonema costatum</i>                                                               | 4-day EC <sub>50</sub> = 0.85 mg/L                            | Not reported                                                                            | US EPA, 1993.                                                                                                                                                                                                                                                                                                |
| 2,4-D                 | Aquatic Plant Toxicity – Vascular Plants<br>Duckweed ( <i>Lemna gibbons</i> )                                       | EC <sub>50</sub> = 0.695 mg a.i./L<br>NOEC = 0.0581 mg a.i./L | Vascular plants more than 2 orders of magnitude more sensitive than non-vascular plants | US EPA, 2005a<br>MRID 44295101. Hughes, J.; Williams, T.; Conder, L. (1997) Effect of 2,4-Dichlorophenoxyacetic Acid on the Growth and Reproduction of Lemna gibba G3: (Final Report): Lab Project Number: 10-05-1. Unpublished study prepared by Carolina Ecotox, Inc. 72 p.                                |
|                       | Aquatic Plant Toxicity – Non-vascular Plants<br>Freshwater diatom ( <i>Navicula pelliculosa</i> )                   | EC <sub>50</sub> = 3.88 mg ae/L<br>NOEC = 1.41 mg ae/L        | Highly Toxic                                                                            | US EPA, 2005a<br>MRID 43307902. Hughes, J.; Williams, T.; Conder, L. (1994) The Toxicity of 2,4-D to <i>Navicula pelliculosa</i> : Lab Project Number: 10/01/2. Unpublished study prepared by Carolina Ecotox, Inc. 55 p.                                                                                    |
| 2,4-DB                | Aquatic Plant Toxicity<br>Green Algae ( <i>Selenastrum capricornutum</i> )                                          | LOAEL = 1100 ppb a.i.                                         | Practically Non-Toxic                                                                   | US EPA, 2005b<br>MRID 41407803. Giddings, J. (1990) 2,4-DB Amine-Toxicity to the Freshwater Green Alga <i>Selenastrum capricornutum</i> : Final Report: Lab Report # 90-1- 3196; Study # 10566-0289-6129-430. Unpublished study prepared by Springborn Laboratories, Inc., Environmental Sciences Div. 29 p. |
| Benefin               | Aquatic Plant Toxicity<br>Green algae (formerly <i>Selenastrum capricornutum</i> )<br><i>Kirchneria subcapitata</i> | EC <sub>50</sub> = 0.100 ppm                                  | Very Highly Toxic                                                                       | US EPA, 2004<br>MRID 41613809. Cocke, P.; Koenig, G. (1990) Toxicity of Benefin to a Freshwater Green Alga ( <i>Selenastrum capricornutum</i> ) in a Static Test System: Lab Project Number: J00790. Unpublished study prepared by Lilly Research Laboratories. 43 p.                                        |
| Bromoxynil            | Aquatic Plant Toxicity<br>Freshwater diatom ( <i>Navicula pelliculosa</i> )                                         | EC <sub>50</sub> = 51 ppb a.i. (Octanoate)                    | Toxic                                                                                   | US EPA, 1998a<br>MRID 41606001. Giddings, J. (1990) Bromoxynil Octanoate-Toxicity to the Freshwater Diatom <i>Navicula pelliculosa</i> : Lab Project Number: 90-8-3431:566.1089.6142.440. Unpublished study prepared by Springborn Laboratories, Inc. 50 p.                                                  |
| Clethodim             | No Data Available                                                                                                   |                                                               |                                                                                         |                                                                                                                                                                                                                                                                                                              |
| Clopyralid            | No Data Available                                                                                                   |                                                               |                                                                                         |                                                                                                                                                                                                                                                                                                              |
| Diuron                | Aquatic Plant Toxicity – Non-vascular                                                                               | EC <sub>50</sub> = 2.4 ppb                                    | Moderately Toxic                                                                        | US EPA, 2003                                                                                                                                                                                                                                                                                                 |



| Herbicide   | Test and Species Tested                                                                 | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>     | Effect/Conclusion | Reference                                                                                                                                                                                                                                                                                     |
|-------------|-----------------------------------------------------------------------------------------|----------------------------------------------------|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             | Plants<br>Green Algae ( <i>Selenastrum capricornutum</i> )                              |                                                    |                   | MRID 42218401. Blasberg, J.; Hicks, S.; Bucksath, J. (1991) Acute Toxicity of Diuron to <i>Selenastrum capricornutum</i> Printz: Final Report: Lab Project Number: 39335: AMR-2046-91. Unpublished study prepared by ABC Labs., Inc. 33 p.                                                    |
| EPTC        | Aquatic Plant Toxicity<br>Green Algae                                                   | EC <sub>50</sub> = 1.36 ppm                        | Moderately Toxic  | US EPA, 1999                                                                                                                                                                                                                                                                                  |
| Hexazinone  | Aquatic Plant Toxicity<br>Blue-Green Algae ( <i>Anabaena flos-aquae</i> )               | EC <sub>50</sub> = 0.21 ppm                        | Highly Toxic      | US EPA, 1994<br>MRID 43302701. Thompson, S. (1994) Hexazinone (DPX-A3674): Influence on Growth and Reproduction of Two Select Algal Species: Lab Project Number: AMR 3011-94: 335-94: 9785. Unpublished study prepared by Wildlife International Ltd. and E.I. du Pont de Nemours & Co. 75 p. |
| Imazamox    | No Data Available                                                                       |                                                    |                   |                                                                                                                                                                                                                                                                                               |
| Imazethapyr | No Data Available                                                                       |                                                    |                   |                                                                                                                                                                                                                                                                                               |
| Metribuzin  | Aquatic Plant Toxicity – Vascular<br>Duckweed ( <i>Lemna gibba</i> )                    | EC <sub>50</sub> = 0.13 ppm<br>NOEC = 0.018 ppm    | Highly Toxic      | US EPA, 1998b<br>MRID 43893501. Boeri, R.; Magazu, J.; Ward, T. (1995) Toxicity of Sencor to the Duckweed, <i>Lemna gibba</i> G3: (Amended Report): Lab Project Number: 667-MI: 106982. Unpublished study prepared by T. R. Wilbury Labs, Inc. 32 p.                                          |
|             | Aquatic Plant Toxicity – Non- Vascular<br>Green Algae ( <i>Kirchneria subcapitata</i> ) | EC <sub>50</sub> = 0.021 ppm<br>NOEC = 0.004 ppm   | Very Highly Toxic | US EPA, 1998b<br>MRID 43133601. Gagliano, G.; Orr, W. (1994) Acute Toxicity of SENCOR Technical to the Green Alga ( <i>Selenastrum capricornutum</i> ): Lab Project Number: SE881402. Unpublished study prepared by Miles, Inc. Sponsor report number: 106417. 33 p.                          |
|             | Aquatic Plant Toxicity<br>Marine diatom ( <i>Skeletonema costatum</i> )                 | EC <sub>50</sub> = 0.0087 ppm<br>NOEC = 0.0058 ppm | Very Highly Toxic | US EPA, 1998b<br>MRID 43867701. Bowers, L. (1995) Toxicity of (carbon 14)-Sencor to the Marine Diatom, <i>Skeletonema costatum</i> : Lab Project Number: SE881602: 106992. Unpublished study prepared by Bayer Corp. 34 p.                                                                    |
| Norfluzon   | Aquatic Plant Toxicity – Non- Vascular<br>Green Algae ( <i>Kirchneria subcapitata</i> ) | EC <sub>50</sub> = 13 ppb<br>NOEC = 6.23 ppb       | Slightly Toxic    | US EPA, 1996a<br>MRID 42080406. Hughes, J.; Alexander, M. (1991) The Toxicity of Norflurazon to <i>Selenastrum capricornutum</i> : Lab Project Number: B462-06-1. Unpublished study prepared by Malcolm Pirnie, Inc. 35 p.                                                                    |

| Herbicide   | Test and Species Tested                                                   | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>                    | Effect/Conclusion                                                      | Reference                                                                                                                                                                                                                                                                                                              |
|-------------|---------------------------------------------------------------------------|-------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Paraquat    | Aquatic Plant Toxicity<br><i>Selenastrum capricornutum</i> (Green Algae)  | EC <sub>50</sub> = 0.32 ppm<br>NOEC = 0.08 ppb<br>LOEC = 0.20 ppb | Highly Toxic                                                           | US EPA, 1997b<br>MRID 42601002. Smyth, D.; Sankey, S.; Penwell, A. (1992) Paraquat Dichloride: Toxicity to the Green Alga <i>Selenastrum capricornutum</i> : Lab Project Number: BL4578/B: T168/G (FT11/92). Unpublished study prepared by Imperial Chemical Industries PLC. 23 p.                                     |
| Picloram    | Aquatic Plant Toxicity<br><i>Selenastrum capricornutum</i> (Green Algae)  | EC <sub>50</sub> = 36.9 mg/L                                      | Slightly Toxic                                                         | US EPA, 1995                                                                                                                                                                                                                                                                                                           |
| Pronamide   | No Data Available                                                         |                                                                   |                                                                        |                                                                                                                                                                                                                                                                                                                        |
| Sethoxydim  | No Data Available                                                         |                                                                   |                                                                        |                                                                                                                                                                                                                                                                                                                        |
| Terbacil    | Aquatic Plant Toxicity<br>Freshwater diatom - <i>Navicula pelliculosa</i> | EC <sub>50</sub> = 0.011 ppm<br>NOEC = 0.007 ppm                  | Very Highly Toxic                                                      | US EPA, 1998c<br>MRID 43909802. Hughes, J.; Alexander, M. (1996) DPX-D732-66: Influence on Growth and Reproduction of <i>Navicula pelliculosa</i> : Lab Project Number: AMR 3723-95: 10376: 19-03-1. Unpublished study prepared by Carolina Ecotox, Inc. and Haskell Lab for Toxicology and Industrial Medicine. 62 p. |
| Trifluralin | Aquatic Plant Toxicity<br><i>Selenastrum capricornutum</i> (Green Algae)  | EC <sub>50</sub> = 7.52 ppb<br>NOEC = 5.37 ppb                    | Moderately Toxic<br>Likely to be more toxic than reported in the study | US EPA, 1996b<br>MRID 41934502. Adams, E.; Cocke, P. (1990) Toxicity of Trifluralin to a Freshwater Green Alga ( <i>Selenastrum capricornutum</i> ) in a Static Test System: Lab Project Number: J00989. Unpublished study prepared by Lilly Research Labs. 43 p.                                                      |

**Table N-48. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial**

| Herbicide    | Test and Species Tested                                                                                                      | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>                             | Effect/Conclusion                                                                                                            | Reference                                                                                                                                                                                                                                                                                                                                            |
|--------------|------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Birds</b> |                                                                                                                              |                                                                            |                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                      |
| Glyphosate   | Avian Subacute Dietary Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )                                                | >4640 ppm                                                                  | Reproductive<br>Impairment.<br>No more than slightly<br>toxic to upland game<br>birds and waterfowl<br>Practically Non-Toxic | US EPA, 1993<br>MRID 00108107. Fink, R. (1973) Final Report:<br>Eight-day Dietary LC50-Mallard Ducks: Technical<br>CP67573: Project No. 241-107. (Unpublished study<br>received Jul 12, 1974 under 5F1536; prepared by<br>Environmental Sciences Corp., submitted by<br>Monsanto Co., Washington, DC; CDL:094171-I)                                  |
|              | Avian Chronic Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )                                                      | >4640 ppm                                                                  |                                                                                                                              | US EPA, 1993<br>MRID 00108207. Fink, R.; Beavers, J. (1978) Final<br>Report: One-generation Reproduction study—<br>Bobwhite Quail: Glyphosate Technical: Project No.<br>139-141. (Unpublished study received Nov 13,<br>1978 under 524-308; prepared by Wildlife<br>International, Ltd., submitted by Monsanto Co.,<br>Washington, DC; CDL:235924-B) |
| 2,4-D        | Avian Acute Oral Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )                                                      | >1000 mg ae/kg                                                             | Practically Non-Toxic                                                                                                        | US EPA, 2005a<br>MRID 00160000. Hudson, R.; Tucker, R.; Haegele,<br>M. (1984) Handbook of toxicity of pesticides to<br>wildlife: Second edition. US Fish and Wildlife<br>Service: Resource Publication 153. 91 p.                                                                                                                                    |
|              | Avian Acute Dietary Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> ),<br>Mallard Duck ( <i>Anas platyrhynchos</i> ) | >5620 mg ae/kg                                                             | Practically Non-Toxic                                                                                                        | US EPA, 2005a<br>MRID 41586101. Culotta, J.; Hoxter, K.; Foster, J.;<br>et al. (1990) 2, 4-D (2,4-Dichloroxyacetic Acid): A<br>Dietary LC50 Study with the Northern Bobwhite.<br>Lab Project Number: 103-306. Unpublished study<br>prepared by Wildlife International Ltd. 55 p.                                                                     |
|              | Avian Chronic Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )                                                      | NOEC = 962 ppm<br>LOEC >962 ppm,<br>based on cracked<br>eggs and laid eggs | Moderately Toxic                                                                                                             | US EPA, 2005a<br>MRID 41546202. Culotta, J. ; Foster, J. ; Grimes, J.<br>et al. (1990) A Dietary LC50 Study with the Mallard:<br>Lab Project Number: 103-307. Unpublished study<br>prepared by Wildlife International Ltd. 42 p.                                                                                                                     |
| 2,4-DB       | Avian Acute Oral Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )                                                   | LD <sub>50</sub> = 1536 mg<br>a.i./kg-bw                                   | Reduction in body wt,<br>feed consumption.                                                                                   | US EPA, 2005b<br>MRID 41370102. Pederson, C. (1989) 2,4-DB                                                                                                                                                                                                                                                                                           |

| Herbicide  | Test and Species Tested                                                              | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>  | Effect/Conclusion                                                                                                                                         | Reference                                                                                                                                                                                                                                                                                                                                                                                                                               |
|------------|--------------------------------------------------------------------------------------|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            |                                                                                      | NOAEC = 464 mg<br>a.i./kg-bw                    | Depression, wing<br>droop, etc.<br>Slightly Toxic                                                                                                         | Technical Acid: 21-Day Acute Oral LD50 Study in<br>Bobwhite Quail: Final Report: Lab Project ID: # 89<br>QD 132. Unpublished study prepared by Bio-Life<br>Associates, Ltd. 33 p.                                                                                                                                                                                                                                                       |
|            | Avian Subacute Dietary Toxicity<br>Peking Duck ( <i>Anas domestica</i> )             | LC <sub>50</sub> >1000 mg<br>a.i./kg-diet       | Practically Non-Toxic                                                                                                                                     | US EPA, 2005b<br>MRID 00092162. Weatherholtz, W.M. (1969) Final<br>Report: Acute Toxicity Study-Ducklings: Project No.<br>656113. (Unpublished study received Dec 16, 1970<br>under 1F1089; prepared by TRW, Inc., submitted<br>by Rhodia, Inc., New Brunswick, N.J.; CDL:090849-<br>E)                                                                                                                                                 |
| Benefin    | Avian Chronic Toxicity<br>Northern Bobwhite Quail ( <i>Colinus<br/>virginianus</i> ) | NOAEC <96 ppm<br>a.i.<br>LOAEC = 96 ppm<br>a.i. | Developmental effects:<br>decrease in number of<br>surviving hatchlings,<br>decreased egg set, and<br>decrease in 14-day<br>hatchling survivor<br>weight. | US EPA, 2004<br>MRID 42145502. Murray, A.; Seacat, J.; Grothe, D.<br>(1991). The Toxicity of Benefin to Bobwhite in a<br>One-Generation Reproduction Study: Lab Project<br>Number: A00690. Unpublished study prepared by<br>Lilly Research Labs. 470 p.                                                                                                                                                                                 |
|            | Avian Chronic Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )                 | NOAEC = 288 ppm<br>a.i.                         | Increase in the<br>percentage of cracked<br>eggs                                                                                                          | US EPA, 2004<br>MRID 42145501. Murray, A.; Smith, J.; Grothe, D.<br>(1991) The Toxicity of Benefin to Mallards in a One-<br>Generation Reproduction Study: Lab Project<br>Number: A01090. Unpublished study prepared by<br>Lilly Research Labs. 437 p.                                                                                                                                                                                  |
| Bromoxynil | Avian Acute Oral Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )           | LD <sub>50</sub> = 359 mg<br>a.i./kg            | Moderately Toxic                                                                                                                                          | US EPA 1998a<br>MRID 00114101. Fletcher, D. (1981) Report to<br>Union Carbide Agricultural Products Company:<br>Acute Oral Toxicity Study with Bromoxynil<br>Octanoate, Technical, in Bobwhite Quail: BLAL No.<br>81 QD 6. (Unpublished study received Aug 31,<br>1982 under 264-204; prepared by Bio-Life Assoc.,<br>Ltd., submitted by Union Carbide Agricultural<br>Products Co., Inc., Research Triangle Park, NC;<br>CDL:248229-B) |
|            | Avian Subacute Dietary Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )     | LC <sub>50</sub> = 4530 ppm a.i.                | Slightly Toxic                                                                                                                                            | US EPA, 1998a<br>MRID 00114105. Fletcher, D. (1981) Report to<br>Union Carbide Agricultural Products Company: 8-<br>day Dietary LC50 Study with Bromoxynil Octanoate<br>in Bobwhite Quail: BLAL No. 81 QC 9.<br>(Unpublished study received Aug 31, 1982 under                                                                                                                                                                          |

| Herbicide  | Test and Species Tested                                                          | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub> | Effect/Conclusion                                                                                                                                                                                                                             | Reference                                                                                                                                                                                                                                                                                                                                                      |
|------------|----------------------------------------------------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            |                                                                                  |                                                |                                                                                                                                                                                                                                               | 264-204; prepared by Bio-Life Assoc., Ltd., submitted by Union Carbide Agricultural Products Co., Inc., Research Triangle Park, NC; CDL:248229-F)                                                                                                                                                                                                              |
|            | Avian Chronic Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )             | NOAEL = 102 ppm<br>a.i.<br><br>LOAEL = 340 ppm | Based on number of eggs laid and set, number of viable embryos, number of live 3-week embryos, and lesions of old yolk peritonitis or regressing ovary<br>Can impair the reproduction of birds at dietary concentrations greater than 102 ppm | US EPA, 1998a<br>MRID 42004102. Beavers, J.; Sipler, O.; Smith, G.; et al (1991) Bromoxynil Octanoate: One-Generation Reproduction Study with the Mallard ( <i>Anas platyrhynchos</i> ): Lab Project Number: 171-124. Unpublished study prepared by Wildlife Int. Ltd. 241 p.                                                                                  |
| Clethodim  | Avian Acute Oral Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )       | LD <sub>50</sub> >2250 mg/kg                   | Practically Non-Toxic                                                                                                                                                                                                                         | MSDS, 2007                                                                                                                                                                                                                                                                                                                                                     |
| Clopyralid | No Data Available                                                                |                                                |                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                |
| Diuron     | Avian Acute Oral Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )       | LD <sub>50</sub> = 940 mg/kg                   | Slightly Toxic                                                                                                                                                                                                                                | US EPA, 2003<br>MRID 50150170                                                                                                                                                                                                                                                                                                                                  |
|            | Avian Subacute Dietary Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )    | LD <sub>50</sub> = 1730 mg/kg                  | Slightly Toxic                                                                                                                                                                                                                                | US EPA 2003<br>MRID 00022923 Hill, E.F.; Heath, R.G.; Spann, J.W.; et al. (1975) Lethal Dietary Toxicities of Environmental Pollutants to Birds: Special Scientific Report—Wildlife No. 191. (U.S. Dept. of the Interior, Fish and Wildlife Service, Patuxent Wildlife Research Center; unpublished report)                                                    |
| EPTC       | Avian Acute Toxicity                                                             | LD <sub>50</sub> >2510 mg/kg                   | Non-Toxic                                                                                                                                                                                                                                     | US EPA, 1999                                                                                                                                                                                                                                                                                                                                                   |
| Hexazinone | Avian Acute Oral Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )       | LD <sub>50</sub> = 2251 mg/kg                  | Practically Non-Toxic                                                                                                                                                                                                                         | US EPA, 1994<br>MRID 00073988. Fink, R.; Beavers, J.B.; Brown, R. (1978) Final Report: Acute Oral LD <sub>50</sub> —Bobwhite Quail: Project No. 112-121. (Unpublished study received May 23, 1978 under 352-387; prepared by Wildlife International, Ltd., and Washington College, submitted by E.I. du Pont de Nemours & Co., Wilmington, Del.; CDL:233989-A) |
|            | Avian Subacute Dietary Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> ) | LC <sub>50</sub> >5000 ppm                     | Practically Non-Toxic                                                                                                                                                                                                                         | US EPA, 1994<br>MRID 0072663. Dudeck, S.H.; Bristol, K.L. (1980) Avian Dietary Toxicity (LC <sub>50</sub> ) Study in Bobwhite                                                                                                                                                                                                                                  |

| Herbicide   | Test and Species Tested                                                                                                         | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub> | Effect/Conclusion         | Reference                                                                                                                                                                                                                                                                                  |
|-------------|---------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |                                                                                                                                 |                                                |                           | Quail: Project No. 201-547. Final rept. (Unpublished study received Jan 23, 1981 under 352-387; prepared by Hazleton Laboratories America, Inc., submitted by E.I. du Pont de Nemours & Co., Wilmington, Del.; CDL:244106-A)                                                               |
|             | Avian Chronic Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )                                                         | NOEC < 100 ppm                                 | Effect on survivor weight | US EPA, 1994<br>MRID 41764901. Beavers, J.; Campbell, S.; Smith, G.; (1991) H 17,705: A One Generation Reproduction Study With the Northern Bobwhite ( <i>Colinus virginianus</i> ): Lab Project Number: 112-225: 772-90. Unpublished Study prepared by Wildlife International Ltd. 168 p. |
| Imazamox    | Avian Acute Oral Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> ) and Mallard Duck ( <i>Anas platyrhynchos</i> )       | LD <sub>50</sub> >1950 mg/kg                   | Practically Non-Toxic     | US EPA, 1997a.<br>Imazamox – Pesticide Fact Sheet.                                                                                                                                                                                                                                         |
|             | Avian Subacute Dietary Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> ) and Mallard Duck ( <i>Anas platyrhynchos</i> ) | LC <sub>50</sub> >5572 ppm                     |                           |                                                                                                                                                                                                                                                                                            |
|             | Avian Chronic Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> ) and Mallard Duck ( <i>Anas platyrhynchos</i> )          | NOEC >2000 ppm<br>LOEC >2000 ppm               |                           |                                                                                                                                                                                                                                                                                            |
| Imazethapyr | No Data Available                                                                                                               |                                                |                           |                                                                                                                                                                                                                                                                                            |
| Metribuzin  | Avian Acute Oral Toxicity<br>Northern Bobwhite Quail ( <i>Colinus virginianus</i> )                                             | LD <sub>50</sub> = 169.2 mg/kg                 | Moderately Toxic          | US EPA, 1998b<br>EPA Accession No. 255025                                                                                                                                                                                                                                                  |
|             | Avian Subacute Dietary Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )                                                | LC <sub>50</sub> >4000 ppm                     | Practically Non-Toxic     | US EPA, 1998b<br>EPA Accession No. 255025                                                                                                                                                                                                                                                  |
|             | Avian Subacute Dietary Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )                                                   | LC <sub>50</sub> >5000 ppm                     | Practically Non-Toxic     | US EPA, 1998b<br>MRID 00065507. Lamb, D.W.; Burke, M.A. (1977) Dietary Toxicity of ~@æSencor Technical to Bobwhite Quail and Mallard Ducks: Report No. 51593. (Unpublished study received Apr 13, 1977 under 3125-270; submitted by Mobay Chemical Corp., Kansas City, Mo.; CDL:229312-A)  |
|             | Avian Chronic Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )                                                            | NOEC = 368 ppm<br>LOEC > 368 ppm               | Not reported              | US EPA, 1998b<br>MRID 43860501. Hancock, G. (1995) Effect of Technical SENCOR on Mallard Reproduction: Lab                                                                                                                                                                                 |

| Herbicide | Test and Species Tested                                                          | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub> | Effect/Conclusion        | Reference                                                                                                                                                                                                                                                                                                                                                                                      |
|-----------|----------------------------------------------------------------------------------|------------------------------------------------|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|           |                                                                                  |                                                |                          | Project Number: SE740801: 106983. Unpublished study prepared by Bayer Corp. 107 p.                                                                                                                                                                                                                                                                                                             |
| Norfluzon | Avian Acute Oral Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )          | LD <sub>50</sub> >2510 mg/kg                   | Practically Non-Toxic    | US EPA, 1996a<br>MRID 00048362. Fink, R.; Beavers, J.B.; Brown, R. (1980) Final Report: Acute Oral LD50-Mallard Duck: Project No. 131-113. (Unpublished study received Nov. 3, 1980, under 11273-24; prepared by Wildlife International, Ltd.; submitted by Sandoz, Inc., Crop Protection, San Diego, Calif.; CDL:243646-A)                                                                    |
|           | Avian Acute Oral Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )       | LD <sub>50</sub> >1000 mg/kg                   | Slightly Toxic           | US EPA, 1996a<br>MRID 00063622. Gough, B.J.; Shellenberger, T.E. (1971) Letter sent to Zenas B. Noon, Jr. dated May 18, 1971: Acute toxicological evaluations of San-9789 with fish and wildlife. (Unpublished study received Nov. 14, 1972, under 3G1310; prepared by Gulf South Research Institute, Atchafalaya Basin Laboratories, submitted by Sandoz, Inc. Homestead, Fla.; CDL:092234-F) |
|           | Avian Subacute Dietary Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> ) | LC <sub>50</sub> >10000 ppm                    | Practically Non-Toxic    | US EPA, 1996a<br>MRID 00037051. Fink, R. (1972) Final Report: Eight-Day Dietary LC50—Bobwhite Quail: Project No. 620-124. (Unpublished study received on unknown date under 2G1338; prepared by Environmental Sciences Corp.; submitted by Sandoz-Wander, Inc., Homestead, Fla.; CDL: 093577-C)                                                                                                |
|           | Avian Subacute Dietary Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )    | LC <sub>50</sub> >10000 ppm                    | Practically Non-Toxic    | US EPA, 1996a<br>MRID 00077292. Fink, R. (1972) Final Report: Eight-Day Dietary LC50—Mallard Ducks: Project No. 620-125. (Unpublished study received Nov 14, 1972 under 3G1310; prepared by Environmental Sciences Corp., submitted by Sandoz, Inc., Homestead, Fla.; CDL:092234-G)                                                                                                            |
|           | Avian Chronic Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )          | NOEC = 40 ppm<br>LOEC = 200 ppm                | Reduced hatching success | US EPA, 1996a<br>MRID 42615301. Beavers, J.; Sipler, O.; Jaber, M. (1992) Norflurazon Technical: A One-generation Reproduction Study with the Bobwhite ( <i>Colinus virginianus</i> ): Lab Project Number: 131-151. Unpublished study prepared by Wildlife International, Ltd. 164 p.                                                                                                          |
|           | Avian Chronic Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )             | NOEC = 40 ppm<br>LOEC = 200 ppm                | Hatching weight affected | US EPA, 1996a<br>MRID 42615392. Beavers, J.; Sipler, O.; Jaber, M.                                                                                                                                                                                                                                                                                                                             |

| Herbicide  | Test and Species Tested                                                          | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>      | Effect/Conclusion                                                                                             | Reference                                                                                                                                                                                                                                                                                                                                                                            |
|------------|----------------------------------------------------------------------------------|-----------------------------------------------------|---------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            |                                                                                  |                                                     |                                                                                                               | (1992) Norflurazon Technical: A One-generation Reproduction Study with the Mallard ( <i>Anas platyrhynchos</i> ): Lab Project Number: 131-152. Unpublished study prepared by Wildlife International, Ltd. 163 p.                                                                                                                                                                     |
| Paraquat   | Avian Acute Oral Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )       | LD <sub>50</sub> = 176 mg/kg –<br>cation equivalent | Moderately Toxic                                                                                              | US EPA, 1997b<br>MRID 00029001. Fink, R.; Beavers, J.B.; Grimes, J.; et al. (1979) Acute Oral LD <sub>50</sub> – Bobwhite Quail: Paraquat dichloride Technical Salt (SX1142): Project No. 162-121. Final Rept. (Unpublished study received Feb 21, 1980 under 239-2422; prepared by Wildlife International, Ltd., submitted by Chevron Chemical Co., Richmond, Calif.; CDL:241819-A) |
|            | Avian Subacute Dietary Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> ) | LC <sub>50</sub> = 981 ppm                          | Moderately Toxic                                                                                              | US EPA, 1997b<br>MRID 00022923. Hill, E.; Heath, R.; Spann, J. (1975) U.S. Department of Interior, Fish and Wildlife: Lethal Dietary Toxicity of Environmental Pollutants to Birds. Patuxent Wildlife Research Center.                                                                                                                                                               |
|            | Avian Chronic Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )             | NOEC = 30 ppm<br>LOEC = 100 ppm                     | Percent viable eggs,<br>eggs set, normality of<br>hatchlings and number<br>of 14-day old survival<br>affected | US EPA, 1997b<br>MRID 00110455. Fink, R.; Beavers, J.; Joiner, G.; et al. (1982) One-generation Reproduction—Mallard Duck: Paraquat Technical (SX-1305): Project No. 162-145. Final rept. (Unpublished study received Aug 18, 1982 under 239-2186; prepared by Wildlife International Ltd., submitted by Chevron Chemical Co., Richmond, CA; CDL: 248133-D)                          |
| Picloram   | Avian Acute Oral Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )          | LD <sub>50</sub> >2150 mg/kg                        | Practically Non-Toxic                                                                                         | US EPA, 1995<br>MRID 00157173. Beavers, J. (1983) An Acute Oral Toxicity Study in the Mallard with Picloram Technical: Final Report: Project No. 103-221. Unpublished study prepared by Wildlife International Ltd. 15 p.                                                                                                                                                            |
| Pronamide  | Avian Dietary Toxicity                                                           | LD <sub>50</sub> >5000 ppm                          | Practically Non-Toxic                                                                                         | MSDS, 2006                                                                                                                                                                                                                                                                                                                                                                           |
| Sethoxydim | Avian Acute Oral Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )          | LD <sub>50</sub> >2150 mg/kg                        | Practically Non-Toxic                                                                                         | US EPA, 2005                                                                                                                                                                                                                                                                                                                                                                         |
|            | Avian Subacute Dietary Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )    | LC <sub>50</sub> >5620 ppm                          | Practically Non-Toxic                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                      |
|            | Avian Chronic Toxicity                                                           | LOAEC = 100 ppm                                     | Number of hatchlings                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                      |



| Herbicide                               | Test and Species Tested                                                             | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub> | Effect/Conclusion                                 | Reference                                                                                                                                                                                                                                                                                                                                             |
|-----------------------------------------|-------------------------------------------------------------------------------------|------------------------------------------------|---------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                         | Mallard Duck ( <i>Anas platyrhynchos</i> )                                          |                                                | affected                                          |                                                                                                                                                                                                                                                                                                                                                       |
| Terbacil                                | Avian Acute Oral Toxicity<br>Northern Bobwhite Quail ( <i>Colinus virginianus</i> ) | LD <sub>50</sub> >2250 mg/kg                   | Practically Non-Toxic                             | US EPA, 1998c<br>MRID 00157177. Beavers, J. (1986) H #14,673: An Acute Oral Toxicity Study with the Bobwhite: Final Report: Project No. 112-168. Unpublished study prepared by Wildlife International Ltd. 17 p.                                                                                                                                      |
|                                         | Avian Subacute Dietary Toxicity<br>Mallard Duck ( <i>Anas platyrhynchos</i> )       | LC <sub>50</sub> >5000 pm                      | Practically Non-Toxic                             | US EPA, 1998c<br>EPA Accession No. 251146                                                                                                                                                                                                                                                                                                             |
| Trifluralin                             | Avian Acute Oral Toxicity<br>Northern Bobwhite Quail ( <i>Colinus virginianus</i> ) | LD <sub>50</sub> >2000 mg/kg                   | Practically Non-Toxic                             | US EPA, 1996b<br>MRID 00137573. Cochrane, R.; Hudson, H.; Emmerson, J.; et al. (1983) The Toxicity of Trifluralin (Compound 36352) to Bobwhite in a Fourteen-day Acute Oral Study: Study A02383. (Unpublished study received Feb 16, 1984 under 1471-70; submitted by Elanco Products Co., Div. of Eli Lilly and Co., Indianapolis, IN; CDL:252411-A) |
|                                         | Avian Subacute Dietary Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )    | LC <sub>50</sub> >5000 ppm                     | Practically Non-Toxic                             | US EPA, 1996b<br>MRID 00138857. Kehr, C.; Emmerson, J.; Brannon, D.; et al. (1983) The Toxicity of Trifluralin (Compound 36352) to Bobwhite in a Five-day Dietary Study: Study 7016-77. (Unpublished study received Jan 24, 1984 under 1471-70; submitted by Elanco Products Co., Div. of Eli Lilly and Co., Indianapolis, IN; CDL:252283-A)          |
|                                         | Avian Chronic Toxicity<br>Bobwhite Quail ( <i>Colinus virginianus</i> )             | NOEC = 452.3 ppm<br>LOEC = 910.5 ppm           | Cracked eggs<br>percentage of eggs laid increased | US EPA, 1996b<br>MRID 40334706. Beavers, J.; Dukes, V.; Jaber, M. (1987) Trifluralin Technical: A One-generation Reproduction Study with the Bobwhite ( <i>Colinus virginianus</i> ): Project N. 228-101. Unpublished study prepared by Wildlife International Ltd. 89 p.                                                                             |
| <b>Terrestrial Invertebrates (bees)</b> |                                                                                     |                                                |                                                   |                                                                                                                                                                                                                                                                                                                                                       |
| Glyphosate                              | Acute Oral Toxicity<br>Honey bees ( <i>Apis mellifera</i> )                         | LD50 >100 µg/bee                               | Practically Non-Toxic                             | US EPA, 1993<br>MRID 00026489. Fraser, W.D.; Jenkins, G. (1972) The Acute Contact and Oral Toxicities of CP67573 and Mon2139 to Worker Honey Bees. (Unpublished study received on unknown date under 4G1444; prepared by Huntingdon Research Centre, submitted by Monsanto Co., Washington, D.C.; CDL:093848-R)                                       |
|                                         | Acute Contact Toxicity<br>Honey bees ( <i>Apis mellifera</i> )                      | LD50 >100 µg/bee                               | Practically Non-Toxic                             |                                                                                                                                                                                                                                                                                                                                                       |
| 2,4-D                                   | Acute Contact Toxicity<br>Honey bee ( <i>Apis mellifera</i> )                       | LD50 >100 µg/bee                               | Practically Non-Toxic                             | US EPA, 2005a<br>MRID 44517304. Palmer, S.; Krueger, H. (1997) 2,4-D Dimethylamine Salt: An Acute Contact                                                                                                                                                                                                                                             |

| Herbicide   | Test and Species Tested                                            | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub> | Effect/Conclusion     | Reference                                                                                                                                                                                                                                                                                    |
|-------------|--------------------------------------------------------------------|------------------------------------------------|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |                                                                    |                                                |                       | Toxicity Study with the Honey Bee: Lab Project Number: 467-102: 467/052297/BLDNC.EFA/SUB467. Unpublished study prepared by Wildlife International Ltd. 32 p. {OPPTS 850.3020}                                                                                                                |
| 2,4-DB      | Acute Contact Toxicity<br>Honeybee ( <i>Apis mellifera</i> )       | LD <sub>50</sub> = 14.5 µg/bee                 | Practically Non-Toxic | US EPA, 2005b<br>Accession No. 18842                                                                                                                                                                                                                                                         |
| Benefin     | Acute Contact Toxicity<br>Honey bee ( <i>Apis mellifera</i> )      | LD <sub>50</sub> >10 µg/bee                    | Practically Non-Toxic | US EPA, 2004<br>MRID 41613812. Hoxter, K.; Jaber, M. (1990) The Acute Contact Toxicity of Benefin to the Honey Bee: Lab Project Number: 151-115. Unpublished study prepared by Wildlife International Ltd. 30 p.                                                                             |
| Bromoxynil  | Acute Contact Toxicity<br>Honey bee ( <i>Apis mellifera</i> )      | LD <sub>50</sub> = 14.5 µg/bee                 | Practically Non-Toxic | US EPA, 1998a<br>Accession No. 18842                                                                                                                                                                                                                                                         |
| Clethodim   | No Data Available                                                  |                                                |                       |                                                                                                                                                                                                                                                                                              |
| Clopyralid  | No Data Available                                                  |                                                |                       |                                                                                                                                                                                                                                                                                              |
| Diuron      | Acute Oral/Contact Toxicity<br>Honey bee ( <i>Apis mellifera</i> ) | LD <sub>50</sub> = 145 mg/kg                   | Practically Non-Toxic | US EPA, 2003<br>MRID 00036935. Atkins, E.L.; Greywood, E.A.; Macdonald, R.L. (1975) Toxicity of Pesticides and Other Agricultural Chemicals to Honey Bees: Laboratory Studies. By University of California, Dept. of Entomology: UC, Cooperative Extension. (Leaflet 2287; published study.) |
| EPTC        | Acute Oral/Contact Toxicity<br>Honey bee ( <i>Apis mellifera</i> ) | LD <sub>50</sub> >12.05 µg/bee                 | Non-Toxic             | US EPA, 1999                                                                                                                                                                                                                                                                                 |
| Hexazinone  | Acute Contact Toxicity<br>Honey bee ( <i>Apis mellifera</i> )      | LD <sub>50</sub> >100 µg/bee                   | Relatively Non-Toxic  | US EPA, 1994<br>MRID 41216502. Hoxter, K.; Thompson, M.; Jaber, M. (1989) An Acute Contact Toxicity with the Honey Bee: Project ID 112-217. Unpublished study prepared by Wildlife International Ltd. 15 p.                                                                                  |
| Imazamox    | Acute Oral/Contact Toxicity<br>Honey bee ( <i>Apis mellifera</i> ) | LD <sub>50</sub> >25 µg/bee                    | Practically Non-Toxic | US EPA, 1997a<br>Imazamox – Pesticide Fact Sheet.                                                                                                                                                                                                                                            |
| Imazethapyr | No Data Available                                                  |                                                |                       |                                                                                                                                                                                                                                                                                              |
| Metribuzin  | Acute Contact Toxicity<br>Honey bee ( <i>Apis mellifera</i> )      | LD <sub>50</sub> = 60.4 µg/bee                 | Practically Non-Toxic | US EPA, 1998b<br>EPA Accession No. 028772                                                                                                                                                                                                                                                    |
| Norfluazone | Acute Contact Toxicity<br>Honey bee ( <i>Apis mellifera</i> )      | LD <sub>50</sub> >235 µg/bee                   | Practically Non-Toxic | US EPA, 1996a<br>MRID 00146168. Atkins, E. (1985) Letter sent to N. Galihir dated May 20, 1985: Bee adults toxicity dusting test summary. 17 p.                                                                                                                                              |

| Herbicide                                                                                                                         | Test and Species Tested                                                 | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>                                                                                | Effect/Conclusion                                                                     | Reference                                                                                                                                                                                                                                |
|-----------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Paraquat                                                                                                                          | Acute Contact Toxicity<br>Honey bee ( <i>Apis mellifera</i> )           | LD <sub>50</sub> >48 µg/bee                                                                                                   | Relatively Non-toxic                                                                  | US EPA, 1997a<br>MRID 05001991. 05001991 Stevenson, J.H. (1978) The acute toxicity of unformulated pesticides to worker honey bees ( <i>Apis mellifera</i> ). Plant Pathology 27(1):38-40.                                               |
| Picloram                                                                                                                          | Acute Contact Toxicity<br>Honey bee ( <i>Apis mellifera</i> )           | LC <sub>50</sub> >1000 ppm                                                                                                    | Practically Non-Toxic                                                                 | US EPA, 1995                                                                                                                                                                                                                             |
| Pronamide                                                                                                                         | No Data Available                                                       |                                                                                                                               |                                                                                       |                                                                                                                                                                                                                                          |
| Sethoxydim                                                                                                                        | No Data Available                                                       |                                                                                                                               |                                                                                       |                                                                                                                                                                                                                                          |
| Terbacil                                                                                                                          | Acute Contact Toxicity<br>Honey bee ( <i>Apis mellifera</i> )           | LD <sub>50</sub> = 193 µg/bee                                                                                                 | Practically Non-Toxic                                                                 | US EPA, 1998c<br>MRID 00018842                                                                                                                                                                                                           |
| Trifluralin                                                                                                                       | Acute Contact Toxicity<br>Honey bee ( <i>Apis mellifera</i> )           | LD <sub>50</sub> >100 µg/bee                                                                                                  | Practically Non-Toxic                                                                 | US EPA, 1996b<br>MRID 05001991. Stevenson, J.H. (1978) The acute toxicity of unformulated pesticides to worker honey bees ( <i>apis mellifera</i> ). Plant Pathology 27(1): 38-40.                                                       |
|                                                                                                                                   | Acute Oral Toxicity<br>Honey bee ( <i>Apis mellifera</i> )              | LD <sub>50</sub> >50 µg/bee                                                                                                   | Practically Non-Toxic                                                                 | US EPA, 1996b                                                                                                                                                                                                                            |
| <b>Reptile</b>                                                                                                                    |                                                                         |                                                                                                                               |                                                                                       |                                                                                                                                                                                                                                          |
| No data was available from the EPA RED documents or MSDS on the soil microorganism toxicity for the 20 herbicides used in alfalfa |                                                                         |                                                                                                                               |                                                                                       |                                                                                                                                                                                                                                          |
| <b>Terrestrial Plants</b>                                                                                                         |                                                                         |                                                                                                                               |                                                                                       |                                                                                                                                                                                                                                          |
| Glyphosate                                                                                                                        | Seed Germination/Seedling<br>Emergence – Monocots and Dicots            | Applied at a rate up<br>to 10.0 lb ai/A<br>resulted in <25 %<br>effect on the<br>spectrum of<br>monocots and dicots<br>tested | not expected to cause<br>adverse effects on seed<br>germination/seedling<br>emergence | US EPA, 1993<br>MRID 40159301. Bohn, J. (1987) An Evaluation of<br>the Preemergence Herbicidal Activity of CP-70139:<br>Lab Project ID: 056337. Unpublished study<br>prepared by Monsanto Agricultural Co. 25 p.                         |
| 2,4-D                                                                                                                             | Seedling Emergence Toxicity (Tier II)<br>– Monocots<br>Onion, Sorghum   | EC <sub>25</sub> ≥2.1 lbs ae/A                                                                                                | Not reported                                                                          | US EPA, 2005a<br>MRID 42416802. Backus, P. (1992) Effect of 2,4-D<br>Acid on Seed Germination/Seedling Emergence:<br>Tier II: Lab Project Number: 5097-91-0389-BE-001:<br>91-0389. Unpublished study prepared by Ricerca,<br>Inc. 223 p. |
|                                                                                                                                   | Seedling Emergence Toxicity (Tier II)<br>– Dicots<br>Mustard            | EC <sub>25</sub> = 0.033 lbs<br>ae/A                                                                                          | Not reported                                                                          |                                                                                                                                                                                                                                          |
|                                                                                                                                   | Vegetative Vigor Toxicity (Tier II)<br>Monocots<br>Onion                | EC <sub>25</sub> <0.0075 lbs<br>a.i./A                                                                                        | Not reported                                                                          | US EPA, 2005a<br>MRID 42416801. Backus, P. (1992) Effect of 2,4-D<br>Acid on Vegetative Vigor of Plants: Tier II: Lab<br>Project Number: 91-0390: 5097-91-0390-BE-001.<br>Unpublished study prepared by Ricerca, Inc. 124 p.             |
|                                                                                                                                   | Vegetative Vigor Toxicity (Tier II)<br>Dicots<br>Tomato                 | EC <sub>25</sub> = 0.0075 lbs<br>a.i./A                                                                                       | Not reported                                                                          |                                                                                                                                                                                                                                          |
| 2,4-DB                                                                                                                            | Seedling Emergence Toxicity – Dicots<br>Carrot ( <i>Daucus carota</i> ) | EC <sub>25</sub> = 0.081 lbs<br>ae/A                                                                                          | Not reported                                                                          | US EPA, 2005b<br>MRID 41605401. Hoberg, J. (1990) 2,4 DB Amine-                                                                                                                                                                          |

| Herbicide  | Test and Species Tested                                      | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>                                 | Effect/Conclusion                         | Reference                                                                                                                                                                                                                                                                                                                          |
|------------|--------------------------------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            |                                                              | NOAEC = 0.0028<br>lbs ae./A                                                    |                                           | Determination of Effects on Seedling Germination, Seed Emergence and Vegetative Vigor of Ten Plant Species: Lab Project Number: 10566-0289-6130-610: 90-4-3280. Unpublished study prepared by Springborn Laboratories, Inc. 150 p.                                                                                                 |
|            | Vegetative Vigor Toxicity (Tier II)<br>Monocots<br>Onion     | EC <sub>25</sub> = 0.070 lbs<br>a.i./A<br><br>NOAEC = 0.043 lbs<br>a.i./A      | Not reported                              |                                                                                                                                                                                                                                                                                                                                    |
| Benefin    | Seedling Emergence Toxicity –<br>Monocots<br>Sorghum         | EC <sub>25</sub> = 1.3 lbs a.i./A<br>NOAEC = 0.75 ppm<br>a.i./A                | Not reported                              | US EPA, 2004<br>MRID 43599201                                                                                                                                                                                                                                                                                                      |
|            | Vegetative Vigor Toxicity (Tier II)<br>Dicot<br>Soybean      | EC <sub>25</sub> = 2.3 lbs a.i./A<br><br>EC <sub>05</sub> = 0.38 lbs<br>a.i./A | Not reported                              |                                                                                                                                                                                                                                                                                                                                    |
| Bromoxynil | Seedling Emergence Toxicity (Tier II)<br>– Dicots<br>Lettuce | EC <sub>25</sub> = 0.014 lbs<br>a.i./A (Heptanoate)                            | Affects shoot length                      | US EPA, 1998a<br>MRID 43059603. Hoberg, J. (1993) Bromoxynil Heptanoate-Determination of Effects on Seed Germination, Seedling Emergence and Vegetative Vigor of Ten Plant Species: Lab Project Number: 93-10-5003: 10566.0493. 6287.610. Unpublished study prepared by Springborn Labs., Inc., Environmental Sciences Div. 217 p. |
|            | Vegetative Vigor Toxicity (Tier II)<br>Dicot<br>Cabbage      | EC <sub>25</sub> = 0.011 lbs<br>a.i./A (Heptanoate)                            | Affects shoot weight                      |                                                                                                                                                                                                                                                                                                                                    |
|            | Seed Germination – Dicot<br>Tomato                           | EC <sub>25</sub> >0.45 lbs a.i./A                                              | Affects germination and<br>radicle length | US EPA, 1998a<br>MRID 43273801. Hoberg, J. (1994) Bromoxynil Octanoate–Determination of Effects on Seed Germination of Ten Plant Species: Final Report: Lab Project Number: 94-4-5225: 10566.0394.6339.610. Unpublished study prepared by Springborn Lab., Inc. 72 p.                                                              |
| Clethodim  | No Data Available                                            |                                                                                |                                           |                                                                                                                                                                                                                                                                                                                                    |
| Clopyralid | No Data Available                                            |                                                                                |                                           |                                                                                                                                                                                                                                                                                                                                    |
| Diuron     | Seedling Emergence Toxicity (Tier II)<br>– Monocots<br>Onion | EC <sub>25</sub> = 0.099 lbs<br>a.i./A                                         | Not reported                              | US EPA, 2003<br>MRID 44113401. Heldreth, K.; McKelvey, R. (1996) Influence of Diuron on Seed Germination, Seedling Emergence, and Vegetative Vigor of Several Terrestrial Plants: Supplement No. 1: Lab Project Number: AMR 2069-91: MR 10335. Unpublished study prepared by E. I. du Pont de Nemours and Co. 240 p.               |
|            | Seedling Emergence Toxicity (Tier II)<br>– Dicots<br>Tomato  | EC <sub>25</sub> = 0.08 lbs a.i./A                                             | Not reported                              |                                                                                                                                                                                                                                                                                                                                    |
|            | Vegetative Vigor Toxicity (Tier II)<br>Monocots              | EC <sub>25</sub> = 0.021 lbs<br>a.i./A                                         | Not reported                              |                                                                                                                                                                                                                                                                                                                                    |

| Herbicide   | Test and Species Tested                                          | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>                             | Effect/Conclusion                | Reference                                                                                                                                                                                                                                                                                                             |
|-------------|------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             | Wheat                                                            |                                                                            |                                  |                                                                                                                                                                                                                                                                                                                       |
|             | Vegetative Vigor Toxicity (Tier II)<br>Dicot<br>Tomato           | EC <sub>25</sub> = 0.002 lbs<br>a.i./A                                     | Not reported                     | US EPA, 2003<br>MRID 42398501. McKelvey, R.; Kuratle, H. (1992)<br>Influence of Diuron on Seed Germination, Seedling<br>Emergence, and Vegetative Vigor of Several<br>Terrestrial Plants: Lab Project Number: AMR 2069-<br>91. Unpublished study prepared by E.I. du Pont de<br>Nemours and Co. 234 p.                |
| EPTC        | Seedling Emergence Toxicity (Tier II)<br>– Monocots<br>Wild Oats | EC <sub>25</sub> = 0.10 lbs<br>a.i./A                                      | Not reported                     | US EPA, 1999                                                                                                                                                                                                                                                                                                          |
| Hexazinone  | Seedling Germination                                             | EC <sub>25</sub> >12.0 lbs<br>a.i./acre                                    | Not reported                     | US EPA, 1994<br>MRID 43162501. McKelvey, R.; Heldreth, K. (1994)<br>Influence of Hexazinone on Seed Germination,<br>Seedling Emergence, and Vegetative Vigor of<br>Several Terrestrial Plants: Lab Project Number:<br>AMR 2678-93: AMR 2736-93. Unpublished study<br>prepared by DuPont Agricultural Products. 351 p. |
|             | Seedling Emergence Toxicity (Tier II)<br>– Dicot<br>Tomato       | EC <sub>25</sub> = 0.0064 lbs<br>a.i./A                                    | Not reported                     |                                                                                                                                                                                                                                                                                                                       |
|             | Vegetative Vigor Toxicity (Tier II) –<br>Rape                    | EC <sub>25</sub> = 0.011 lbs<br>a.i./A                                     | Not reported                     |                                                                                                                                                                                                                                                                                                                       |
| Imazamox    | No Data Available                                                |                                                                            |                                  |                                                                                                                                                                                                                                                                                                                       |
| Imazethapyr | No Data Available                                                |                                                                            |                                  |                                                                                                                                                                                                                                                                                                                       |
| Metribuzin  | Seedling Emergence Toxicity (Tier II)<br>– Monocots<br>Onion     | EC <sub>25</sub> = 0.020 lbs<br>a.i./A<br><br>NOEC = 0.014 lbs<br>a.i./A   | Survival affected                | US EPA, 1998b<br>MRID 42447803. Burge, C. (1992) Tier 2 Seed<br>Germination, Seed Emergence, and Seedling Vigor<br>Nontarget Phytotoxicity Study Using Metribuzin:<br>Lab Project Number: 103800: SE201601.<br>Unpublished study prepared by Miles, Inc. 90 p.                                                        |
|             | Seedling Emergence Toxicity (Tier II)<br>– Dicot<br>Turnip       | EC <sub>25</sub> = 0.008% lbs<br>a.i./A<br><br>NOEC = 0.007% lbs<br>a.i./A | Weight affected                  |                                                                                                                                                                                                                                                                                                                       |
|             | Vegetative Vigor Toxicity (Tier II) –<br>Monocots<br>Onion       | EC <sub>25</sub> = 0.017 lbs<br>a.i./A<br><br>NOEC = 0.0112 lbs<br>a.i./A  | Height and weight<br>affected    |                                                                                                                                                                                                                                                                                                                       |
|             | Vegetative Vigor Toxicity (Tier II) –<br>Dicots<br>Turnip        | EC <sub>25</sub> = 0.005 lbs<br>a.i./A<br><br>NOEC = 0.0028 lbs<br>a.i./A  | Weight affected                  |                                                                                                                                                                                                                                                                                                                       |
| Norfluzao   | Seedling Emergence Toxicity (Tier II)<br>– Dicot                 | EC <sub>25</sub> = 0.002 lbs<br>a.i./A                                     | May cause detrimental<br>effects | US EPA, 1996a<br>MRID 43312501. Backus, P. (1994) Effect of                                                                                                                                                                                                                                                           |

| Herbicide  | Test and Species Tested                                       | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>                                                                  | Effect/Conclusion   | Reference                                                                                                                                                                                                                                                                                                                                                            |
|------------|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            | Mustard                                                       | NOEC = 0.00064 lbs<br>a.i./A                                                                                    |                     | Norflurazon on Seedling Emergence (Tier II):<br>Supplemental Test: Lab Project Number: 93-0139:<br>5745-93-0139-BE-001: 5745-93-0139-BE-000.<br>Unpublished study prepared by Ricerca, Inc. 92 p.                                                                                                                                                                    |
|            | Seedling Germination – Dicot<br>Radish                        | EC <sub>25</sub> >100 lbs a.i./A<br><br>NOEC = 2.0 lbs<br>a.i./A                                                | Not reported        | US EPA, 1996a<br>MRID 42080404. Backus, P. (1991) Effect of<br>Norflurazon on Seed Germination/Seedling<br>Emergence (Tier II): Report Addendum: Lab Project<br>Number: 3805-91-0009-BE-001-002. Unpublished<br>study prepared by Ricerca, Inc. 337                                                                                                                  |
|            | Vegetative Vigor Toxicity (Tier II) –<br>Dicots<br>Cucumber   | EC <sub>25</sub> = 0.06 lbs<br>a.i./A<br><br>NOEC = 0.016 lbs<br>a.i./A                                         | Not reported        | US EPA, 1996a<br>MRID 42080405. Backus, P. (1991) Effect of<br>Norflurazon on Vegetative Vigor of Plants (Tier II):<br>Report Addendum: Lab Project Number: 5-910010-<br>BE-001-002. Unpublished study prepared by<br>Ricerca, Inc. 141 p.                                                                                                                           |
| Paraquat   | Seedling Emergence Toxicity (Tier II)<br>– Dicot<br>Cocklebur | EC <sub>25</sub> = 0.85 lbs<br>cation/A                                                                         | Not reported        | US EPA, 1997b<br>MRID 42639601. Canning, L.; White, J. (1992)<br>Paraquat: A Glasshouse Study to Evaluate the<br>Effects on Seedling Emergence of a 300 g ai litre-1<br>(2.5 lb ai US gal-1) Soluble Concentrate<br>Formulation on Terrestrial Non-Target Plants: Lab<br>Project Number: 92JH089: RJ1280B. Unpublished<br>study prepared by ICI Agrochemicals. 56 p. |
|            | Vegetative Vigor Toxicity (Tier II) –<br>Dicots<br>Cocklebur  | EC <sub>25</sub> = 0.013 lbs<br>cation/A                                                                        | Not reported        |                                                                                                                                                                                                                                                                                                                                                                      |
| Picloram   | No Data Available                                             |                                                                                                                 |                     |                                                                                                                                                                                                                                                                                                                                                                      |
| Pronamide  | No Data Available                                             |                                                                                                                 |                     |                                                                                                                                                                                                                                                                                                                                                                      |
| Sethoxydim | Vegetative Vigor Toxicity (Tier II)<br>Ryegrass               | EC <sub>25</sub> = 0.029 lbs<br>a.i./A<br>EC <sub>50</sub> = 0.038 lbs<br>a.i./A<br>NOAEC = 0.025 lbs<br>a.i./A | Not reported        | US EPA, 2005c                                                                                                                                                                                                                                                                                                                                                        |
| Terbacil   | Seedling Emergence Toxicity (Tier II)<br>– Dicot<br>Rape      | EC <sub>25</sub> = 0.0149 lbs<br>a.i./A<br><br>NOEC = 0.063 lbs<br>a.i./A                                       | Dry weight affected | US EPA, 1998c<br>MRID 43895801. Heldreth, K.; McKelvey, R. (1996)<br>Influence of Terbacil on Seed Germination,<br>Seedling Emergence, and Vegetative Vigor of<br>Several Terrestrial Plants: Supplement No. 1: Lab                                                                                                                                                  |

| Herbicide                                                                                                                         | Test and Species Tested                                                        | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>                                                            | Effect/Conclusion                    | Reference                                                                                                                                                                                                                                                                                                            |
|-----------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|--------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                   |                                                                                |                                                                                                           |                                      | Project Number: AMR 2073-91: MR 10421. Unpublished study prepared by DuPont Agricultural Products. 414 p.                                                                                                                                                                                                            |
|                                                                                                                                   | Seedling Emergence Toxicity (Tier II) – Monocots<br>Wheat                      | EC <sub>25</sub> = 0.025 lbs a.i./A<br><br>NOEC = 0.030 lbs a.i./A                                        | Shoot height affected                | US EPA, 1998c<br>MRID 42336701. McKelvey, R.; Kuratle, H. (1992) Influence of Terbacil on Seed Germination, Seedling Emergence, and Vegetative Vigor of Several Terrestrial Plants: Lab Project Number: AMD 2073-91. Unpublished study prepared by E. I. du Pont de Nemours and Comp. 228 p.                         |
|                                                                                                                                   | Vegetative Vigor Toxicity (Tier II) – Dicots<br>Cucumber                       | EC <sub>25</sub> = 0.0058 lbs a.i./A<br><br>NOEC = 0.0031 lbs a.i./A                                      | Dry weight affected                  | US EPA, 1998c<br>MRID 43895801. Heldreth, K.; McKelvey, R. (1996) Influence of Terbacil on Seed Germination, Seedling Emergence, and Vegetative Vigor of Several Terrestrial Plants: Supplement No. 1: Lab Project Number: AMR 2073-91: MR 10421. Unpublished study prepared by DuPont Agricultural Products. 414 p. |
|                                                                                                                                   | Vegetative Vigor Toxicity (Tier II) – Monocots<br>Wheat                        | EC <sub>25</sub> = 0.062 lbs a.i./A<br><br>NOEC = 0.12 lbs a.i./A                                         | Shoot height affected                | US EPA, 1998c<br>MRID 42336701. McKelvey, R.; Kuratle, H. (1992) Influence of Terbacil on Seed Germination, Seedling Emergence, and Vegetative Vigor of Several Terrestrial Plants: Lab Project Number: AMD 2073-91. Unpublished study prepared by E. I. du Pont de Nemours and Comp. 228 p.                         |
| Trifluralin                                                                                                                       | Seedling Germination<br>Onion                                                  | EC <sub>25</sub> = 0.33 lbs a.i./A<br><br>EC <sub>50</sub> = 4.3 lbs a.i./A<br><br>NOEC = 0.13 lbs a.i./A | Radicle length affected              | US EPA, 1996b<br>MRID 42695601. Schwab, D. (1993) Evaluating the Effects of Trifluralin on the Germination of Non-Target Terrestrial Plants: Lab Project Number: 40619. Unpublished study prepared by ABC Laboratories, Inc. 42 p.                                                                                   |
| <b>Soil Microorganisms</b>                                                                                                        |                                                                                |                                                                                                           |                                      |                                                                                                                                                                                                                                                                                                                      |
| No data was available from the EPA RED documents or MSDS on the soil microorganism toxicity for the 20 herbicides used in alfalfa |                                                                                |                                                                                                           |                                      |                                                                                                                                                                                                                                                                                                                      |
| <b>Freshwater Invertebrates</b>                                                                                                   |                                                                                |                                                                                                           |                                      |                                                                                                                                                                                                                                                                                                                      |
| Glyphosate                                                                                                                        | Acute Toxicity to Freshwater Invertebrates<br><i>Chironomus plumosus</i>       | 48-hr LC <sub>50</sub> = 55 ppm (31-97, 95% CL)                                                           | Slightly Toxic                       | US EPA, 1993                                                                                                                                                                                                                                                                                                         |
|                                                                                                                                   | Chronic Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i> | MATC > 50 -< 96 mg/L                                                                                      | Caused reduced reproductive capacity | US EPA, 1993<br>MRID 00124763. McAllister, W.; McKee, M.; Schofield, M.; et al. (1982) Chronic Toxicity of Glyphosate (AB-82-036) to <i>Daphnia magna</i> under                                                                                                                                                      |

| Herbicide  | Test and Species Tested                                                         | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>                | Effect/Conclusion                                    | Reference                                                                                                                                                                                                                                                                                                                          |
|------------|---------------------------------------------------------------------------------|---------------------------------------------------------------|------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            |                                                                                 |                                                               |                                                      | Flow-through Test Conditions: Chronic Toxicity Final Report ABC #28742. (Unpublished study received Dec 27, 1982 under 524-308; prepared by Analytical Bio-Chemistry Laboratories, Inc., submitted by Monsanto Co., Washington, DC; CDL:249160-A)                                                                                  |
| 2,4-D      | Acute Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i>    | 48-hr LC <sub>50</sub> = 25 mg ae/L                           | Slightly Toxic                                       | US EPA, 2005a<br>MRID 41158301. Alexander, H.; Mayes, M.; Gersich, F. (1983) The Acute Toxicity of (2,4-Dichlorophenoxy)acetic Acid to Representative Aquatic Organisms: Project Study ID: ES-DR-0002-2297-4. Unpublished study prepared by Dow Chemical U.S.A. 26 p.                                                              |
|            | Chronic Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i>  | NOEC = 79 mg ae/L<br>LOEC = 151 mg ae/L<br>MATC = 109 mf ae/L | NOEC is calculated based on number of young produced | US EPA, 2005<br>MRID 41835211. Ward, T.; Boeri, R. (1991) Chronic Toxicity of 2,4-D to the Daphnid <i>Daphnia magna</i> : Lab Project Number: 9040-D. Unpublished study prepared by Resource Analysts, Inc./EnviroSystems Div. 38 p.                                                                                               |
| 2,4-DB     | Acute Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i>    | 48-hr EC <sub>50</sub> = 25 mg a.i./L                         | Slightly Toxic                                       | US EPA, 2005b<br>MRID 41407801. McNamara, P. (1990) 2,4 DB-acid– Acute Toxicity to Daphnids ( <i>Daphnia magna</i> ) during a 48hour Flow-through Acute Exposure: Final Report: Lab Report # 89-7-3031; Study # 10566.0289.6125.115. Unpublished study prepared by Springborn Laboratories, Inc., Environmental Sciences Div. 39p. |
|            | Acute Toxicity to Freshwater Invertebrates – Stonefly ( <i>Pteronarcys</i> sp.) | 48-hr EC <sub>50</sub> = 15 mg a.i./L                         | Slightly Toxic                                       | US EPA, 2005b<br>MRID 40094602                                                                                                                                                                                                                                                                                                     |
| Benefin    | Acute Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i>    | 48-hr EC <sub>50</sub> = 2.18 ppm a.i.                        | Moderately Toxic                                     | US EPA, 2004<br>MRID 42390802. Newstead, J.; Brock, D. (1992) The Acute Toxicity of Balan EC (FN 0270) a Formulation Containing Benfen (EL-110, Compound 054521), to <i>Daphnia magna</i> in a Static Renewal Test System: Lab Project Number: C01692. Unpublished study prepared by Lilly Research Labs. 36 p.                    |
| Bromoxynil | Acute Toxicity to Freshwater Invertebrates                                      | EC <sub>50</sub> = 11 ppb a.i. (Octanoate)                    | Very Highly Toxic                                    | US EPA, 1998a<br>MRID 00109417. Harper, K.; Ball, I. (1964) The                                                                                                                                                                                                                                                                    |



| Herbicide  | Test and Species Tested                                                          | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>                       | Effect/Conclusion                                                                                   | Reference                                                                                                                                                                                                                                                                                            |
|------------|----------------------------------------------------------------------------------|----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            | Waterflea <i>Daphnia magna</i>                                                   |                                                                      |                                                                                                     | Acute Toxicity of NPH 1320 Formulation of M & B 10731 to (a) <i>Daphnia</i> (Crustacea cladocera): 1093/65/9. (Unpublished study received Jul 28, 1982 under 359-564; prepared by Huntingdon Research Centre, Eng., submitted by Rhone-Poulenc, Inc., Monmouth Junction, NJ; CDL:247924-E)           |
|            | Acute Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i>     | EC <sub>50</sub> = 31 ppb<br>a.i.(heptanoate)                        | Very Highly Toxic                                                                                   | US EPA, 1998a<br>MRID 43059602. Putt, A. (1993) Bromoxynil Heptanoate-Acute Toxicity to Daphnids ( <i>Daphnia magna</i> ) Under Flow-Through Conditions: Lab Project Number: 93-11-5050: 10566.0693.6304.115. Unpublished study prepared by Springborn Labs., Inc., Environmental Sciences Div. 74p. |
|            | Acute Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i>     | EC <sub>50</sub> = 19,220 ppb<br>a.i.                                | Slightly Toxic                                                                                      | US EPA, 1998a<br>MRID 00155070. Surprenant, D. (1985) Acute Toxicity of Bromoxynil Phenol to Daphnids ( <i>Daphnia magna</i> ): Study #565-0285-6110-110: Report #BW-85-9-1840. Unpublished study prepared by Springborn Bionomics, Inc. 15 p.                                                       |
|            | Chronic Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i>   | NOAEL = 2.5 ppb<br>a.i.<br>LOAEL = 5.9 ppb<br>a.i.<br>MATC = 3.8 ppb | Invertebrate reproductive impairment may occur at bromoxynil octanoate levels greater than 2.5 ppb. | US EPA, 1998a<br>MRID 41928302. Putt, A. (1991) Bromoxynil Octanoate: Chronic Toxicity to Daphnids ( <i>Daphnia magna</i> ) Under Flow-Through Conditions: Lab Project Number: 10566. 0990. 6166. 130: 91-4-3718. Unpublished study prepared by Springborn Laboratories, Inc. 73 p.                  |
| Clethodim  | Acute Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i>     | EC <sub>50</sub> >1000 mg/L                                          | Practically Non-Toxic                                                                               | MSDS, 2007                                                                                                                                                                                                                                                                                           |
| Clopyralid | No Data Available                                                                |                                                                      |                                                                                                     |                                                                                                                                                                                                                                                                                                      |
| Diuron     | Acute Toxicity to Freshwater Invertebrates<br>Scud ( <i>Gammarus fasciatus</i> ) | 48-hr EC <sub>50</sub> = 0.16 ppm                                    | Highly Toxic                                                                                        | US EPA, 2003<br>MRID 40094602. Johnson, W.; Finley, M. (1980) Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates: Resource Publication 137. US Fish and Wildlife Service, Washington, D.C. 106 p.                                                                             |
|            | Acute Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i>     | 48-hr EC <sub>50</sub> = 1.4 ppm                                     | Moderately Toxic                                                                                    |                                                                                                                                                                                                                                                                                                      |
| EPTC       | Acute Toxicity to Freshwater                                                     | LC <sub>50</sub> = 6.5 ppm                                           | Moderately Toxic                                                                                    | US EPA, 1999                                                                                                                                                                                                                                                                                         |

| Herbicide   | Test and Species Tested                                                           | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>        | Effect/Conclusion                            | Reference                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-------------|-----------------------------------------------------------------------------------|-------------------------------------------------------|----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             | Invertebrates                                                                     |                                                       |                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Hexazinone  | Acute Toxicity to Freshwater<br>Invertebrates<br>Waterflea <i>Daphnia magna</i>   | EC <sub>50</sub> = 151.6 ppm                          | Practically Non-Toxic                        | US EPA, 1994<br>MRID. 00116269. Schneider, P. (1976) 48-hour<br>LC50 to <i>Daphnia magna</i> : Haskell Laboratory<br>Report No. 262-76. (Unpublished study received<br>Dec 30, 1977; under<br>352-387; submitted by E.I. du Pont de Nemours &<br>Co., Inc., Wilmington, DE; CDL:232556-A; 235401)                                                                                                                                                                                     |
|             | Chronic Toxicity to Freshwater<br>Invertebrates<br>Waterflea <i>Daphnia magna</i> | MATC = 48.5 ppm                                       | Survival affected                            | US EPA, 1994<br>MRID 41406002. Pierson, K. (1990) Chronic<br>Toxicity of IN A3674-207 to <i>Daphnia magna</i> : Lab<br>Project Number: HLR 68-90: MR-8705-001.<br>Unpublished study prepared by E.I. du Pont de<br>Nemours and Co., Inc. 198 p.                                                                                                                                                                                                                                       |
| Imazamox    | Acute Toxicity to Freshwater<br>Invertebrates<br>Waterflea <i>Daphnia magna</i>   | LC <sub>50</sub> >122 ppm                             | Practically Non-Toxic                        | US EPA, 1997a<br>Imazamox – Pesticide Fact Sheet.                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Imazethapyr | No Data Available                                                                 |                                                       |                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Metribuzin  | Acute Toxicity to Freshwater<br>Invertebrates<br>Waterflea <i>Daphnia magna</i>   | LC <sub>50</sub> = 4.2 ppm                            | Moderately Toxic                             | US EPA, 1998b<br>MRID 00072083                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|             | Chronic Toxicity to Freshwater<br>Invertebrates<br>Waterflea <i>Daphnia magna</i> | NOEC = 1.29 ppm<br>LOEC = 2.62 ppm<br>MATC = 1.84 ppm | Length and number of<br>offspring affected   | US EPA, 1998b<br>MRID 42447802. Gagliano, G.; Bowers, L. (1992)<br>Chronic Toxicity of Sencor Technical to the<br>Waterflea ( <i>Daphnia magna</i> ) under Flow-through<br>Conditions: Lab Project Number: 103248:<br>SE840701. Unpublished study prepared by Miles,<br>Inc. 75 p.                                                                                                                                                                                                    |
| Norfluzon   | Acute Toxicity to Freshwater<br>Invertebrates<br>Waterflea <i>Daphnia magna</i>   | EC <sub>50</sub> >15 ppm<br><br>NOEC = 15 ppm         | Slightly Toxic                               | US EPA, 1996a<br>MRID 00035709. Vilkas, A.G.; Browne, A.M. (1980)<br>The Acute Toxicity of Norflurazon (99.4% Active<br>Ingredient) to the Water Flea, <i>Daphnia magna</i><br>Straus: UCCES Project No. 11506-16-04.<br>(Unpublished study including letter dated May 20,<br>1980, from R.J. McCormack to R.E. Stoll, received<br>Jun 5, 1980, under 11273-19; prepared by Union<br>Carbide Corp.; submitted by Sandoz, Inc. -- Crop<br>Protection, San Diego, Calif.: CDL:242619-A) |
|             | Chronic Toxicity to Freshwater<br>Invertebrates                                   | NOEC = 1.0 ppm                                        | Percent survival and<br>offspring production | US EPA, 1996a<br>EPA Accession No. FAONOR03                                                                                                                                                                                                                                                                                                                                                                                                                                           |

| Herbicide   | Test and Species Tested                                                        | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub>             | Effect/Conclusion | Reference                                                                                                                                                                                                                                                                                                                                              |
|-------------|--------------------------------------------------------------------------------|------------------------------------------------------------|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             | Waterflea <i>Daphnia magna</i>                                                 | LOEC = 2.6 ppm<br><br>MATC >1.0 <2.6 ppm                   | affected          |                                                                                                                                                                                                                                                                                                                                                        |
| Paraquat    | Acute Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i>   | EC <sub>50</sub> = 1.2 ppm                                 | Moderately Toxic  | US EPA, 1997b<br>MRID 00114473. 00114473 Wheeler, R. (1978) 48 Hour Acute Static Toxicity of Paraquat Dichloride Salt (SX957) to 1st Stage Nymph Water Fleas ( <i>Daphnia magna</i> Straus). (Unpublished study received Sep 15, 1978 under 239-2422; submitted by Chevron Chemical Co., Richmond, CA; CDL:235419-A)                                   |
| Picloram    | Acute Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i>   | LC <sub>50</sub> = 34.4 mg/L                               | Slightly Toxic    | US EPA, 1995<br>MRID 00151783. Gersich, F.; Hopkins, D.; Milazzo, D. (1984) The Acute and Chronic Toxicity of Technical Picloram (4-Amino-3,5,6-trichloropicolinic acid) to <i>Daphnia magna</i> Straus: ES-690. Unpublished study prepared by Dow Chemical USA. 16 p.                                                                                 |
| Pronamide   | No Data Available                                                              |                                                            |                   |                                                                                                                                                                                                                                                                                                                                                        |
| Sethoxydim  | No Data Available                                                              |                                                            |                   |                                                                                                                                                                                                                                                                                                                                                        |
| Terbacil    | Acute Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i>   | 48-hr EC <sub>50</sub> = 65 ppm                            | Slightly Toxic    | US EPA, 1998c<br>MRID 00390018.                                                                                                                                                                                                                                                                                                                        |
| Trifluralin | Acute Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i>   | EC <sub>50</sub> = 560 ppb                                 | Highly Toxic      | US EPA, 1996<br>MRID 40094602. Johnson, W.; Finley, M. (1980) Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates: Resource Publication 137. U.S. Fish and Wildlife Service, Washington, D.C. 106 p.                                                                                                                             |
|             | Chronic Toxicity to Freshwater Invertebrates<br>Waterflea <i>Daphnia magna</i> | NOEC = 2.4 ppb<br><br>LOEC = 7.2 ppb<br><br>MATC = 4.8 ppb | Survival affected | US EPA, 1996b<br>MRID 05008271. Macek, K.J.; Lindberg, M.A.; Sauter, S.; Buxton, K.S.; Costa, P.A. (1976) Toxicity of Four Pesticides to Water Fleas and Fathead Minnows. Duluth, Minn.: U.S. Environmental Protection Agency, Environmental Research Laboratory. (EPA report no. EPA-600/3-76-099; available from: NTIS, Springfield, VA; PB-262 912) |

Table N-49. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data – Aquatic Marine

| Herbicide                             | Test and Species Tested                                                                              | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub> | Effect/Conclusion     | Reference                                                                                                                                                                                                                                                                                                                         |
|---------------------------------------|------------------------------------------------------------------------------------------------------|------------------------------------------------|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Marine and Estuarine Organisms</b> |                                                                                                      |                                                |                       |                                                                                                                                                                                                                                                                                                                                   |
| Glyphosate                            | Acute Toxicity to Estuarine and Marine Organisms<br>Atlantic oyster ( <i>Crassostrea virginica</i> ) | TL50 > 10 mg/L for 48 hours                    | Slightly Toxic        | US EPA, 1993<br>MRID 00108110. Bentley, R. (1973) Acute Toxicity of Roundup (Technical) to Atlantic Oyster ( <i>Crassostrea virginica</i> ). (Unpublished study received Jul 12, 1974 under 5F1536; prepared by Bionomics, Inc., submitted by Monsanto Co., Washington, DC; CDL:094171-L)                                         |
| 2,4-D                                 | Acute Toxicity to Estuarine and Marine Organisms<br>Eastern oyster ( <i>Crassostrea virginica</i> )  | 96-hr LC <sub>50</sub> = 57 mg ae/L            | Slightly Toxic        | US, EPA 2005a<br>MRID 42979701. Ward et al. (1993)                                                                                                                                                                                                                                                                                |
|                                       | Acute Toxicity to Estuarine and Marine Fish<br>Tidewater silverside ( <i>Menidia beryllina</i> )     | 96-hr LC <sub>50</sub> = 175 mg ae/L           | Practically Non-Toxic | US EPA, 2005a<br>MRID 41737307. Vaishnav, D.; Yurk, J.; Wade, B. (1990) 2,4-Dichlorophenoxyacetic Acid: Acute Toxicity to Tidewater Silverside ( <i>Menidia Beryllina</i> ) Under Flowthrough Conditions: Lab Project Number: 3903008000- 0210-3140. Unpublished study prepared by Environmental Science and Engineering Inc.37p. |
| 2,4-DB                                | No Data Available                                                                                    |                                                |                       |                                                                                                                                                                                                                                                                                                                                   |
| Benefin                               | Acute Toxicity to Estuarine and Marine Invertebrates<br>Mysid shrimp ( <i>Americamysis bahia</i> )   | EC <sub>50</sub> = 0.043 ppm a.i.              | Very Highly Toxic     | US EPA, 2004<br>MRID 41613804. Sousa, J. (1990) Benefin-Acute Toxicity to Mysid Shrimp ( <i>Mysidopsis bahia</i> ) Under Flowthrough Conditions: Lab Project Number: 90-06- -3343; 1982.1289.6102.515. Unpublished study prepared by Spring born Laboratories, Inc. 55 p.                                                         |
| Bromoxynil                            | Acute Toxicity to Estuarine and Marine Invertebrates<br>Mysid shrimp ( <i>Americamysis bahia</i> )   | LC <sub>50</sub> = 65 ppb a.i.                 | Very Highly Toxic     | US EPA, 1998a<br>MRID 43487601. Machado, M. (1994) Bromoxynil Octanoate Technical–Acute Toxicity to Mysids ( <i>Mysidopsis bahia</i> ) Under Flow-through Conditions: Final Report: Lab Project Number: 94-10-5502:10566.0894.6344.515. Unpublished study prepared by Springborn Labs, Inc. 70 p.                                 |
| Clethodim                             | No Data Available                                                                                    |                                                |                       |                                                                                                                                                                                                                                                                                                                                   |
| Clopyralid                            | No Data Available                                                                                    |                                                |                       |                                                                                                                                                                                                                                                                                                                                   |
| Diuron                                | Acute Toxicity to Estuarine and Marine Invertebrates<br>Striped mullet ( <i>Mugil cephalus</i> )     | 96-hr LC <sub>50</sub> = 6.3 ppm               | Moderately Toxic      | US EPA, 2003<br>MRID 40228401.                                                                                                                                                                                                                                                                                                    |

| Herbicide   | Test and Species Tested                                                                                    | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub> | Effect/Conclusion                   | Reference                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------|------------------------------------------------------------------------------------------------------------|------------------------------------------------|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             | Acute Toxicity to Estuarine and Marine Invertebrates                                                       | 96-hr LC <sub>50</sub> = 6.7 ppm               | Moderately Toxic                    | US EPA, 2003<br>MRID 41418805                                                                                                                                                                                                                                                                                                                                                                             |
|             | Chronic Toxicity to Estuarine and Marine Organisms<br>Sheepshead minnow ( <i>Cyprinodon variegatus</i> )   | LOEC = 0.44 ppm                                | Reduces growth and affects survival | US EPA, 2003<br>MRID 42312901. Ward, T.; Boeri, R. (1992) Early Life Stage Toxicity of DPX-14740-166 (Diuron) to the Sheepshead Minnow, <i>Cyprinodon variegatus</i> : Lab Project Number: 866-91. Unpublished study prepared by Resource Analysts, Inc. 513 p.                                                                                                                                           |
|             | Acute Toxicity to Estuarine and Marine Invertebrates<br>Brown shrimp ( <i>Penaeus aztecus</i> )            | 48-hr EC <sub>50</sub> = 1 ppm                 | Moderately Toxic                    | US EPA, 2003<br>MRID 40228401.                                                                                                                                                                                                                                                                                                                                                                            |
|             | Chronic Toxicity to Estuarine and Marine Invertebrates<br>Mysid shrimp ( <i>Americamysis bahia</i> )       | NOEC = 0.27 ppm<br>LOEC = 0.56 ppm             | Affects growth and Reproduction     |                                                                                                                                                                                                                                                                                                                                                                                                           |
| EPTC        | No Data Available                                                                                          |                                                |                                     |                                                                                                                                                                                                                                                                                                                                                                                                           |
| Hexazinone  | Acute Toxicity to Estuarine and Marine Invertebrates<br>Grass shrimp                                       | 96-hr LC <sub>50</sub> = 78 ppm                | Slightly Toxic                      | US EPA, 1994<br>MRID 00047164. Heitmuller, T. (1976) Acute Toxicity of H-9877 to Embryos of Eastern Oysters ( <i>Crassostrea virginica</i> ), to Grass Shrimp ( <i>Palaemonetes pugio</i> ), and to Fiddler Crabs ( <i>Uca pugnator</i> ). (Unpublished study received Jul 25, 1979 under 352378; prepared by EG&G Bionomics, submitted by E.I. du Pont de Nemours & Co., Wilmington, Del.; CDL:099674-B) |
| Imazamox    | No Data Available                                                                                          |                                                |                                     |                                                                                                                                                                                                                                                                                                                                                                                                           |
| Imazethapyr | No Data Available                                                                                          |                                                |                                     |                                                                                                                                                                                                                                                                                                                                                                                                           |
| Metribuzin  | Acute Toxicity to Estuarine and Marine Invertebrates<br>Sheepshead minnow ( <i>Cyprinodon variegatus</i> ) | LC <sub>50</sub> = 85 ppm                      | Slightly Toxic                      | US EPA, 1998b<br>MRID 42094502. Gagliano, G. (1991) Raw Data Supplement for Acute Toxicity of Sencor Technical to Sheepshead Minnow ( <i>Cyprinodon variegatus</i> ): Lab Project Number: 274-1285-6105-500: 91756-1. Unpublished study prepared by Springborn Bionomics, Inc. 13 p.                                                                                                                      |
|             | Acute Toxicity to Estuarine and Marine Invertebrates<br>Eastern oyster ( <i>Crassostrea virginica</i> )    | LC <sub>50</sub> = 49.8 ppm                    | Slightly Toxic                      | US EPA, 1998b<br>MRID 47023411                                                                                                                                                                                                                                                                                                                                                                            |
|             | Acute Toxicity to Estuarine and Marine Invertebrates<br>Pink shrimp ( <i>Penaeus duorarum</i> )            | LC <sub>50</sub> = 48.3 ppm                    | Slightly Toxic                      | US EPA, 1998b<br>MRID 00106197. Heitmuller, T. (1975) Acute Toxicity of Sencor to Eastern Oysters ( <i>Crassostrea virginica</i> ), Pink Shrimp ( <i>Penaeus duorarum</i> ), and                                                                                                                                                                                                                          |

| Herbicide   | Test and Species Tested                                                                                    | Toxicity<br>LC <sub>50</sub> /LD <sub>50</sub> | Effect/Conclusion     | Reference                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-------------|------------------------------------------------------------------------------------------------------------|------------------------------------------------|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |                                                                                                            |                                                |                       | Fiddler Crabs ( <i>Uca pugilator</i> ): submitter* 43851. (Unpublished study received Aug 19, 1975 under 3125-294; prepared by Bionomics-EG & G, Inc., submitted by Mobay Chemical Corp., Kansas City, MO; CDL:165011-A)                                                                                                                                                                                                                |
| Norfluzon   | Acute Toxicity to Estuarine and Marine Invertebrates – shell deposition<br>Eastern oyster                  | LC <sub>50</sub> = 3.8 mg/L                    | Moderately Toxic      | US EPA, 1996a<br>MRID 43041802. Graves, W.; Swigert, J. (1993) Norflurazon: A 96-Hour Shell Deposition Test with the Eastern Oyster ( <i>Crassostrea virginica</i> ): Lab Project Number: 131A-156A. Unpublished study prepared by Wildlife International Ltd. 43 p.                                                                                                                                                                    |
| Paraquat    | No Data Available                                                                                          |                                                |                       |                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Picloram    | No Data Available                                                                                          |                                                |                       |                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Pronamide   | No Data Available                                                                                          |                                                |                       |                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Sethoxydim  | No Data Available                                                                                          |                                                |                       |                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Terbacil    | Acute Toxicity to Estuarine and Marine Invertebrates<br>Sheepshead minnow ( <i>Cyprinodon variegatus</i> ) | 96-hr LC <sub>50</sub> = 108.5 ppm             | Practically Non-Toxic | US EPA, 1998c<br>MRID 41896100                                                                                                                                                                                                                                                                                                                                                                                                          |
|             | Acute Toxicity to Estuarine and Marine Invertebrates<br>Eastern oyster ( <i>Crassostrea virginica</i> )    | 48-hr LC <sub>50</sub> >4.9 ppm                | Moderately Toxic      | US EPA, 1998c<br>MRID 00012333. Bentley, R.E. (1973) Bioassay Report Submitted to E.I. du Pont de Nemours & Company, Newark, Delaware: Sinbar Terbacil Weed Killer, 80% Wettable Powder: Acute Toxicity of H-8309 to Atlantic Oyster ( <i>Crassostrea virginica</i> ). (Unpublished study received Apr 11, 1974 under 352-317; prepared by Bionomics, Inc., submitted by E.I. du Pont de Nemours & Co., Wilmington, Del.; CDL:129203-C) |
| Trifluralin | Acute Toxicity to Estuarine and Marine Invertebrates<br>Sheepshead minnow ( <i>Cyprinodon variegatus</i> ) | LC <sub>50</sub> = 190 ppb                     | Highly Toxic          | US EPA, 1996b<br>MRID 42449901. Parrish, P.; Dyer, E.; Enos, J.; et al. (1978) Chronic Toxicity of Chlordane, Trifluralin, and Pentachlorophenol to Sheepshead Minnows ( <i>Cyprinodon variegatus</i> ): Lab Project Number: EPA-600/3-78-010. Unpublished study prepared by EG&G Bionomics 69 p.                                                                                                                                       |

## 5.2 Comparative Environmental Impact of Glyphosate and Other Herbicides Used on Alfalfa

Glyphosate is considered to be more environmentally and toxicologically benign than many of the herbicides that it replaces in GT crops (Brookes and Barfoot, 2006). Peterson and Hulting (2004) examined the ecological risks of glyphosate and 15 other herbicides used on spring wheat populations in the northern U.S. Great Plains (MN, ND, SD, WY, and MT). Glyphosate is used in GT wheat systems, while the 15 other herbicides are widely used on spring wheat. The herbicides were as follows: 2,4-D, bromoxynil, clodinafop, clopyralid, dicamba, fenoxaprop, flucarbazone, MCPA, metasulfuron, thifensulfuron, tralkoxydim, triallate, triasulfuron, tribenuron, and trifluralin. A Tier 1 quantitative risk assessment method was used to evaluate the acute dietary risk to birds and wild mammals, the acute risk to aquatic vertebrates, aquatic invertebrates, and aquatic plants, and the effects on seedling emergence and vegetative vigor to non-target terrestrial plants. Estimated groundwater exposures to the 16 herbicides (including glyphosate) were assessed. The assessment did not include chronic risks, risks to estuarine or marine animals, or risks to nontarget insect pollinators (Peterson and Hulting, 2004). The ecological risks for the 15 herbicides relative to glyphosate were highly variable, with glyphosate having less relative risk to non-target terrestrial and aquatic plant life and groundwater than most other active ingredients. The study predicted that glyphosate use in GT crops will be less toxic to terrestrial and aquatic wildlife than several of the herbicides which it replaces (Peterson and Hulting, 2004).

The environmental impact of other herbicides used on alfalfa in comparison to glyphosate includes an assessment of pesticide active ingredient use, as well as the assessment of the specific pesticides used via an indicator known as the Environmental Impact Quotient (EIQ). This universal indicator, developed by Kovach et al (1992 & updated annually), effectively integrates the various environmental impacts of individual pesticides into a single indicator value of impact; however, it does not take into account all environmental issues/impacts. This provides a balanced assessment of the impact of herbicides on the environment as it draws on key toxicity and environmental exposure data related to individual products (as applicable to impacts on farm workers, consumers and ecology), thus, providing a consistent but a fairly comprehensive measure of environmental impact as applied by Brookes and Barfoot in 2006 for genetically modified crop impact assessments.

The sixteen following herbicides are used in conventional alfalfa: 2,4-DB, benefin, bromoxynil, clethodim, diuron, EPTC, hexazinone, imazamox, imazethapyr, metribuzin, norfluzon, paraquat, pronamide, sethoxydim, terbacil, and trifluralin. The following four herbicides are suggested to remove a stand of GT alfalfa 2,4-D, dicamba, clopyralid, and picloram. These herbicides are evaluated for their environmental impact via a method developed by New York State Integrated Pest Management Program, where the EIQ is formulated based on toxicity and environmental fate data for several herbicides and insecticides used on agricultural practices (Kovach et al., 1992 & updated annually). The EIQ has been used to organize the extensive toxicological data available on pesticides and compare these pesticides even though these pesticides have several modes of actions. The formula for determining the EIQ value of individual pesticides is listed below and is the average of the farm worker, consumer, and

ecological components (Kovach et al., 1992 & updated annually). Further discussion on the development and methods can be found at <http://nysipm.cornell.edu/publications/eiq/default.asp>

$$EIQ = \{C[(DT*5)+(DT*P)] + [(C*((S+P)/2)*SY)+(L)] + [(F*R)+(D*((S+P)/2)*3)+(Z*P*3)+(B*P*5)]\} / 3$$

DT = dermal toxicity,

C = chronic toxicity,

SY = systemicity,

F = fish toxicity,

L = leaching potential,

R = surface loss potential,

D = bird toxicity,

S = soil half-life,

Z = bee toxicity,

B = beneficial arthropod toxicity,

P = plant surface half-life.

The lower the EIQ values the less environmental impact the herbicide exerts on the environment, as table N-50 illustrates besides EPTC glyphosate is the most environmentally benign. Data on the herbicide 2,4-DB is not in the EIQ calculations. 2,4-DB is a selective systemic herbicide in the chlorophenoxy family, in plants it is converted to 2,4-D; however, relatively little data is available on 2,4-DB and is absent in the EIQ calculations. Ecotoxicologically, 2,4-DB was considered a risk to terrestrial plants (from spray drift and run off after aerial and ground applications), freshwater fish (threatened and endangered species), and small and medium mammals (threatened and endangered species) by EPA as reported in the Reregistration Eligibility Report (2005a) when using the maximum application rate on alfalfa. The environmental fate properties of the 20 pesticides are discussed in section 3.2 and the ecotoxicology in section 5.1 above.

As is evident from table N-50 all but EPTC have higher EIQ values and therefore pose a higher risk to the environment.



**Table N-50. Environmental Impact Quotient Comparison of Alfalfa Herbicides (Kovach et al., 1992 & updated annually)**

| Herbicide         | EQ Total Value | Farm worker EQ | Consumer EQ  | Ecology EQ   |
|-------------------|----------------|----------------|--------------|--------------|
| <i>Glyphosate</i> | 15.30          | 8.00           | 5.00         | 33.00        |
| 2,4-D             | 18.67          | 8.00           | 8.00         | 40.00        |
| 2,4-DB            | Not Reported   | Not Reported   | Not Reported | Not Reported |
| Benefin           | 16.00          | 6.00           | 3.00         | 39.00        |
| Bromoxynil        | 20.00          | 16.00          | 9.0          | 35.00        |
| Clethodim         | 17.00          | 12.00          | 8.00         | 31.00        |
| Clpyralid         | 18.10          | 8.00           | 8.00         | 38.35        |
| Dicamba           | 28.00          | 16.00          | 9.00         | 59.00        |
| Diuron            | 20.50          | 15.00          | 10.5         | 36.00        |
| EPTC              | 9.40           | 6.00           | 4.00         | 18.30        |
| Hexazinone        | 18.00          | 8.00           | 9.00         | 37.00        |
| Imazamox          | 19.50          | 8.00           | 8.00         | 42.55        |
| Imazethapyr       | 27.30          | 8.00           | 7.00         | 66.85        |
| Metribuzin        | 28.40          | 8.00           | 8.00         | 69.10        |
| Norfluzon         | 18.80          | 9.00           | 9.50         | 38.03        |
| Paraquat          | 31.00          | 8.00           | 5.00         | 79.95        |
| Picloram          | 18.00          | 8.00           | 9.00         | 37.00        |
| Pronamide         | 36.00          | 24.00          | 10.00        | 74.00        |
| Sethoxydim        | 27.50          | 8.00           | 4.93         | 69.60        |
| Terbacil          | 16.80          | 12.00          | 11.00        | 27.50        |
| Trifluralin       | 18.80          | 9.00           | 5.50         | 42.00        |

These calculations are defined by Kovach and colleagues as such:

Farm worker risk is defined as the sum of applicator exposure (DT\*5) plus picker exposure (DT\*P) times the long-term health effect or chronic toxicity (C). Chronic toxicity of a specific pesticide is calculated as the average of the ratings from various long-term laboratory tests conducted on small mammals. These tests are designed to determine potential reproductive effects (ability to produce offspring), teratogenic effects (deformities in unborn offspring), mutagenic effects (permanent changes in hereditary material such as genes and chromosomes), and oncogenic effects (tumor growth). Within the farm worker component, applicator exposure is determined by multiplying the dermal toxicity (DT) rating to small laboratory mammals (rabbits or rats) times a coefficient of five to account for the increased risk associated with handling concentrated pesticides. Picker exposure is equal to dermal toxicity (DT) times the rating for plant surface residue half-life potential (the time required for one-half of the chemical to break down). This residue factor takes into account the weathering of pesticides that occurs in agricultural systems and the days to harvest restrictions that may be placed on certain pesticides.

The consumer component is the sum of consumer exposure potential ( $C*((S+P)/2)*SY$ ) plus the potential groundwater effects (L). Groundwater effects are placed in the consumer component because they are more of a human health issue (drinking well contamination) than a wildlife issue. Consumer exposure is calculated as chronic toxicity (C) times the average for residue potential in soil and plant surfaces (because roots and other plant parts are eaten) times the systemic potential rating of the pesticide (the pesticide's ability to be absorbed by plants).

The ecological component of the model is composed of aquatic and terrestrial effects and is the sum of the effects of the chemicals on fish ( $F \cdot R$ ), birds ( $D \cdot ((S+P)/2) \cdot 3$ ), bees ( $Z \cdot P \cdot 3$ ), and beneficial arthropods ( $B \cdot P \cdot 5$ ). The environmental impact of pesticides on aquatic systems is determined by multiplying the chemical toxicity to fish rating times the surface runoff potential of the specific pesticide (the runoff potential takes into account the half-life of the chemical in surface water).

The impact of pesticides on terrestrial systems is determined by summing the toxicities of the chemicals to birds, bees, and beneficial arthropods. Because terrestrial organisms are more likely to occur in commercial agricultural settings than fish, more weight is given to the pesticidal effects on these terrestrial organisms. Impact on birds is measured by multiplying the rating of toxicity to birds by the average half-life on plant and soil surfaces times three. Impact on bees is measured by taking the pesticide toxicity ratings to bees times the half-life on plant surfaces times three. The effect on beneficial arthropods is determined by taking the pesticide toxicity rating to beneficial natural enemies times the half-life on plant surfaces times five. Because arthropod natural enemies spend almost all of their life in agroecosystem communities (while birds and bees are somewhat transient), their exposure to the pesticides, in theory, is greater. To adjust for this increased exposure, the pesticide impact on beneficial arthropods is multiplied by five. Mammalian wildlife toxicity is not included in the terrestrial component of the equation because mammalian exposure (farm worker and consumer) is already included in the equation, and these health effects are the results of tests conducted on small mammals such as rats, mice, rabbits, and dogs.

After the data on individual factors were collected, pesticides were grouped by classes (fungicides, insecticides/miticides, and herbicides), and calculations were conducted for each pesticide. When toxicological data were missing, the average for each environmental factor within a class was determined, and this average value was substituted for the missing values. Thus, missing data did not affect the relative ranking of a pesticide within a class.

Researchers at Ghent University developed the pesticide occupational and environmental risk (POCER) indicator (Devos et al., 2008). POCER is a similar concept as EIQ and includes ten modules; (1) risk to pesticide operator; (2) risk to worker; (3) risk to bystander; (4) persistence in the soil; (5) risk of ground water contamination; (6) acute risk to aquatic organisms; (7) acute risk to birds; (8) acute risk to bees; (9) acute risk to earthworms; and (10) risk to beneficial arthropods. The toxicological reference values used in the effect assessment are certified endpoints defined in Annex VI of Directive 91/414/EEC. Using GT corn and non-GT corn as an example, the POCER values for glyphosate or glufosinate used alone were about one sixth less than other herbicide regimes (31 regimes were evaluated). This environmental benefit of glyphosate over other herbicides was attributed to lower potential for leaching and lower toxicity to aquatic organisms (Devos et al., 2008).

Using the above standardized methods for ranking environmental impact, researchers have concluded that glyphosate is less harmful to the environment than many other herbicides and that the shift of herbicide use has resulted in a net lower environmental impact from herbicides.

### 5.3 Summary of Findings

The increase in glyphosate due to adoption of GT crops in 1996 has caused concern. Ecological effects, exposures, and risks from direct exposure to the 20 alfalfa herbicides were evaluated in this section, section 3.4 evaluated the chemical fate. For all ecological receptors, the most sensitive toxicity endpoints that were publicly available were used for the EIQ assessment. Data sources for toxicity for each ecological receptor are referenced in each table. As table N-50 illustrates all of the common alfalfa herbicides pose a higher risk to the environment than glyphosate, excluding EPTC. Thus with the possible replacement or decreased reliance on these pesticides with glyphosate on GT alfalfa the environmental risk is decreased. Risk analysis incorporates toxicity and exposure data and without integrating these factors the assessment is limited. However, performing comparative Tier 1 risk assessments of all 20 herbicides to glyphosate will only assess the worst case scenario making these assessments, general and not conclusive. Actual herbicide use rates vary with the season, geography, biology of the weeds in the area, and cultivator. It is clear glyphosate usage trends are increasing and that glyphosate is more toxicologically and environmentally benign than the pesticides glyphosate may be replacing.

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Num: 321992, Decision No. 360557. Office Of Prevention, Pesticides, And Toxic Substances. Author J.R. Tomerlin

Wilke, C.W. 1998. Roundup ready alfalfa might benefit corn, too. Hay and Forage Grower. [http://hayandforage.com/mag/farming\\_roundup\\_ready\\_alfalfa\\_2/index.html](http://hayandforage.com/mag/farming_roundup_ready_alfalfa_2/index.html)

## **Appendix N-2.**

## **Literature Search**

### **1.0 Literature Search Strategy**

Develop a risk assessment for increased glyphosate and other chemical usage on wildlife, amphibians, plants and ecosystems

#### **1.1 Purpose**

The purpose of this literature search is to locate references about the potential impacts to wildlife, amphibians, plants, and ecosystems from increased glyphosate and other chemical usage.

We propose that the following DIALOG databases be included in the search:

|                                    |                                                 |
|------------------------------------|-------------------------------------------------|
| File 5: BIOSIS                     | File 117: Water Resources                       |
| File 6: NTIS                       | Abstracts                                       |
| File 10: AGRICOLA                  | File 144: PASCAL                                |
| File 34: SciSearch                 | File 154: MEDLINE                               |
| File 41: Pollution Abstracts       | File 156:ToxFile                                |
| File 40: Enviroline                | File 245: WATERNET™                             |
| File 72: EMBASE                    | File 250: CAB Abstracts                         |
| File 76: Environmental Sciences    | File 266: Federal Research In Progress (FEDRIP) |
| File 79: Aqualine                  | File 399: CA SEARCH®: Chemical Abstracts®       |
| File 98: General Science Abstracts |                                                 |

Descriptions of these files are available at <http://library.dialog.com/bluesheets/>.

#### **1.2 Scope of Search**

The search will focus any published references after 1999. A reference list with abstracts will be screened for relevance to the ecotoxicity of glyphosate. English language only publications will be retrieved.

The following list will be retrieved and expanded upon.

#### **1.3 Strategy Overview**

A list of search parameters is listed below.

#### **1.4 Synonyms**

Glyphosate  
Glyphosate, isopropylamine salt

Glyphosate, sodium salt  
Glyphosate, potassium  
Glyphosate, ammonium  
Glyphosate, sulfosate  
*N*-(phosphonomethyl) glycine  
Roundup®  
Roundup Ultra®  
Roundup WeatherMAX  
Honcho®

## 1.5 Keywords

|                         |                      |
|-------------------------|----------------------|
| Acute                   | Inhal*               |
| Adverse                 | Irritation           |
| Alfalfa                 | Invertebrate         |
| Ampibian                |                      |
| Aquatic                 | Leach*               |
| Arthropod               | Mammal               |
| Bird                    | Metabo*              |
| Bioconcentration factor | Microorganism(s)     |
| Cancer*                 | Mortality            |
| Carcino*                | Mutagen*             |
| Chronic                 | Neuro*               |
| Crop                    | NOAEC                |
| Degradation             | NOEC                 |
| Derma*                  | Non-target organisms |
| Developmental           | Persistence          |
|                         | Reproduc*            |
| Dietary risk            | Reptile              |
| Dissipat*               | Residue              |
| Dose                    | Risk                 |
| Ecosystem(s)            | Risk quotient        |
| Ecotoxico*              | Roundupnoff          |
| Emission                | Sensiti*             |
| Endpoint                | Soil                 |
| Environmental health    | Spray drift          |
| Exposure(s)             | Subchronic           |
| Fish                    | Survival             |
| Frog                    |                      |
| Growth                  | Terato*              |
| Hazard quotient         | Terrestrial          |
| Health effect(s)        | Tolerance            |
| Ingest*                 | Toxic*               |
|                         | Usage Patterns       |

## 1.6 Supplemental Websearch

www.scholar.google.com

Terms:

alfalfa AND glyphosate

alfalfa AND glyphosate AND risk

glyphosate AND occurrence

glyphosate AND fate

glyphosate AND occurrence

www.google.com

Terms:

2,4-D AND RED AND MSDS

2,4-DB AND RED AND MSDS

Benefin AND RED AND MSDS

Bromoxynil AND RED AND MSDS

Clethodim AND RED AND MSDS

Diuron AND RED AND MSDS

EPTC AND RED AND MSDS

Hexazinone AND RED AND MSDS

Imazamox AND RED AND MSDS

Imazethapyr AND RED AND MSDS

Metribuzin AND RED AND MSDS

Norfluzaon AND RED AND MSDS

Paraquat AND RED AND MSDS

Picloram AND RED AND MSDS

Promamide AND RED AND MSDS

Sethoxydim AND RED AND MSDS

Terbacil AND RED AND MSDS

Trifluralin AND RED AND MSDS

Roundup Ready label

## 1.7 Submission of Citations for Approval

Using reference management software, pooled information obtained from the various bibliographic databases will be screened to remove duplicates. Additionally, ICF will review the list prior to submission and eliminate any irrelevant citations. Information provided to US EPA will include the following (when available):

Author(s). Publication Year. Title. Source Document Name, Volume, Page Numbers.

Abstract

Descriptors/Identifiers (*i.e.*, keywords and subject headings)

*Literature Search Results:*

File 10:AGRICOLA 70-2008/Apr  
 (c) format only 2008 Dialog  
 File 154:MEDLINE(R) 1990-2008/Jun 03  
 (c) format only 2008 Dialog  
 File 156:ToxFile 1965-2008/May W4  
 (c) format only 2008 Dialog  
 File 266:FEDRIP 2008/Feb  
 Comp & dist by NTIS, Intl Copyright All Rights Res  
 File 245:WATERNET(TM) 1971-2008Apr  
 (c) 2008 American Water Works Association  
 File 55:Biosis Previews(R) 1993-2008/Jun W1  
 (c) 2008 The Thomson Corporation  
 File 6:NTIS 1964-2008/Jun W2  
 (c) 2008 NTIS, Intl Cpyrght All Rights Res  
 File 41:Pollution Abstracts 1966-2008/May  
 (c) 2008 CSA.  
 File 40:Enviroline(R) 1975-2008/Apr  
 (c) 2008 Congressional Information Service  
 File 76:Environmental Sciences 1966-2008/Jun  
 (c) 2008 CSA.  
 File 24:CSA Life Sciences Abstracts 1966-2008/Mar  
 (c) 2008 CSA.  
 File 117:Water Resources Abstracts 1966-2008/Mar  
 (c) 2008 CSA.  
 File 144:Pascal 1973-2008/May W4  
 (c) 2008 INIST/CNRS  
 File 50:CAB Abstracts 1972-2008/Apr  
 (c) 2008 CAB International  
 File 44:Aquatic Science & Fisheries Abstracts 1966-2008/Mar  
 (c) 2008 CSA.  
 File 71:ELSEVIER BIOBASE 1994-2008/May W3  
 (c) 2008 Elsevier B.V.  
 File 143:Biol. & Agric. Index 1983-2008/Apr  
 (c) 2008 The HW Wilson Co

S1 31158 GLYPHOSATE OR PHOSPHONOMETHYL()GLYCINE OR ROUNDUP OR RODEO  
 OR AQUA()STAR OR SHACKLE OR GLYPHOSPHATE  
 S2 13844 RN=1071-83-6 OR PHOSPHONOMETHYLIMINOACETIC()ACID OR SILGLIF  
 OR PONDMASTER OR AQUANEAT OR AQUAMASTER  
 S3 12713 (S1 OR S2)/2000:2008  
 S4 6842306 ACUTE OR SUBACUTE OR CHRONIC OR SUBCHRONIC OR INGEST? OR I-  
 NHAL? OR DOSE OR DOSAGE OR DIETARY  
 S5 4866541 TOXIC? OR (HEALTH OR ADVERSE)(3N)(EFFECT OR EFFECTS OR RISK  
 OR RISKS OR IMPACT OR IMPACTS) OR NEUROTOXIC? OR GENOTOXIC? -  
 OR IMMUNOTOXIC?  
 S6 4789703 CANCER? OR CARCINO? OR TUMOR? OR NEOPLAS?  
 S7 4311730 DERMA? OR SKIN OR REPRODUCTI? OR TERATOL? OR TERATOGEN? OR  
 IRRITAT? OR IRRITANT OR NEUROLOG?  
 S8 9723660 MUTAGEN? OR MUTAT? OR SENSITIZ? OR EXPOS? OR METABOLI?  
 S9 3685201 USAGE()PATTERN? ? OR SPRAY()DRIFT? OR TOLERANCE OR PERSIST-  
 ENCE OR INHIBITION OR DEGRADATION OR ALFALFA OR LEACH?  
 S10 4011984 DISSIPAT? OR ENDPOINT? ? OR NOAEC OR NOEC OR SURVIVAL OR R-  
 ESIDUE? ? OR MORTALITY OR ROUNDUPNOFF  
 S11 3068036 BIOCONCENTRATION()FACTOR OR BCF OR HAZARD()QUOTIENT OR EMI-  
 SSION? ? OR SOIL OR SOILS  
 S12 3037946 ARTHOPOD? ? OR BIRD OR BIRDS OR ECOSYSTEM? ? OR ECOTOXIC? -

OR INVERTEBRATE? ?

S13 10631892 MAMMAL? OR MAMMALS OR MAMMALIAN OR MICROORGANISM? ?

S14 206481 AMPHIBIAN? ? OR FROG OR FROGS OR TOAD OR TOADS OR SALAMANDER?  
?

S15 1269061 FISH OR FISHES

S16 1094967 WILDLIFE OR AQUATIC OR TROUT OR GUPPIES OR MINNOWS OR DEER

S17 183586 FOXES OR WATERFOWL OR DUCKS OR LOONS OR MERGANSERS OR SALMON

S18 114502 OTTERS OR CLAMS OR SHELLFISH OR HERONS OR EGRETS OR OSPREY OR  
EAGLES

S22 11698 S3 NOT (S20 OR S21) (eliminate most foreign languages)

S23 2887 S22 AND S19

S24 1505 RD S23 (unique items)

S25 535 S24 AND (S4 OR S5 OR S6)

S26 698 S24 AND (S7 OR S8 OR S9)

S27 776 S24 AND (S10 OR S11)

S28 1184 S25 OR S26 OR S27 (all 3 sets of terms)

---

S29 162 S25 AND S26 AND S27 (multiple terms in cite)

30/6/3 (Item 3 from file: 50)

0008952114 CAB Accession Number: 20053221561

Accumulation of shikimate in corn and soybean \*exposed\* to various rates  
of \*glyphosate\*.

Publication Year: 2005

30/6/4 (Item 4 from file: 154)

26658890 PMID: 18504846

\*Acute\* \*toxic\* hazard evaluations of \*glyphosate\* herbicide on  
terrestrial vertebrates of the Oregon coast range.  
May \*2008\*

30/6/6 (Item 6 from file: 50)

0008956849 CAB Accession Number: 20063000997

Alterations induced by \*glyphosate\* on lupin photosynthetic apparatus  
and nodule ultrastructure and some oxygen diffusion related proteins.

Publication Year: 2005

30/6/8 (Item 8 from file: 50)

0009478587 CAB Accession Number: 20083065495

Analysis of \*glyphosate\* and aminomethylphosphonic acid by capillary  
electrophoresis with electrochemiluminescence detection.

Publication Year: 2007

30/6/9 (Item 9 from file: 71)

04037470 2008096560

Analysis of the \*toxicity\* of \*glyphosate\* and Faena(R) using the  
freshwater \*invertebrates\* Daphnia magna and Lecane quadridentata

30/6/11 (Item 11 from file: 55)

18840814 BIOSIS NO.: 200600186209

Applying weight gain in Pomacea lineata (spix 1824) (Mollusca:

Prosobranchia) as a measure of herbicide \*toxicity\*

\*2005\*

30/6/13 (Item 13 from file: 10)



4781473 43913461 Holding Library: AGL  
 Assessment of \*toxicity\* of a \*glyphosate\* -based formulation using  
 bacterial systems in lake water  
 \*2007\*  
 URL: <http://dx.doi.org/10.1016/j.chemosphere.2006.12.020>

30/6/14 (Item 14 from file: 50)  
 0008545429 CAB Accession Number: 20033214911  
 Biochemical and ultrastructural alterations in Nile tilapia  
 ( *Oreochromis niloticus* ) induced by \*glyphosate\* herbicide.  
 Book Title: Proceedings 11th International Symposium of the World  
 Association of Veterinary Laboratory Diagnosticians and OIE Seminar on  
 Biotechnology, Bangkok, Thailand, 9-13 November, 2003  
 Publication Year: 2003

30/6/15 (Item 15 from file: 50)  
 0008514013 CAB Accession Number: 20033176082  
 Boll abscission responses of \*glyphosate\*-resistant cotton ( *Gossypium*  
*hirsutum* ) to \*glyphosate\*.  
 Publication Year: 2003

30/6/21 (Item 21 from file: 40)  
 00685328 ENVIROLINE NUMBER: 05-14167  
 Can the Choice of \*Endpoint\* Lead to Contradictory Results of Mixture-  
 \*Toxicity\* Experiments?  
 Jul 05

30/6/22 (Item 22 from file: 154)  
 15730410 PMID: 15095878  
 Chemical and biomonitoring to assess potential \*acute\* effects of Vision  
 herbicide on native \*amphibian\* larvae in forest wetlands.  
 Apr \*2004\*

30/6/24 (Item 24 from file: 55)  
 0019859641 BIOSIS NO.: 200700519382  
 Combination of a pesticide \*exposure\* and a bacterial challenge: In vivo  
 effects on immune response of Pacific oyster, *Crassostrea gigas* (Thunberg)  
 \*2007\*

30/6/25 (Item 25 from file: 10)  
 4307003 43655726 Holding Library: AGL  
 A comparative ecological risk assessment for herbicides used on spring  
 wheat: the effect of \*glyphosate\* when used within a \*glyphosate\*-tolerant  
 wheat system  
 \*2004\*

30/6/26 (Item 26 from file: 41)  
 0000274448 IP ACCESSION NO: 5832216  
 Comparative \*acute\* \*toxicity\* of the commercial herbicides \*glyphosate\* to  
 neotropical tadpoles *Scinax nasicus* (Anura: Hylidae)  
 PUBLICATION DATE: \*2003\*

30/6/27 (Item 27 from file: 10)  
 4477186 43805039 Holding Library: AGL  
 Comparative analysis of the effects of locally used herbicides and their  
 active ingredients on a wild-type wine *Saccharomyces cerevisiae* strain

\*2006\*

URL: <http://pubs.acs.org/journals/jafcau/index.html>

30/6/28 (Item 28 from file: 50)

0009509971 CAB Accession Number: 20083103403

Compared environmental balances of broad-spectrum and selective herbicides.

Book Title: Environmental fate and ecological effects of pesticides

Publication Year: 2007

30/6/29 (Item 29 from file: 10)

4428862 43791928 Holding Library: AGL

A Comparative Risk Assessment of Genetically Engineered, \*Mutagenic\*, and Conventional Wheat Production Systems \h [electronic resource]

\*2005\*

URL: <http://dx.doi.org/10.1007/s11248-005-1411-8>

30/6/32 (Item 32 from file: 40)

00622807 ENVIROLINE NUMBER: 02-09575

Cannabis Eradication in the Contiguous United States and Hawaii: Final Supplement to the Environmental Impact Statements

Aug 01

30/6/34 (Item 34 from file: 50)

0008723815 CAB Accession Number: 20043193096

Conventional soybean plant and progeny response to \*glyphosate\*.

Publication Year: 2004

30/6/35 (Item 35 from file: 50)

0008187365 CAB Accession Number: 20013170867

Crop injury from sublethal rates of herbicide. I. Tomato.

Publication Year: 2001

30/6/36 (Item 36 from file: 50)

0008363151 CAB Accession Number: 20033016359

Carrier volume affects herbicide activity in simulated \*spray\* \*drift\* studies.

Publication Year: 2002

30/6/37 (Item 37 from file: 50)

0008178402 CAB Accession Number: 20023038276

Case study in benefits and risks of agricultural biotechnology: \*Roundup\* Ready soybeans.

Book Title: Market development for genetically modified foods

Publication Year: 2001

30/6/39 (Item 39 from file: 10)

4709127 43901339 Holding Library: AGL

Direct and indirect effects of the herbicides \*Glyphosate\*, Bentazone and MCPA on eelgrass (*Zostera marina*)

\*2007\*

URL: <http://dx.doi.org/10.1016/j.aquatox.2007.01.004>

30/6/40 (Item 40 from file: 50)

0007974497 CAB Accession Number: 20003013096  
 Use of the drosophila wing spot test in the \*genotoxicity\* testing of  
 different herbicides.  
 Publication Year: 2000

30/6/41 (Item 41 from file: 50)  
 0009010362 CAB Accession Number: 20063078964  
 Detection of transgenic and endogenous plant DNA in digesta and tissues  
 of sheep and pigs fed \*Roundup\* Ready canola meal.  
 Publication Year: 2006

30/6/43 (Item 43 from file: 50)  
 0008440975 CAB Accession Number: 20033093957  
 Determination of the herbicide \*glyphosate\* and its \*metabolite\* in  
 biological specimens by gas chromatography-mass spectrometry. A Case of  
 poisoning by \*Roundup\*(R) herbicide.  
 Publication Year: 2003

30/6/46 (Item 46 from file: 50)  
 0008102025 CAB Accession Number: 20013122257  
 \*Ecotoxicological\* risk assessment for \*Roundup\*(R) herbicide.  
 Publication Year: 2000

30/6/47 (Item 47 from file: 10)  
 4754178 43989730 Holding Library: AGL  
 \*Ecotoxicological\* assessment of the effects of \*glyphosate\* and  
 chlorpyrifos in an Argentine soya field  
 \*2007\*  
 URL: <http://dx.doi.org/10.1065/jss2007.04.224>

30/6/48 (Item 48 from file: 156)  
 045311 NLM Doc No: NTIS/02923942 Sec. Source ID: NTIS/PB2003104525  
 Effects of Bromacil, Diuron, \*Glyphosate\*, and Sulfometuron-Methyl on  
 Periphyton Assemblages and Rainbow \*Trout\*.  
 \*2003\*

30/6/49 (Item 49 from file: 50)  
 0008323461 CAB Accession Number: 20023173257  
 Effect of carrier volume on corn ( Zea mays ) and soybean ( Glycine max )  
 response to simulated drift of \*glyphosate\* and glufosinate.  
 Publication Year: 2002

30/6/50 (Item 50 from file: 40)  
 00611081 ENVIROLINE NUMBER: 01-17996  
 Effects of \*Acute\* \*Exposure\* to a Commercial Formulation of Glyposate on  
 the Tadpoles of Two Species of Anurans  
 Oct 01

30/6/51 (Item 51 from file: 50)  
 0008800581 CAB Accession Number: 20053061482  
 The influence of different treatment length on the induction of  
 micronuclei in bovine lymphocytes after \*exposure\* to \*glyphosate\*.  
 Publication Year: 2004

30/6/52 (Item 52 from file: 55)  
 18370247 BIOSIS NO.: 200510064747

Effect of \*glyphosate\* contaminated feed on Roundupmen fermentation parameters

and in sacco \*degradation\* of grass hay and corn grain

\*2005\*

30/6/53 (Item 53 from file: 50)  
0008324453 CAB Accession Number: 20023165260

The effect of \*glyphosate\* on carbohydrate \*metabolism\* in the Indian catfish *Heteropneustes fossilis* (Bloch).

Publication Year: 2001

30/6/55 (Item 55 from file: 50)  
0008612071 CAB Accession Number: 20043045175

Influence of \*glyphosate\* on photosynthetic properties of wild type and mutant strains of cyanobacterium *Anabaena doliolum* .

Publication Year: 2004

30/6/56 (Item 56 from file: 50)  
0009217430 CAB Accession Number: 20073036246

Effect of \*glyphosate\* on various blood parameters of fresh water \*fishes\*, *Heteropneustes fossilis* .

Publication Year: 2006

30/6/57 (Item 57 from file: 10)  
4639811 43891893 Holding Library: AGL

Effects of \*glyphosate\* on \*soil\* microbial communities and its mineralization in a Mississippi \*soil\*

\*2007\*

URL: <http://dx.doi.org/10.1002/ps.1351>

30/6/58 (Item 58 from file: 10)  
3955906 23244378 Holding Library: AGL

The effect of the herbicide \*glyphosate\* on non-target spiders. I. Direct effects on *Lepthyphantes tenuis* under laboratory conditions

\*2001\*

URL: <http://www.interscience.wiley.com/jpages/1526-498X/>

30/6/59 (Item 59 from file: 50)  
0009232568 CAB Accession Number: 20073080455

Effect of herbicides on *Trichoderma harzianum* .

Publication Year: 2006

30/6/60 (Item 60 from file: 76)  
0001671293 IP ACCESSION NO: 5799221

The effects of the herbicide \*rodeo\* registered on Pacific oyster gametogenesis and tissue accumulation

PUBLICATION DATE: \*2003\*

30/6/61 (Item 61 from file: 50)  
0008507835 CAB Accession Number: 20033179278

The influence of herbicide \*roundup\* on immunocompetent cells of carp ( *Cyprinus carpio* ) and European sheatfish ( *SiluRoundups glanis* ).

Publication Year: 2003

30/6/62 (Item 62 from file: 71)

02238564            2003024276  
Effects of herbicide treatments on biotic components in regenerating northern forests

30/6/63            (Item 63 from file: 50)  
0009113200        CAB Accession Number: 20063200340  
Effect of metosulam and \*glyphosate\* on flower abnormalities of strawberry.  
Publication Year: 2006

30/6/64            (Item 64 from file: 55)  
18010019        BIOSIS NO.: 200400380808  
Influence of insecticidal toxins from *Bacillus thuringiensis* subsp. *kurstaki* on the \*degradation\* of \*glyphosate\* and glufosinate-ammonium in \*soil\* samples  
\*2004\*

30/6/65            (Item 65 from file: 50)  
0009367307        CAB Accession Number: 20073245031  
Influence of pesticides on growth and sporulation of *Ascochyta cypericola* .  
Publication Year: 2007

30/6/66            (Item 66 from file: 50)  
0008536913        CAB Accession Number: 20033205456  
The effects of refining consumer \*exposure\* assessments of \*glyphosate\*.  
Book Title: The BCPC International Congress: Crop Science and Technology, Volumes 1 and 2. Proceedings of an international congress held at the SECC, Glasgow, Scotland, UK, 10-12 November 2003  
Publication Year: 2003

30/6/67            (Item 67 from file: 55)  
18166086        BIOSIS NO.: 200500073151  
Effects of refining predicted \*chronic\* \*dietary\* intakes of pesticide \*residues\*: a case study using \*glyphosate\*  
\*2004\*

30/6/68            (Item 68 from file: 50)  
0009026430        CAB Accession Number: 20063095861  
Influence of a range of dosages of MCPA, \*glyphosate\* , and thifensulfuron: tribenuron (2:1) on conventional canola ( *Brassica napus* ) and white bean ( *Phaseolus vulgaris* ) growth and yield.  
Publication Year: 2006

30/6/69            (Item 69 from file: 50)  
0009026346        CAB Accession Number: 20063095955  
Effect of various pesticides on the non-target species *Microctonus hyperodae* , a biological control agent of *Listronotus bonariensis* .  
Publication Year: 2006

30/6/70            (Item 70 from file: 154)  
15730409        PMID: 15095877  
Effects of Vision herbicide on \*mortality\*, avoidance response, and growth of \*amphibian\* larvae in two forest wetlands.  
Apr \*2004\*

30/6/72            (Item 72 from file: 50)

0008725807 CAB Accession Number: 20043184107  
The effects of subchronic exposure of Wistar rats to the herbicide glyphosate (Biocarb(R)).  
Publication Year: 2004

30/6/73 (Item 73 from file: 50)  
0007976555 CAB Accession Number: 20003021195  
Influence of sublethal \*glyphosate\* rates on leaf mineral concentration of tomato.  
Publication Year: 2000

30/6/74 (Item 74 from file: 50)  
0009249000 CAB Accession Number: 20073056777  
Evaluating \*glyphosate\* treatments on \*roundup\* ready \*alfalfa\* for crop injury and feed quality.  
Publication Year: 2007

30/6/75 (Item 75 from file: 55)  
16340693 BIOSIS NO.: 200100512532  
An exploratory analysis of the effect of pesticide \*exposure\* on the risk of spontaneous abortion in an Ontario farm population  
\*2001\*

30/6/77 (Item 77 from file: 55)  
18132623 BIOSIS NO.: 200500039688  
Field and semifield evaluation of impacts of transgenic canola pollen on \*survival\* and development of worker honey bees  
\*2004\*

30/6/78 (Item 78 from file: 50)  
0009175167 CAB Accession Number: 20073029990  
Foliar-applied \*glyphosate\* substantially reduced uptake and transport of iron and manganese in sunflower ( *Helianthus annuus* L.) plants.  
Publication Year: 2006

30/6/79 (Item 79 from file: 50)  
0009099546 CAB Accession Number: 20063183330  
The phenylurea cytokinin 4PU-30 protects maize plants against \*glyphosate\* action.  
Publication Year: 2006

30/6/80 (Item 80 from file: 50)  
0008583216 CAB Accession Number: 20043033506  
Phytotoxic activity of root absorbed \*glyphosate\* in corn seedlings ( *Zea mays* L.).  
Publication Year: 2003

30/6/81 (Item 81 from file: 50)  
0007990864 CAB Accession Number: 20003016083  
Phytotoxic effects of \*glyphosate\* on pepper ( *Capsicum annuum* ).  
Publication Year: 2000

30/6/82 (Item 82 from file: 50)  
0008797751 CAB Accession Number: 20053044974

Physiological and behavioural responses of Roundupditapes decussatus to

\*roundup\* and reldan.

Publication Year: 2003

30/6/84 (Item 84 from file: 50)

0009261041 CAB Accession Number: 20073122116

\*Glyphosate\* behavior in a Rhodic Oxisol under no-till and conventional agricultural systems.

Publication Year: 2005

30/6/85 (Item 85 from file: 50)

0009107095 CAB Accession Number: 20063163588

\*Glyphosate\* -induced anther indehiscence in cotton is partially temperature dependent and involves cytoskeleton and secondary wall modifications and auxin accumulation.

Publication Year: 2006

30/6/86 (Item 86 from file: 50)

0009488769 CAB Accession Number: 20083072286

\*Glyphosate\* \*inhibition\* of ferric reductase activity in iron deficient sunflower roots.

Publication Year: 2008

30/6/87 (Item 87 from file: 50)

0009174193 CAB Accession Number: 20063219364

\*Glyphosate\* poisoning.

Publication Year: 2004

30/6/88 (Item 88 from file: 55)

16347830 BIOSIS NO.: 200100519669

\*Glyphosate\* \*toxicity\* and the effects of long-term vegetation control on \*soil\* microbial communities  
\*2001\*

30/6/89 (Item 89 from file: 154)

15848429 PMID: 15230326

Growth and \*survival\* of five \*amphibian\* species \*exposed\* to combinations of pesticides.

Jul \*2004\*

30/6/90 (Item 90 from file: 50)

0009443255 CAB Accession Number: 20073293296

Herbicidal effects on nontarget vegetation: investigating the limitations of current pesticide registration guidelines.

Publication Year: 2007

30/6/91 (Item 91 from file: 50)

0007906976 CAB Accession Number: 20002303132

Herbicide \*toxicity\* of *Halophila ovalis* assessed by chlorophyll a fluorescence.

Publication Year: 2000

30/6/92 (Item 92 from file: 50)

0008377518 CAB Accession Number: 20033017437

Herbicides, weeds and endangered species: management of bitou bush (*Chrysanthemoides monilifera* ssp. *rotundata*) with \*glyphosate\* and impacts

on the endangered *shRoundupb*, *Pimelea spicata* .

Publication Year: 2002

30/6/93 (Item 93 from file: 50)

0009021925 CAB Accession Number: 20063092172

Hormesis: is it an important factor in herbicide use and allelopathy?

Publication Year: 2006

30/6/94 (Item 94 from file: 50)

0008015132 CAB Accession Number: 20013047380

Histochemical and histopathological study of the intestine of the earthworm ( *Pheretima elongata* ) \*exposed\* to a field \*dose\* of the herbicide \*glyphosate\*.

Publication Year: 2000

30/6/95 (Item 95 from file: 50)

0009101668 CAB Accession Number: 20063158786

Impact of chemical pesticides on \*survival\* and feeding rate of the woodlouse *Porcellio scaber* (Isopoda, Oniscidea) in Benghazi, Libya.

Publication Year: 2006

30/6/96 (Item 96 from file: 10)

4059934 23324987 Holding Library: AGL

Induction of \*mortality\* and malformation in *Scinax nasicus* tadpoles \*exposed\* to \*glyphosate\* formulations

\*2003\*

30/6/97 (Item 97 from file: 40)

00723207 ENVIROLINE NUMBER: 07-20186

Influences of Environmental Factors and Antidote Addition on \*Glyphosate\*

\*Toxicity\* to Freshwater \*Fish\*, *Labeo rohita* (Hamilton)

Aug 07

30/6/98 (Item 98 from file: 50)

0008507846 CAB Accession Number: 20033179267

The \*ingestion\* of *Aeromonas salmonicida* subsp. *Salmonicida* by \*fish\* blood phagocytes in vitro under influence of herbicides.

Publication Year: 2003

30/6/99 (Item 99 from file: 55)

17079285 BIOSIS NO.: 200300038004

\*Inhibition\* of *Paracoccidioides brasiliensis* by pesticides: Is this a partial explanation for the difficulty in isolating this fungus from the \*soil\*?

\*2002\*

30/6/101 (Item 101 from file: 50)

0009352189 CAB Accession Number: 20073226527

Initial screening of herbicides tolerated by native plants.

Publication Year: 2007

30/6/102 (Item 102 from file: 50)

0009185085 CAB Accession Number: 20073037698

In vivo SUP 31 P and SUP 1 H HR-MAS NMR spectroscopy analysis of the



unstarved Aporectodea caliginosa (Lumbricidae).  
Publication Year: 2006

30/6/103 (Item 103 from file: 50)  
0008096000 CAB Accession Number: 20013136857  
Investigation of the herbicide \*glyphosate\* and the plant growth  
regulators chlormequat and mepiquat in cereals produced in Denmark.  
Publication Year: 2001

30/6/104 (Item 104 from file: 55)  
18534283 BIOSIS NO.: 200510228783  
Isolation and characterization of endophytic bacteria from soybean (Glycine  
max) grown in \*soil\* treated with \*glyphosate\* herbicide  
\*2005\*

30/6/105 (Item 105 from file: 10)  
4818757 44029585 Holding Library: AGL  
Longitudinal changes in microbial planktonic communities of a French  
river in relation to pesticide and nutrient inputs  
\*2008\*  
URL: <http://dx.doi.org/10.1016/j.aquatox.2007.11.016>

30/6/106 (Item 106 from file: 50)  
0008533092 CAB Accession Number: 20033200447  
Linking fluorescence induction curve and biomass in herbicide screening.  
Publication Year: 2003

30/6/107 (Item 107 from file: 50)  
0008294936 CAB Accession Number: 20023141455  
A model on Agave tequilana Weber for detection of damaged DNA from  
diseased cells and cells \*exposed\* to \*glyphosate\*.  
Publication Year: 2001

30/6/108 (Item 108 from file: 154)  
15730408 PMID: 15095876  
Multiple stress effects of Vision herbicide, pH, and food on zooplankton  
and larval \*amphibian\* species from forest wetlands.  
Apr \*2004\*

30/6/110 (Item 110 from file: 50)  
0009215291 CAB Accession Number: 20073086923  
Monitoring of \*Roundup\* Ready soybean in Romania.  
Publication Year: 2006

30/6/111 (Item 111 from file: 50)  
0009150628 CAB Accession Number: 20063213806  
Morphological responses of different eucalypt clones submitted to  
glyphosate drift.  
Publication Year: 2007

30/6/112 (Item 112 from file: 50)  
0009371755 CAB Accession Number: 20073254236  
\*Metabolic\* effects in rapeseed ( Brassica napus L.) seedlings after  
root \*exposure\* to \*glyphosate\*.  
Publication Year: 2007

30/6/113 (Item 113 from file: 50)

0008949274 CAB Accession Number: 20053212470  
Matrix solid-phase dispersion extraction and determination by  
high-performance liquid chromatography with fluorescence detection of  
\*residues\* of \*glyphosate\* and aminomethylphosphonic acid in tomato  
fRoundupit.  
Publication Year: 2005

30/6/114 (Item 114 from file: 50)  
0009458833 CAB Accession Number: 20083018898  
Nitrogen \*metabolism\* and flower symmetry of petunia corollas treated  
with \*glyphosate\*.  
Publication Year: 2007

30/6/116 (Item 116 from file: 55)  
0019760681 BIOSIS NO.: 200700420422  
The occurrence of hormesis in plants and algae  
\*2007\*

30/6/117 (Item 117 from file: 154)  
16224136 PMID: 15683179  
Oral bioavailability of \*glyphosate\*: studies using two intestinal cell  
lines.  
Jan \*2005\*

30/6/118 (Item 118 from file: 55)  
0020129332 BIOSIS NO.: 200800176271  
Oxidative stress biomarkers and heart function in bullfrog tadpoles  
\*exposed\* to \*Roundup\* Original (R)  
\*2008\*

30/6/119 (Item 119 from file: 50)  
0008953985 CAB Accession Number: 20053201727  
Plasma enzymes in Clarias gariepinus \*exposed\* to \*chronic\* levels of  
\*Roundup\* (\*glyphosate\*)\*.  
Publication Year: 2005

30/6/122 (Item 122 from file: 10)  
4006383 23284250 Holding Library: AGL  
Predicted impact of transgenic, herbicide-tolerant corn on drinking water  
quality in vulnerable watersheds of the mid-western USA  
\*2002\* URL: <http://www.interscience.wiley.com/jpages/1526-498X/>

30/6/123 (Item 123 from file: 50)  
0009358132 CAB Accession Number: 20073201439  
Pre-harvest \*glyphosate\* for weed control and as a harvest aid in  
cereals.  
Publication Year: 2007

30/6/124 (Item 124 from file: 50)  
0009262935 CAB Accession Number: 20073099434  
Pesticide contamination inside farm and nonfarm homes.  
Publication Year: 2005

30/6/128 (Item 128 from file: 50)  
0008514031 CAB Accession Number: 20033176064  
Rice ( *Oryza sativa* ) and corn ( *Zea mays* ) response to simulated drift  
of \*glyphosate\* and glufosinate.  
Publication Year: 2003

30/6/129 (Item 129 from file: 50)  
0008941279 CAB Accession Number: 20053199375  
Rice ( *Oryza sativa* ) response to drift rates of \*glyphosate\*.  
Publication Year: 2005

30/6/130 (Item 130 from file: 154)  
16074964 PMID: 15559279  
Reduced grazing rates in *Daphnia pulex* caused by contaminants:  
implications for trophic cascades.  
Nov \*2004\*

30/6/131 (Item 131 from file: 10)  
4708092 43878069 Holding Library: AGL  
Relating olfactory \*neurotoxicity\* to altered olfactory-mediated  
behaviors in rainbow \*trout\* \*exposed\* to three currently-used pesticides  
\*2007\*  
URL: <http://dx.doi.org/10.1016/j.aquatox.2006.11.006>

30/6/132 (Item 132 from file: 50)  
0008312147 CAB Accession Number: 20023154025  
\*Reproductive\* abnormalities in \*glyphosate\*-resistant cotton caused by  
lower CP4-EPSPS levels in the male \*reproductive\* tissue.  
Publication Year: 2002

30/6/133 (Item 133 from file: 40)  
00717922 ENVIROLINE NUMBER: 07-12457  
Review of Potential Environmental Impacts of Transgenic \*Glyphosate\*  
-Resistant Soybean in Brazil  
Jun-Jul 07

30/6/134 (Item 134 from file: 50)  
0008737391 CAB Accession Number: 20043209129  
Residual and contact herbicide transport through field lysimeters via  
preferential flow.  
Publication Year: 2004

30/6/135 (Item 135 from file: 50)  
0009458598 CAB Accession Number: 20083019420  
Risk assessment of pesticides for \*soils\* of the Central Amazon, Brazil:  
comparing outcomes with temperate and tropical data.  
Publication Year: 2008

30/6/136 (Item 136 from file: 55)  
18145344 BIOSIS NO.: 200500052409  
Response of the pacific oyster *Crassostrea gigas* to pesticide \*exposition\*  
under experimental conditions  
\*2004\*

30/6/137 (Item 137 from file: 50)  
0009195492 CAB Accession Number: 20073052042  
Shikimic acid accumulation in field-grown corn ( *Zea mays* ) following

simulated \*glyphosate\* drift.

Publication Year: 2007

30/6/140 (Item 140 from file: 55)

0019924580 BIOSIS NO.: 200700584321

A summary of \*acute\* risk of four common herbicides to \*birds\* and \*mammals\*  
\*2007\*

30/6/141 (Item 141 from file: 50)

0008334223 CAB Accession Number: 20023169906

Sensitivity of the rooted macrophyte *Myriophyllum aquaticum* (Vell.)

Verdcourt to seventeen pesticides determined on the basis of EC SUB 50 .

Publication Year: 2002

30/6/144 (Item 144 from file: 154)

25229130 PMID: 17855366

StRoundupctural basis of \*glyphosate\* \*tolerance\* resulting from  
\*mutations\*

of Pro101 in *Escherichia coli* 5-enolpyRoundupvylshikimate-3-phosphate  
synthase.

Nov 9 \*2007\*

30/6/145 (Item 145 from file: 50)

0008782535 CAB Accession Number: 20053041105

Soybean response to plant growth regulator herbicides is affected by  
other postemergence herbicides.

Publication Year: 2005

30/6/146 (Item 146 from file: 50)

0009247492 CAB Accession Number: 20073074062

\*Tolerance\* of direct-seeded green onions to herbicides applied before  
or after crop emergence.

Publication Year: 2007

30/6/147 (Item 147 from file: 55)

17228558 BIOSIS NO.: 200300187277

Trifloxysulfuron-sodium: A new post emergence herbicide for use in cotton and  
sugarcane.

BOOK TITLE: Conference Proceedings BCPC Conference Weeds. Volume 1-2

\*2001\*

30/6/149 (Item 149 from file: 50)

0009509965 CAB Accession Number: 20083103409

Transport pathway of strongly sorbing pesticides through  
stRoundupctured drained \*soils\*. Book Title: Environmental fate and  
ecological effects of pesticides

Publication Year: 2007

30/6/150 (Item 150 from file: 55)

17303922 BIOSIS NO.: 200300262566

The \*teratogenic\* potential of the herbicide \*glyphosate\*-\*Roundup\*(R) in  
Wistar rats.

\*2003\*

30/6/151 (Item 151 from file: 50)

0008513370 CAB Accession Number: 20033177547  
 \*Toxicity\* of chemicals commonly used in Australian apple orchards to the European earwig *Forficula auricularia* L. (\*Dermaptera\*: Forficulidae).  
 Publication Year: 2003

30/6/152 (Item 152 from file: 50)  
 0009509923 CAB Accession Number: 20083103448  
 \*Toxicity\* determination on three sturgeon species \*exposed\* to the \*glyphosate\*.  
 Book Title: Environmental fate and ecological effects of pesticides  
 Publication Year: 2007

30/6/153 (Item 153 from file: 144)  
 17863363 PASCAL No.: 06-0462203  
 \*Toxicity\* of \*glyphosate\* as Glypro (R) and LI700 to red-eared slider (*Trachemys scripta elegans*) embryos and early hatchlings  
 \*2006\*

30/6/154 (Item 154 from file: 154)  
 16617123 PMID: 16193763  
 \*Toxicity\* of herbicides in highway \*Roundupnoff\*.  
 Sep \*2005\*

30/6/156 (Item 156 from file: 55)  
 18116593 BIOSIS NO.: 200500023658  
 \*Toxicity\* of pesticides to earthworm, *Polypheritima elongata* (Michaelson)  
 \*2004\*

30/6/159 (Item 159 from file: 50)  
 0009466386 CAB Accession Number: 20083049187  
 Wheat response to simulated \*glyphosate\* drift.  
 Publication Year: 2007

30/6/160 (Item 160 from file: 50)  
 0008983814 CAB Accession Number: 20063055099  
 Yield and physiological response of nontransgenic cotton to simulated \*glyphosate\* drift.  
 Publication Year: 2005

30/6/161 (Item 161 from file: 50)  
 0009464511 CAB Accession Number: 20083049177  
 Yield and physiological response of peanut to \*glyphosate\* drift.  
 Publication Year: 2007

30/6/162 (Item 162 from file: 55)  
 15782120 BIOSIS NO.: 200000500433  
 (14C)\*glyphosate\* transport in undisturbed topsoil columns  
 \*2000\*

|     |     |                                        |
|-----|-----|----------------------------------------|
| S31 | 925 | S28 NOT (S29 OR HUMAN)                 |
| S32 | 464 | S31 AND (S1 OR S2 OR S19)/TI           |
| S33 | 228 | S32 AND (S1 OR S2)/TI,DE AND S19/TI,DE |

34/6/1 (Item 1 from file: 55)  
 19398523 BIOSIS NO.: 200700058264  
 \*Acute\* cytotoxicity in \*mammal\* cells \*exposed\* in vitro to a \*glyphosate\*  
 -based formulation.  
 \*2006\*

34/6/2 (Item 2 from file: 55)  
0020055267 BIOSIS NO.: 200800102206  
Actue \*toxic\* effects of round-up herbicide on wood \*frog\* tadpoles (*Rana sylvatica*)  
\*2007\*

34/6/3 (Item 3 from file: 55)  
19326478 BIOSIS NO.: 200600671873  
\*Aquatic\* macroinvertebrates in the Altes Land, an intensely used orchard region in Germany: Correlation between community stRoundupcture and potential for pesticide \*exposure\*  
\*2006\*

34/6/4 (Item 4 from file: 10)  
4076652 23339868 Holding Library: AGL  
\*Aquatic\* \*toxicity\* of \*glyphosate\* -based formulations: comparison between different organisms and the effects of environmental factors  
\*2003\*

34/6/5 (Item 5 from file: 55)  
0020116582 BIOSIS NO.: 200800163521  
\*Alfalfa\* containing the \*glyphosate\*-tolerant trait has no effect on feed intake, milk composition, or milk production of dairy cattle  
\*2008\*

34/6/6 (Item 6 from file: 55)  
18846865 BIOSIS NO.: 200600192260  
Alterations induced by \*glyphosate\* on lupin photosynthetic apparatus and nodule ultrastrRoundupcture and some oxygen diffusion related proteins  
\*2005\*

34/6/8 (Item 8 from file: 76)  
0001848606 IP ACCESSION NO: 6727320  
An assessment of the hazard of a mixture of the herbicide \*Rodeo\* registered and the non-ionic surfactant R-11 registered to \*aquatic\* \*invertebrates\* and larval \*amphibians\*  
PUBLICATION DATE: \*2005\*

34/6/10 (Item 10 from file: 55)  
0020250234 BIOSIS NO.: 200800297173  
Biochemical bases for a widespread \*tolerance\* of cyanobacteria to the phosphonate herbicide \*glyphosate\*  
\*2008\*

34/6/11 (Item 11 from file: 55)  
18505242 BIOSIS NO.: 200510199742  
Biodegradation of \*glyphosate\* by wild yeasts  
\*2004\*

34/6/12 (Item 12 from file: 50)  
0009057643 CAB Accession Number: 20063130115  
Chemical control of lotus (*Nelumbo nucifera* Gaertn) in \*fish\* culture pond and its impact on water quality.  
Publication Year: 2005

34/6/13 (Item 13 from file: 55)  
18193137 BIOSIS NO.: 200500099050  
Chemical and microbiological \*soil\* characteristics controlling  
\*glyphosate\* mineralisation in Danish surface \*soils\*  
\*2004\*

34/6/14 (Item 14 from file: 10)  
4540678 43837610 Holding Library: AGL  
Changes in microbial community stRoundupcture following herbicide  
(  
\*glyphosate\*) additions to forest \*soils\*  
\*2006\*  
URL: <http://dx.doi.org/10.1016/j.apsoil.2006.03.002>

34/6/15 (Item 15 from file: 50)  
0009242634 CAB Accession Number: 20073054556  
Change in the enzyme spectra of \*soil\* \*microorganisms\* Micrococcus  
luteus CCM 248 and Stenotrophomonas maltophilia UKM V-257 under the effect of  
certain pesticides.  
Publication Year: 2006

34/6/16 (Item 16 from file: 55)  
0020280171 BIOSIS NO.: 200800327110  
Characterization and plant expression of a \*glyphosate\*-tolerant  
enolpyRoundupvylshikimate phosphate synthase  
\*2008\*

34/6/18 (Item 18 from file: 55)  
0019634137 BIOSIS NO.: 200700293878  
\*Chronic\* \*exposure\* to sub-lethal concentration of a \*glyphosate\*-based  
herbicide alters hormone profiles and affects \*reproduction\* of female  
Jundia (Rhamdia quelen)  
\*2007\*

34/6/19 (Item 19 from file: 55)  
18079093 BIOSIS NO.: 200400460322  
Comparative effects of pH and Vision(R) herbicide on two life stages of  
four anuran \*amphibian\* species  
\*2004\*

34/6/20 (Item 20 from file: 55)  
18748524 BIOSIS NO.: 200600093919  
Comparative effects of the \*Roundup\* and \*glyphosate\* on mitochondrial  
oxidative phosphorylation  
\*2005\*

34/6/21 (Item 21 from file: 154)  
17325875 PMID: 16998229  
Comparative \*genotoxicity\* of the herbicides \*Roundup\*, Stomp and Reglone  
in plant and \*mammalian\* test systems.  
Nov \*2006\*

34/6/22 (Item 22 from file: 55)  
18338650 BIOSIS NO.: 200510033150

Comparison of broiler performance when fed diets containing corn grain with insect-protected (corn rootworm and European corn borer) and herbicide-tolerant (\*Glyphosate\*) traits, control corn, or commercial reference corn  
\*2005\*

34/6/23 (Item 23 from file: 55)  
18763895 BIOSIS NO.: 200600109290  
Comparison of broiler performance when fed diets containing corn grain with insect-protected (Corn rootworm and European corn borer) and herbicide-tolerant (\*Glyphosate\*) traits, control corn, or commercial reference corn - Revisited (vol 84, pg 587, 2005)  
\*2005\*

34/6/24 (Item 24 from file: 55)  
17613093 BIOSIS NO.: 200300581812  
Comparison of broiler performance when fed diets containing grain from \*Roundup\* Ready (NK603), YieldGardXRoundup Ready (MON810XNK603), non-transgenic control, or commercial corn.  
\*2003\*

34/6/25 (Item 25 from file: 55)  
0019727439 BIOSIS NO.: 200700387180  
Comparison of the forage and grain composition from insect-protected and \*glyphosate\*-tolerant MON 88017 corn to conventional corn (Zea mays L.)  
\*2007\*

34/6/26 (Item 26 from file: 55)  
16669437 BIOSIS NO.: 200200262948  
Comparison of swine performance when fed diets containing \*Roundup\* Ready(R) corn (GA21), parental line or conventional corn  
\*2001\*

34/6/27 (Item 27 from file: 55)  
17809226 BIOSIS NO.: 200400179983  
The composition of grain and forage from \*glyphosate\*-tolerant wheat MON 71800 is equivalent to that of conventional wheat (Triticum aestivum L.).  
\*2004\*

34/6/28 (Item 28 from file: 55)  
0019523699 BIOSIS NO.: 200700183440  
Conventional and real-time polymerase chain reaction assessment of the fate of transgenic DNA in sheep fed \*Roundup\* Ready (R) rapeseed meal  
\*2006\*

34/6/29 (Item 29 from file: 144)  
15697805 PASCAL No.: 02-0406115  
Current methods for assessing safety of genetically modified crops as exemplified by data on \*Roundup\* Ready SUP 1 soybeans : Genetically modified food: Hazard identification and risk assessment  
\*2002\*

34/6/30 (Item 30 from file: 154)  
17181261 PMID: 16899736



The current status and environmental impacts of \*glyphosate\*-resistant crops: a review.  
Sep-Oct \*2006\*

34/6/31 (Item 31 from file: 55)  
17167599 BIOSIS NO.: 200300124709  
A critical assessment of the potential \*wildlife\* \*toxicity\* of  
\*glyphosate\* in Ontario with consideration for endocrine disruption.  
\*2002\*

34/6/32 (Item 32 from file: 154)  
16817442 PMID: 16373198  
Cytogenetic effect of technical \*glyphosate\* on cultivated bovine  
peripheral lymphocytes.  
Jan \*2006\*

34/6/33 (Item 33 from file: 55)  
17229710 BIOSIS NO.: 200300188429  
Cytotoxicity induced by herbicides \*glyphosate\* and alachlor in vitro.  
\*2001\*

34/6/34 (Item 34 from file: 55)  
0019635433 BIOSIS NO.: 200700295174  
\*Degradation\* of \*glyphosate\* in \*soil\* and its effect on fungal population  
\*2006\*

34/6/35 (Item 35 from file: 55)  
18079821 BIOSIS NO.: 200400461050  
\*Degradation\* of the herbicide \*glyphosate\* by actinomycetes  
\*2004\*

34/6/36 (Item 36 from file: 55)  
15583172 BIOSIS NO.: 200000301485  
Delayed control of weeds in \*glyphosate\*-tolerant sugar beet and the  
consequences on aphid infestation and yield  
\*2000\*

34/6/37 (Item 37 from file: 50)  
0009026937 CAB Accession Number: 20063094934  
The detection of chromosome aberrations by the \*FISH\* method in bovine  
peripheral lymphocytes after in vitro \*glyphosate\*-based herbicide  
\*exposure\*.  
Publication Year: 2005

34/6/38 (Item 38 from file: 55)  
17929653 BIOSIS NO.: 200400300410  
Detection of recombinant marker DNA in genetically modified \*glyphosate\*  
-tolerant soybean and use in environmental risk assessment  
\*2004\*

34/6/39 (Item 39 from file: 55)  
18956110 BIOSIS NO.: 200600301505  
Detection of transgenic and endogenous plant DNA in digesta and tissues of  
sheep and pigs fed Roundup Ready canola meal  
\*2006\*

34/6/40 (Item 40 from file: 55)  
18203742 BIOSIS NO.: 200500120807  
Development and characterization of a CP4 EPSPS-based, \*glyphosate\*  
-tolerant corn event  
\*2005\*

34/6/41 (Item 41 from file: 55)  
0019528226 BIOSIS NO.: 200700187967  
Development and characterization of \*alfalfa\* populations tolerant to  
\*glyphosate\*.  
\*2006\*

34/6/42 (Item 42 from file: 55)  
15588207 BIOSIS NO.: 200000306520  
Developmental \*toxicity\* studies with \*glyphosate\* and selected surfactants  
in rats  
\*2000\*

34/6/43 (Item 43 from file: 55)  
17940714 BIOSIS NO.: 200400311471  
Discovery and directed evolution of a \*glyphosate\*\*tolerance\* gene  
\*2004\*

34/6/44 (Item 44 from file: 154)  
15182283 PMID: 12746143  
Ecological risk assessment for \*aquatic\* organisms from over-water uses  
of \*glyphosate\*.  
May-Jun \*2003\*

34/6/45 (Item 45 from file: 55)  
19116676 BIOSIS NO.: 200600462071  
\*Ecotoxicological\* studies on the pejerrey (*Odontesthes bonariensis*, Pisces  
Atherinopsidae)  
\*2006\*

34/6/46 (Item 46 from file: 10)  
3871392 22086048 Holding Library: AGL  
\*Ecotoxicological\* risk assessment for \*roundup\* herbicide  
\*2000\*

34/6/47 (Item 47 from file: 55)  
17477485 BIOSIS NO.: 200300446204  
Efficacy of \*glyphosate\* and five surfactants for controlling giant salvinia.  
\*2002\*

34/6/48 (Item 48 from file: 10)  
4605020 43874017 Holding Library: AGL  
Influence of conservation tillage and \*glyphosate\* on \*soil\*  
stRoundupcture  
and organic carbon fractions through the cycle of a 3-year potato rotation  
in Atlantic Canada  
\*2007\*  
URL: <http://dx.doi.org/10.1016/j.still.2006.04.004>

34/6/49 (Item 49 from file: 55)

18853156 BIOSIS NO.: 200600198551  
Influence of CrylAc toxin on mineralization and bioavailability of  
\*glyphosate\* in \*soil\*  
\*2006\*

34/6/50 (Item 50 from file: 10)  
3948680 23236975 Holding Library: AGL  
Effects of \*acute\* \*exposure\* to a commercial formulation of \*glyphosate\*  
on the tadpoles of two species of anurans  
\*2001\*

34/6/51 (Item 51 from file: 55)  
17013026 BIOSIS NO.: 200200606537  
Effect of feeding diets containing corn grain with \*Roundup\* (event GA21 or  
NK603), control, or conventional varieties on steer feedlot performance and  
carcass characteristics  
\*2002\*

34/6/52 (Item 52 from file: 55)  
19403590 BIOSIS NO.: 200700063331  
Effects of feeding \*Roundup\* Ready (R) \*alfalfa\* on intake and milk  
production of dairy cows.  
\*2006\*

34/6/53 (Item 53 from file: 10)  
4333655 43741419 Holding Library: AGL  
Effect of freezing and thawing on microbial activity and \*glyphosate\*  
\*degradation\* in two Norwegian \*soils\*  
\*2005\*  
URL: <http://www.interscience.wiley.com/jpages/1526-498X/>

34/6/54 (Item 54 from file: 10)  
4672744 43899272 Holding Library: AGL  
Effects of \*glyphosate\* and foliar amendments on activity of  
\*microorganisms\* in the soybean rhizosphere  
\*2007\*

34/6/55 (Item 55 from file: 10)  
4380802 43767771 Holding Library: AGL  
Influence of \*glyphosate\* and its formulation (\*Roundup\*) on the  
\*toxicity\* and bioavailability of metals to *Ceriodaphnia dubia*  
\*2005\*

34/6/58 (Item 58 from file: 154)  
17191742 PMID: 16174533  
Effect of \*glyphosate\* herbicide on acetylcholinesterase activity and  
\*metabolic\* and hematological parameters in piava (*Leporinus obtusidens*).  
Oct \*2006\*

34/6/59 (Item 59 from file: 55)  
0020017068 BIOSIS NO.: 200800064007  
The effect of \*glyphosate\* on digestion horizontal gene transfer during in  
vitro Roundupminal fermentation of genetically modified canola  
\*2007\*

34/6/60 (Item 60 from file: 55)  
18449754 BIOSIS NO.: 200510144254

The effect of \*glyphosate\* on the frequency of micronuclei in bovine lymphocytes in vitro  
\*2005\*

34/6/61 (Item 61 from file: 55)  
17186188 BIOSIS NO.: 200300144907  
Effect of \*glyphosate\* on growth, chlorophyll, and nodulation in \*glyphosate\*-resistant and susceptible soybean (Glycine max) varieties.  
\*2000\*

34/6/62 (Item 62 from file: 55)  
16170753 BIOSIS NO.: 200100342592  
Effects of \*glyphosate\* on lignicolous freshwater fungi of Hong Kong  
\*2001\*

34/6/63 (Item 63 from file: 55)  
19393400 BIOSIS NO.: 200700053141  
Influence of \*glyphosate\* on Rhizoctonia and Fusarium root rot in sugar beet  
\*2006\*

34/6/64 (Item 64 from file: 55)  
17434644 BIOSIS NO.: 200300393074  
Effects of \*glyphosate\* on root diseases in \*glyphosate\*-tolerant soybeans.  
\*2003\*

34/6/65 (Item 65 from file: 55)  
16880375 BIOSIS NO.: 200200473886  
Effect of \*glyphosate\* on atrazine \*degradation\* in \*soil\*  
\*2002\*

34/6/66 (Item 66 from file: 55)  
0019661986 BIOSIS NO.: 200700321727  
Effects of \*glyphosate\* on \*soil\* microbial communities and its Mississippi \*soil\*  
\*2007\*

34/6/67 (Item 67 from file: 55)  
15478291 BIOSIS NO.: 200000196604  
Effect of \*glyphosate\* on \*soil\* microbial activity and biomass  
\*2000\*

34/6/68 (Item 68 from file: 55)  
19145233 BIOSIS NO.: 200600490628  
Effects of \*glyphosate\* (\*Roundup\* (R)) on glutathione-S-transferase activity in mudworms, lumbriculus variegates  
\*2006\*

34/6/69 (Item 69 from file: 41)  
0000291054 IP ACCESSION NO: 7355741  
Effect of \*Glyphosate\* Rate and Spray Volume on Control of Giant Salvinia  
PUBLICATION DATE: \*2007\*

34/6/70 (Item 70 from file: 144)  
16245262 PASCAL No.: 03-0406315

Influence of \*glyphosate\*-tolerant (event nk603) and corn rootworm protected (event MON863) corn silage and grain on feed consumption and milk production in Holstein cattle  
\*2003\*

34/6/71 (Item 71 from file: 55)  
17789347 BIOSIS NO.: 200400170104  
Effect of \*glyphosate\* \*toxicity\* on growth, pigment and alkaline phosphatase activity in cyanobacterium *Anabaena doliolum*: A role of inorganic phosphate in \*glyphosate\* \*tolerance\*.  
\*2004\*

34/6/72 (Item 72 from file: 50)  
0008267099 CAB Accession Number: 20023112697  
Effect of herbicidal control of water hyacinth on \*fish\* health at the Ere channel, Ogun State, Nigeria.  
Publication Year: 2002

34/6/73 (Item 73 from file: 55)  
18295030 BIOSIS NO.: 200500212095  
Effect of the herbicide \*glyphosate\* on liver lipoperoxidation in pregnant rats and their fetuses  
\*2005\*

34/6/74 (Item 74 from file: 55)  
16022114 BIOSIS NO.: 200100193953  
Effect of the herbicide \*glyphosate\* on enzymatic activity in pregnant rats and their fetuses  
\*2001\*

34/6/75 (Item 75 from file: 55)  
15379018 BIOSIS NO.: 200000097331  
Effects of herbicides on *Fusarium solani* f. sp. *glycines* and development of sudden death syndrome in \*glyphosate\*-tolerant soybean  
\*2000\*

34/6/76 (Item 76 from file: 55)  
17107788 BIOSIS NO.: 200300066507  
Effects of herbicides on root rot and damping-off caused by *Rhizoctonia solani* in \*glyphosate\*-tolerant soybean.  
\*2002\*

34/6/77 (Item 77 from file: 154)  
17520900 PMID: 17166697  
Effects of the herbicide \*Roundup\* on the epididymal region of drakes *Anas platyrhynchos*.  
Feb \*2007\*

34/6/78 (Item 78 from file: 55)  
17563801 BIOSIS NO.: 200300519164  
The effect of johnsongrass (*Sorghum halepense*) control method on the incidence and severity of viRoundups diseases in \*glyphosate\*-tolerant corn (*Zea mays*).  
\*2003\*

34/6/79 (Item 79 from file: 10)  
4656412 43711275 Holding Library: AGL

Effects of incorporated corn \*residues\* on \*glyphosate\* mineralization and sorption in \*soil\*

\*2005\*

URL: <http://agspace.nal.usda.gov/handle/10113/783>

34/6/80 (Item 80 from file: 50)

0008323417 CAB Accession Number: 20023173364

The effect of nitrogenous additives to \*glyphosate\* for water hyacinth *Eichhornia crassipes* (Mart) Solms-Laub control.

Publication Year: 2002

34/6/81 (Item 81 from file: 55)

16880379 BIOSIS NO.: 200200473890

Effect of \*Roundup\* Ultra on microbial activity and biomass from selected \*soils\*

\*2002\*

34/6/82 (Item 82 from file: 55)

17478316 BIOSIS NO.: 200300447035

Effect of \*Roundup\* Ultra on atrazine \*degradation\* in \*soil\*.

\*2003\*

34/6/83 (Item 83 from file: 55)

0019699914 BIOSIS NO.: 200700359655

The influence of \*roundup\* on the dynamics of histological changes in organs of carps

\*2007\*

34/6/84 (Item 84 from file: 55)

18335235 BIOSIS NO.: 200510029735

Influence of \*Roundup\* Ready (R) soybean production systems and \*glyphosate\* application on pest and beneficial insects in wide-row soybean

\*2004\*

34/6/85 (Item 85 from file: 55)

17883376 BIOSIS NO.: 200400254133

Influence of \*Roundup\* Ready soybean production systems and \*glyphosate\* application on pest and beneficial insects in narrow-row soybean.

\*2004\*

34/6/86 (Item 86 from file: 55)

17883375 BIOSIS NO.: 200400254132

Influence of \*Roundup\* Ready soybean and \*Roundup\* Ultra herbicide on *Geocoris punctipes* (Say) (Heteroptera: Lygaeidae) in the laboratory.

\*2004\*

34/6/87 (Item 87 from file: 55)

0019780937 BIOSIS NO.: 200700440678

Effect of \*roundup\* 360 SL herbicide on the number of *Aeromonas hydrophila* and *Pseudomonas fluorescens* in lake water

\*2006\*

34/6/88 (Item 88 from file: 10)

4217830 43677817 Holding Library: AGL

Effects of thiophanate-methyl and \*glyphosate\* on asexual and sexual

\*reproduction\* in the rotifer *Brachionus calyciflorus* Pallas  
\*2004\*

34/6/89 (Item 89 from file: 55)  
17419855 BIOSIS NO.: 200300388574  
Effects of Atrazine and \*Glyphosate\* \*ingestion\* on body weight and  
nutritional well-being of *Coturnix* quail.  
\*2002\*

34/6/90 (Item 90 from file: 55)  
18140355 BIOSIS NO.: 200500047105  
The effects of sub-\*chronic\* \*exposure\* of Wistar rats to the herbicide  
\*Glyphosate\*-Biocarb(R)  
\*2004\*

34/6/91 (Item 91 from file: 55)  
0020099473 BIOSIS NO.: 200800146412  
The effect of sub-\*acute\* and sub-\*chronic\* \*exposure\* of rats to the  
\*glyphosate\*-based herbicide \*Roundup\*  
\*2008\*

34/6/92 (Item 92 from file: 55)  
18252938 BIOSIS NO.: 200500159110  
The effect of *Saccharomyces cerevisiae* on the stability of the herbicide  
\*glyphosate\* during bread leavening  
\*2005\*

34/6/93 (Item 93 from file: 55)  
0019808198 BIOSIS NO.: 200700467939  
Influence of \*soil\* moisture on root colonization of \*glyphosate\*-treated  
soybean by *Fusarium* species  
\*2007\*

34/6/94 (Item 94 from file: 50)  
0008240831 CAB Accession Number: 20023046981  
Effects of silvicultural systems and vegetation control on tree growth  
in a coastal montane \*ecosystem\*: seven year results.  
Publication Year: 2002

34/6/95 (Item 95 from file: 55)  
15531055 BIOSIS NO.: 200000249368  
Effects of 2,4-D, \*glyphosate\* and paraquat on growth, photosynthesis and  
chlorophyll-A synthesis of *Scenedesmus quadricauda* Berb 614  
\*2000\*

34/6/96 (Item 96 from file: 144)  
17977161 PASCAL No.: 07-0037753  
Equal performance of taqman, MGB, molecular beacon, and SYBR green-based  
detection assays in detection and quantification of \*roundup\* ready soybean  
\*2006\*

34/6/97 (Item 97 from file: 55)  
17021705 BIOSIS NO.: 200200615216  
Enhanced in vitro \*toxicity\* of the herbicide \*glyphosate\* to neuroblastoma  
cells chronically pre-treated with the organophosphate pesticide diazinon  
\*2002\*

34/6/98 (Item 98 from file: 40)  
00688705 ENVIROLINE NUMBER: 05-16659  
Environmental Fate of Herbicides Trifluralin, Metazachlor, Metamitron and  
Sulcotrione Compared with That of \*Glyphosate\*, a Substitute Broad  
SpectRoundupm Herbicide for Different \*Glyphosate\*-Resistant Crops  
Sep 05

34/6/99 (Item 99 from file: 55)  
0020266079 BIOSIS NO.: 200800313018  
Environmental fate and non-target impact of \*glyphosate\*-based herbicide (  
\*Roundup\* (R)) in a subtropical wetland  
\*2008\*

34/6/100 (Item 100 from file: 55)  
15848420 BIOSIS NO.: 200100020259  
Evaluation of \*glyphosate\* resistance in transgenic lettuce  
\*2000\*

34/6/101 (Item 101 from file: 55)  
18302406 BIOSIS NO.: 200500206208  
Evolution of a microbial acetyltransferase for modification of \*glyphosate\*:  
a novel \*tolerance\* strategy  
\*2005\*

34/6/102 (Item 102 from file: 55)  
18245749 BIOSIS NO.: 200500152814  
Evaluation of transgenic cotton varieties and a \*glyphosate\* application on  
seedling disease incidence  
\*2004\*

34/6/103 (Item 103 from file: 55)  
18473297 BIOSIS NO.: 200510167797  
Evaluation of transgenic cotton varieties and a \*glyphosate\* application on  
seedling disease incidence (vol 158, pg 363, 2004)  
\*2005\*

34/6/104 (Item 104 from file: 50)  
0008223474 CAB Accession Number: 20023037510  
Experimental control of Reynoutria congeners: a comparative study of a  
hybrid and its parents.  
Book Title: Plant invasions: species ecology and \*ecosystem\* management  
Publication Year: 2001

34/6/105 (Item 105 from file: 55)  
16840220 BIOSIS NO.: 200200433731  
Expression of glpA/B operon in transgenic chloroplasts to degrade  
\*glyphosate\*  
\*2002\*

34/6/106 (Item 106 from file: 55)  
18338441 BIOSIS NO.: 200510032941  
Expression of a wheat cytochrome P450 monooxygenase in yeast and its  
\*inhibition\* by \*glyphosate\*  
\*2005\*



34/6/107 (Item 107 from file: 55)  
0020254853 BIOSIS NO.: 200800301792  
Escape and establishment of transgenic \*glyphosate\*-resistant creeping  
bentgrass *Agrostis stolonifera* in Oregon, USA: a 4-year study  
\*2008\*

34/6/108 (Item 108 from file: 55)  
0019676470 BIOSIS NO.: 200700336211  
Establishment of submerged \*aquatic\* vegetation in everglades stormwater  
treatment areas: Value of early control of torpedograss (*Panicum repens*)  
\*2007\*

34/6/109 (Item 109 from file: 55)  
0019893198 BIOSIS NO.: 200700552939  
Estimation of \*toxicity\* of \*glyphosate\*-based herbicides by biotesting  
method using Cladocera  
\*2007\*

34/6/110 (Item 110 from file: 55)  
17308466 BIOSIS NO.: 200300277185  
Field efficacy assessment of transgenic \*Roundup\* Ready wheat.  
\*2003\*

34/6/111 (Item 111 from file: 55)  
16174885 BIOSIS NO.: 200100346724  
Field response of \*glyphosate\*-tolerant soybean to herbicides and sudden  
death syndrome  
\*2001\*

34/6/112 (Item 112 from file: 55)  
17138671 BIOSIS NO.: 200300097390  
Fungicidal effects of \*glyphosate\* and \*glyphosate\* formulations on four  
species of entomopathogenic fungi.  
\*2002\*

34/6/113 (Item 113 from file: 55)  
18179162 BIOSIS NO.: 200500086227  
Formulated \*glyphosate\* activates the DNA-response checkpoint of the cell  
cycle leading to the prevention of G2/M transition  
\*2004\*

34/6/114 (Item 114 from file: 55)  
19150222 BIOSIS NO.: 200600495617  
Physiological mechanisms of \*glyphosate\* resistance  
\*2006\*

34/6/115 (Item 115 from file: 55)  
17228606 BIOSIS NO.: 200300187325  
Physiological and morphological effects of \*glyphosate\* applications on  
\*glyphosate\*-resistant cotton.  
BOOK TITLE: Conference Proceedings BCPC Conference Weeds. Volume 1-2  
\*2001\*

34/6/116 (Item 116 from file: 55)  
19306201 BIOSIS NO.: 200600651596

\*Glyphosate\* and bioherbicide interaction for controlling kudzu (*Pueraria lobata*), redvine (*Broundupnnichia ovata*), and tRoundupmpetcreeper (*Campsis radicans*)

\*2006\*

34/6/117 (Item 117 from file: 55)

19137976 BIOSIS NO.: 200600483371

Is \*glyphosate\* a developmental and/or \*reproductive\* \*toxicant\*? a critical analysis of the literature

\*2006\*

34/6/118 (Item 118 from file: 50)

0008976551 CAB Accession Number: 20063025598

\*Glyphosate\* affects soybean root exudation and rhizosphere \*microorganisms\*.

Publication Year: 2005

34/6/119 (Item 119 from file: 41)

0000288265 IP ACCESSION NO: 6909916

\*Glyphosate\* affects soybean root exudation and rhizosphere micro-organisms

PUBLICATION DATE: \*2005\*

34/6/120 (Item 120 from file: 55)

18202240 BIOSIS NO.: 200500109305

\*Glyphosate\* herbicide \*degradation\* in waterlogged \*soil\*

\*2004\*

34/6/121 (Item 121 from file: 55)

16017568 BIOSIS NO.: 200100189407

\*Glyphosate\* inhibits melanization of *Cryptococcus neoformans* and prolongs \*survival\* of mice after systemic infection

\*2001\*

34/6/122 (Item 122 from file: 55)

18763957 BIOSIS NO.: 200600109352

\*Glyphosate\* inhibits Roundupst diseases in \*glyphosate\*-resistant wheat and soybean

2005

34/6/123 (Item 123 from file: 55)

15873200 BIOSIS NO.: 200100045039

\*Glyphosate\* applied to genetically modified herbicide-tolerant sugar beet and 'volunteer' potatoes reduces populations of potato cyst nematodes and the number and size of daughter tubers

\*2000\*

34/6/124 (Item 124 from file: 55)

19036463 BIOSIS NO.: 200600381858

\*Glyphosate\* and previous crop \*residue\* effect on deleterious and beneficial \*soil\*-borne fungi from a peanut-corn-soybean rotations

\*2006\*

34/6/125 (Item 125 from file: 55)

16875063 BIOSIS NO.: 200200468574

\*Glyphosate\*-resistant goosegrass. Identification of a \*mutation\* in the target enzyme 5-enolpyRoundupvylshikimate-3-phosphate synthase  
\*2002\*

34/6/126 (Item 126 from file: 55)  
18717316 BIOSIS NO.: 200600062711  
\*Glyphosate\*-resistant soybean management system effect on Sclerotinia stem rot  
\*2005\*

34/6/127 (Item 127 from file: 154)  
15267957 PMID: 12848496  
\*Glyphosate\*-tolerant canola meal is equivalent to the parental line in diets fed to rainbow \*trout\*.  
Jul 16 \*2003\*

34/6/128 (Item 128 from file: 55)  
18937151 BIOSIS NO.: 200600282546  
Gametic selection by \*glyphosate\* in soybean plants hemizygous for the CP4 EPSPS transgene  
\*2006\*

34/6/129 (Item 129 from file: 55)  
0019717164 BIOSIS NO.: 200700376905  
Gene flow from GM \*glyphosate\*-tolerant to conventional soybeans under field conditions in Japan  
\*2006\*

34/6/130 (Item 130 from file: 55)  
0019651451 BIOSIS NO.: 200700311192  
Genetically modified canola and Roundupminal bacteria: investigations of horizontal gene transfer and effects of \*glyphosate\* in vitro.  
\*2006\*

34/6/131 (Item 131 from file: 55)  
19100548 BIOSIS NO.: 200600445943  
Genetic analysis of \*glyphosate\* \*tolerance\* in Halomonas variabilis strain HTG(7)  
\*2006\*

34/6/132 (Item 132 from file: 55)  
0020213151 BIOSIS NO.: 200800260090  
\*Genotoxic\* potential of \*glyphosate\* formulations: Mode-of-action investigations  
\*2008\*

34/6/134 (Item 134 from file: 50)  
0008333643 CAB Accession Number: 20023175861  
Herbicidal control of water hyacinth and its impact on \*fish\* growth and water quality.  
Publication Year: 2002

34/6/135 (Item 135 from file: 10)  
4823622 44034750 Holding Library: AGL  
Herbicides, \*glyphosate\* resistance and \*acute\* \*mammalian\* \*toxicity\*:  
simulating an environmental effect of \*glyphosate\*-resistant weeds in the USA

\*2008\*

URL: <http://dx.doi.org/10.1002/ps.1497>

34/6/136 (Item 136 from file: 55)  
17151542 BIOSIS NO.: 200300110261  
How the \*mutation\* glycine96 to alanine confers \*glyphosate\* insensitivity  
to 5-enolpyRoundupvyl shikimate-3-phosphate synthase from Escherichia coli.  
\*2002\*

34/6/137 (Item 137 from file: 55)  
0019870466 BIOSIS NO.: 200700530207  
Histopathological responses of the gill and liver tissues of Clarias  
gariepinus fingerlings to the herbicide, \*glyphosate\*  
\*2006\*

34/6/138 (Item 138 from file: 10)  
4059978 23325087 Holding Library: AGL  
Ichthyophthirius multifiliis and Tetrahymena thermophila tolerate  
\*glyphosate\* but not a commercial herbicidal formulation  
\*2003\*

34/6/139 (Item 139 from file: 55)  
18846837 BIOSIS NO.: 200600192232  
Identification of a \*glyphosate\*-resistant mutant of rice 5-  
enolpyRoundupvylshikimate 3-phosphate synthase using a directed evolution-  
strategy  
\*2006\*

34/6/140 (Item 140 from file: 55)  
0019957404 BIOSIS NO.: 200800004343  
Identification of a new gene encoding EPSPS with high \*glyphosate\*  
resistance from the metagenomic library  
\*2007\*

34/6/141 (Item 141 from file: 55)  
17937828 BIOSIS NO.: 200400308585  
Impact of \*glyphosate\* on the Bradyrhizobium japonicum symbiosis with  
\*glyphosate\*-resistant transgenic soybean: A minireview  
\*2004\*

34/6/142 (Item 142 from file: 10)  
4307662 43661048 Holding Library: AGL  
The impact of the herbicide \*glyphosate\* on leaf litter \*invertebrates\*  
within Bitou bush, Chrysanthemoides monilifera ssp rotundata, infestations  
\*2004\*  
URL: <http://www.interscience.wiley.com/jpages/1526-498X/>

34/6/143 (Item 143 from file: 10)  
4313605 43721508 Holding Library: AGL  
The impact of insecticides and herbicides on the biodiversity and  
productivity of \*aquatic\* communities  
\*2005\*

34/6/145 (Item 145 from file: 55)  
19388070 BIOSIS NO.: 200700047811

The impact of insecticides and herbicides on the biodiversity and  
productivity of \*aquatic\* communities - Response  
\*2006\*

34/6/146 (Item 146 from file: 55)  
15794075 BIOSIS NO.: 200000512388  
The induction of glutathione-S-transferase (GST) in the liver of *Notemigonus*  
*chryssoleucas* in response to the herbicides \*glyphosate\* and triclopyr  
\*2000\*

34/6/147 (Item 147 from file: 50)  
0009389149 CAB Accession Number: 20073265931  
Integrated weed control using a retardant \*dose\* of \*glyphosate\*: a new  
management tool for water hyacinth?  
Publication Year: 2007

34/6/148 (Item 148 from file: 10)  
4859461 44034749 Holding Library: AGL  
Integrating \*soil\* conservation practices and \*glyphosate\*-resistant  
crops: impacts on \*soil\*  
\*2008\*  
URL: <http://hdl.handle.net/10113/12231>

34/6/149 (Item 149 from file: 40)  
00732099 ENVIROLINE NUMBER: 08-12297  
Interactions Between \*Glyphosate\* and Autochthonous \*Soil\* Fungi Surviving  
in Aqueous Solution of \*Glyphosate\*  
Apr 08

34/6/150 (Item 150 from file: 55)  
16817340 BIOSIS NO.: 200200410851  
Interaction of \*glyphosate\* \*tolerance\* with soybean cyst nematode resistance  
\*2002\*

34/6/151 (Item 151 from file: 55)  
0019890690 BIOSIS NO.: 200700550431  
In vitro and in vivo evaluation of the \*genotoxicity\* of the herbicide  
\*glyphosate\* in mice  
\*2006\*

34/6/152 (Item 152 from file: 55)  
18581240 BIOSIS NO.: 200510275740  
In vitro evaluation of \*glyphosate\*-induced DNA damage in fibrosarcoma  
cells HT1080 and Chinese hamster ovary (CHO) cells.  
\*2004\*

34/6/153 (Item 153 from file: 10)  
4380835 43767826 Holding Library: AGL  
\*Leaching\* of \*glyphosate\* and AMPA under two \*soil\* management practices  
in Burgundy vineyards (Vosne-Romanee, 21-France)  
\*2005\*

34/6/154 (Item 154 from file: 10)  
4319336 43739244 Holding Library: AGL  
The lethal impact of \*roundup\* on \*aquatic\* and terrestrial \*amphibians\*  
\*2005\*

34/6/155 (Item 155 from file: 55)  
17434646 BIOSIS NO.: 200300393076  
Microbial activity and atrazine \*degradation\* in \*soil\* from mixtures of  
\*glyphosate\* and atrazine.  
\*2003\*

34/6/156 (Item 156 from file: 10)  
4859626 44035810 Holding Library: AGL  
Microbial respiration in \*soils\* of the Argentine pampas after  
metsulfuron methyl, 2,4-D, and \*glyphosate\* treatments  
\*2008\*

34/6/157 (Item 157 from file: 55)  
18725999 BIOSIS NO.: 200600071394  
Molecular basis for the \*glyphosate\*-insensitivity of the reaction of  
5-enolpyRoundupvylshikimate 3-phosphate synthase with shikimate  
\*2005\*

34/6/158 (Item 158 from file: 55)  
0019727690 BIOSIS NO.: 200700387431  
The molecular basis of \*glyphosate\* resistance by an optimized microbial  
acetyltransferase  
\*2007\*

34/6/159 (Item 159 from file: 55)  
19273872 BIOSIS NO.: 200600619267  
Molecular basis for the herbicide resistance of \*Roundup\* Ready crops  
\*2006\*

34/6/160 (Item 160 from file: 50)  
0008755339 CAB Accession Number: 20053015364  
Monitoring of pesticide \*residues\* in drainage water and \*fish\* samples  
collected from different governorates, Egypt.  
Publication Year: 2005

34/6/161 (Item 161 from file: 55)  
16327678 BIOSIS NO.: 200100499517  
\*Metabolism\* of the phosphonate herbicide \*glyphosate\* by a  
non-nitrate-utilizing strain of *Penicillium chrysogenum*  
\*2001\*

34/6/162 (Item 162 from file: 55)  
0020143348 BIOSIS NO.: 200800190287  
A metagenome approach to the study of phosphohydrolases and \*glyphosate\*  
transport and \*degradation\* in bacteria  
\*2007\*

34/6/163 (Item 163 from file: 55)  
0020052217 BIOSIS NO.: 200800099156  
Mycotoxin occurrence and *Aspergillus flavus* \*soil\* propagules in a corn and  
cotton \*glyphosate\*-resistant cropping systems  
\*2007\*

34/6/164 (Item 164 from file: 55)  
17778324 BIOSIS NO.: 200400144985

The nematode *Caenorhabditis elegans* as a model of organophosphate-induced  
\*mammalian\* \*neurotoxicity\*.

\*2004\*

34/6/165 (Item 165 from file: 55)  
0019539164 BIOSIS NO.: 200700198905  
Nitrogenase activity, nitrogen content, and yield responses to \*glyphosate\*  
in \*glyphosate\*-resistant soybean  
\*2007\*

34/6/166 (Item 166 from file: 55)  
19002015 BIOSIS NO.: 200600347410  
Nutrient digestibility in sheep fed diets containing \*Roundup\* Ready or  
conventional fodder beet, sugar beet, and beet pulp  
\*2005\*

34/6/167 (Item 167 from file: 55)  
16629990 BIOSIS NO.: 200200223501  
Nutritional evaluation of Bt (MON810) and \*Roundup\* Ready(R) corn compared  
with commercial hybrids in broilers  
\*2001\*

34/6/168 (Item 168 from file: 55)  
17344841 BIOSIS NO.: 200300313560  
A new \*glyphosphate\* \*tolerance\* strategy in transgenic crops.  
\*2003\*

34/6/169 (Item 169 from file: 55)  
19012060 BIOSIS NO.: 200600357455  
New insights on \*glyphosate\* mode of action in nodular \*metabolism\*: Role  
of shikimate accumulation  
\*2006\*

34/6/170 (Item 170 from file: 55)  
16858458 BIOSIS NO.: 200200451969  
Studies on a new group of biodegradable surfactants for \*glyphosate\*  
\*2002\*

34/6/171 (Item 171 from file: 55)  
18769979 BIOSIS NO.: 200600115374  
Oxidative \*degradation\* of \*glyphosate\* and aminomethylphosphonate by  
manganese oxide  
\*2005\*

34/6/172 (Item 172 from file: 55)  
0020096663 BIOSIS NO.: 200800143602  
Oxidative stress biomarkers and bioconcentration of reldan and \*roundup\* by  
the edible clam *Roundupditapes decussatus*  
\*2007\*

34/6/173 (Item 173 from file: 40)  
00731623 ENVIROLINE NUMBER: 08-03611  
Oxidative Stress Biomarkers and Heart Function in Bullfrog Tadpoles  
\*Exposed\* to \*Roundup\* Original  
Apr 08

34/6/174 (Item 174 from file: 55)

17572880 BIOSIS NO.: 200300527777  
Plant phenology effects on \*soil\* microbial C and N cycling in a semiarid  
\*ecosystem\*.  
\*2003\*

34/6/175 (Item 175 from file: 55)  
16252653 BIOSIS NO.: 200100424492  
Plant growth and nitrogenase activity of \*glyphosate\*-tolerant soybean in  
response to foliar \*glyphosate\* applications  
\*2001\*

34/6/176 (Item 176 from file: 55)  
15980030 BIOSIS NO.: 200100151869  
Plastid-expressed 5-enolpyruvylshikimate-3-phosphate synthase genes  
provide  
high level \*glyphosate\* \*tolerance\* in tobacco  
\*2001\*

34/6/177 (Item 177 from file: 55)  
17871314 BIOSIS NO.: 200400240261  
Performance of growing-finishing pigs fed diets containing \*Roundup\* Ready  
corn (event nk603), a nontransgenic genetically similar corn, or  
conventional corn lines.  
\*2004\*

34/6/179 (Item 179 from file: 55)  
16988476 BIOSIS NO.: 200200581987  
Performance of lactating dairy cows fed \*glyphosate\*-tolerant corn (event  
NK603)  
\*2002\*

34/6/180 (Item 180 from file: 55)  
15784018 BIOSIS NO.: 200000502331  
Progeny analysis of \*glyphosate\* selected transgenic soybeans derived from  
Agrobacterium-mediated transformation  
\*2000\*

34/6/181 (Item 181 from file: 55)  
18477773 BIOSIS NO.: 200510172273  
Preemergence herbicide and \*glyphosate\* effects on seedling diseases in  
\*glyphosate\*-resistant cotton  
\*2005\*

34/6/182 (Item 182 from file: 55)  
16988458 BIOSIS NO.: 200200581969  
Protocols for detection of EPSP synthase gene in sheep fed diets containing  
\*Roundup\* Ready(R) canola  
\*2002\*

34/6/183 (Item 183 from file: 55)  
16974789 BIOSIS NO.: 200200568300  
\*Persistence\* of transgenic DNA from \*Roundup\* Ready(R) canola during  
processing for feed and in vitro Roundupminal incubation  
\*2002\*



34/6/184 (Item 184 from file: 55)  
0019889751 BIOSIS NO.: 200700549492  
Putative porin of Bradyrhizobium sp (Lupinus) bacteroids induced by  
\*glyphosate\*  
\*2007\*

34/6/185 (Item 185 from file: 10)  
4319337 43739245 Holding Library: AGL  
Pesticides and \*amphibians\*: the importance of community context  
\*2005\*

34/6/186 (Item 186 from file: 6)  
2262545 NTIS Accession Number: MIC-103-01962/XAB  
Pesticides in Ontario: A critical assessment of potential \*toxicity\* of  
agricultural products to \*wildlife\* , with consideration for endocrine  
disRoundupption, vol. 2: Triazine herbicides, \*glyphosate\*, and metolachlor  
(Technical report series no. no. 369)  
c2002

34/6/187 (Item 187 from file: 55)  
18047665 BIOSIS NO.: 200400418454  
Use of quantitative real-time and conventional PCR to assess the stability  
of the cp4 epsps transgene from \*Roundup\* Ready(R) canola in the  
intestinal, Roundupminal, and fecal contents of sheep  
\*2004\*

34/6/188 (Item 188 from file: 55)  
19322751 BIOSIS NO.: 200600668146  
ReconstRoundupction of enzymatic activity from split genes encoding  
\*glyphosate\*-tolerant EPSPS protein of Psedomonas fluorescens G2 strain by  
intein mediated protein complementation  
\*2006\*

34/6/189 (Item 189 from file: 55)  
0020231831 BIOSIS NO.: 200800278770  
Redvine (BRoundupnnichia ovata) and tRoundupmpetcreeper (Campsis radicans)  
controlled  
under field conditions by a synergistic interaction of the bioherbicide,  
Myrothecium verRoundupcaria, with \*glyphosate\*  
\*2008\*

34/6/190 (Item 190 from file: 55)  
0020042689 BIOSIS NO.: 200800089628  
Relation between \*mortality\* of prickly sculpin and diurnal extremes in  
water quality at \*Rodeo\* Lagoon, Marin County, California  
\*2007\*

34/6/191 (Item 191 from file: 55)  
19397633 BIOSIS NO.: 200700057374  
\*Roundup\* biactive modifies cadmium \*toxicity\* to Daphnia carinata  
\*2006\*

34/6/192 (Item 192 from file: 55)  
15987937 BIOSIS NO.: 200100159776  
\*Roundup\* inhibits steroidogenesis by disRounduppting steroidogenic \*acute\*  
regulatory (StAR) protein expression

\*2000\*

34/6/193 (Item 193 from file: 55)  
0019805173 BIOSIS NO.: 200700464914  
Review of \*glyphosate\* and ALS-inhibiting herbicide crop resistance and  
resistant weed management

\*2007\*

34/6/194 (Item 194 from file: 55)  
18072453 BIOSIS NO.: 200400440372  
Results of a 13 week safety assurance study with rats fed grain from  
\*glyphosate\*-tolerant corn

\*2004\*

34/6/195 (Item 195 from file: 50)  
0008704096 CAB Accession Number: 20043187113  
Responses of farmland \*wildlife\* to genetically modified  
herbicide-tolerant crops.  
Publication Year: 2004

34/6/196 (Item 196 from file: 55)  
18615702 BIOSIS NO.: 200510310202  
Response of gill atpase and liver esterase of *Pseudorasbora parva* to a two  
month \*exposure\* to \*glyphosate\* and metsulfuron methyl

\*2004\*

34/6/197 (Item 197 from file: 71)  
03298590 2005038842  
Response of gill ATPase and liver esterase of *Pseudorasbora parva* to a two  
month \*exposure\* to \*glyphosate\* and metsulfuron methyl

34/6/198 (Item 198 from file: 50)  
0008392481 CAB Accession Number: 20033050366  
Response of *Typha latifolia* L. to cutting, competition, water level and  
\*glyphosate\* under field conditions.  
Publication Year: 2002

34/6/199 (Item 199 from file: 55)  
18716267 BIOSIS NO.: 200600061662  
Roundupst control in \*glyphosate\*-tolerant wheat following application of the  
herbicide \*glyphosate\*

\*2005\*

34/6/200 (Item 200 from file: 55)  
0019821153 BIOSIS NO.: 200700480894  
Resistance to \*glyphosate\* in the cyanobacterium *Microcystis aeruginosa*  
as  
result of pre-selective \*mutations\*

\*2007\*

34/6/201 (Item 201 from file: 10)  
4439392 43795987 Holding Library: AGL  
Sublethal effects of the herbicide \*glyphosate\* on \*amphibian\*  
metamorphosis and development

\*2005\*

34/6/202 (Item 202 from file: 55)  
18902939 BIOSIS NO.: 200600248334  
Substitution of Ala-183 to Thr in 5-enolpyRoundupvylshikimste 3-phosphate  
synthase of E-coli (k12) and transformation of this constRoundupct to  
rapeseed  
(Brassica napus) for reducing of \*glyphosate\* affinity  
\*2005\*

34/6/203 (Item 203 from file: 55)  
18690500 BIOSIS NO.: 200600035895  
Safety assessment and feeding value for pigs, poultry and Roundupminant  
animals of pest protected (Bt) plants and herbicide-tolerant (\*glyphosate\*,  
glufosinate) plants: interpretation of experimental results observed  
worldwide on GM plants  
\*2004\*

34/6/204 (Item 204 from file: 55)  
17434643 BIOSIS NO.: 200300393073  
\*Soil\* biological processes are influenced by \*Roundup\* Ready soybean  
production.  
\*2003\*

34/6/205 (Item 205 from file: 55)  
15649416 BIOSIS NO.: 200000367729  
\*Soil\* fungi and herbicidal activity of \*glyphosate\* on seedlings of  
selected conifer and broadleaf species  
\*2000\*

34/6/206 (Item 206 from file: 10)  
4687654 43837865 Holding Library: AGL  
\*Soil\* Microbial Activity Is Affected by \*Roundup\* WeatherMax and  
Pesticides Applied to Cotton (Gossypium hirsutum)  
\*2006\*  
URL: <http://hdl.handle.net/10113/666>

34/6/207 (Item 207 from file: 10)  
4345921 43735813 Holding Library: AGL  
\*Soil\* microbial and nematode communities as affected by \*glyphosate\* and  
tillage practices in a \*glyphosate\*-resistant cropping system  
\*2005\*

34/6/208 (Item 208 from file: 10)  
4070843 23329624 Holding Library: AGL  
\*Soil\* carbon and nitrogen mineralization as affected by atrazine and  
\*glyphosate\*  
\*2002\*

34/6/209 (Item 209 from file: 10)  
4543722 43852442 Holding Library: AGL  
Spatial variability of \*glyphosate\* mineralization and \*soil\* microbial  
characteristics in two Norwegian sandy loam \*soils\* as affected by surface  
topographical features  
\*2006\*  
URL: <http://dx.doi.org/10.1016/j.soilbio.2005.08.014>

34/6/210 (Item 210 from file: 55)

17124601 BIOSIS NO.: 200300083320  
Suitability of transgenic \*glyphosate\*-resistant soybeans to green  
cloverworm (Lepidoptera: Noctuidae).  
\*2002\*

34/6/211 (Item 211 from file: 55)  
17658152 BIOSIS NO.: 200400028909  
Synthesis, characterization, and in vitro antitumor activity of osteotropic  
diam(m)ineplatinum(II) complexes bearing a  
N,N-bis(phosphonomethyl)glycine ligand.  
\*2003\*

34/6/212 (Item 212 from file: 50)  
0008616052 CAB Accession Number: 20043055447  
Symposium on 'A tiered assessment of Vision(R) (\*glyphosate\*) effects on  
\*amphibians\*', Annual Meeting of the Society of Environmental \*Toxicology\*  
and Chemistry (SETAC), 2001.  
Publication Year: 2004

34/6/213 (Item 213 from file: 55)  
18383270 BIOSIS NO.: 200510077770  
\*Tolerance\* of Bradyrhizobium strains to \*glyphosate\* formulations  
\*2005\*

34/6/214 (Item 214 from file: 55)  
17241794 BIOSIS NO.: 200300200513  
\*Tolerance\* to Hoplolaimus columbus in \*glyphosate\*-resistant, transgenic  
soybean cultivars.  
\*2002\*

34/6/215 (Item 215 from file: 55)  
16631351 BIOSIS NO.: 200200224862  
Use of transgenic \*glyphosate\*-\*tolerance\* in sugar beet to control aphids  
and potato cyst nematodes  
BOOK TITLE: Conference Proceedings BCPC Conference Pests Diseases  
\*2000\*

34/6/217 (Item 217 from file: 154)  
26328898 PMID: 17933590  
\*Toxicity\* and effects of a \*glyphosate\* -based herbicide on the  
Neotropical \*fish\* Prochilodus lineatus.  
Mar \*2008\*

34/6/218 (Item 218 from file: 55)  
0020041052 BIOSIS NO.: 200800087991  
The \*toxic\* effects of sub-\*chronic\* \*exposure\* of \*glyphosate\*-based  
herbicide \*Roundup\* on the rats  
\*2007\*

34/6/219 (Item 219 from file: 154)  
15950438 PMID: 15352482  
\*Toxicity\* of \*glyphosate\*-based pesticides to four North American \*frog\*  
species.  
Aug \*2004\*

34/6/220 (Item 220 from file: 40)  
00708711 ENVIROLINE NUMBER: 07-01067  
\*Toxicity\* of \*Glyphosate\* as Glypro and LI700 to Red-Eared Slider  
(Trachemys scripta elegans) Embryos and Early Hatchlings  
Oct 06

34/6/221 (Item 221 from file: 10)  
3885075 22090983 Holding Library: AGL  
\*Toxicity\* of \*glyphosate\* and triclopyr using the \*frog\* embryo  
\*teratogenesis\* assay--Xenopus  
\*2000\*

34/6/222 (Item 222 from file: 55)  
17558692 BIOSIS NO.: 200300514055  
\*Toxicity\* test of \*roundup\* on the fiddler crab Uca pugnax (Smith) and the  
ribbed mussel Geukensia demissa (Dillwyn).  
\*2003\*

34/6/223 (Item 223 from file: 55)  
17526654 BIOSIS NO.: 200300480609  
A T42M substitution in bacterial 5-enolpyRoundupvylshikimate-3-phosphate  
synthase (EPSPS) generates enzymes with increased resistance to  
\*glyphosate\*.  
\*2003\*

34/6/224 (Item 224 from file: 144)  
17115056 PASCAL No.: 05-0182167  
Vadose zone processes and chemical transport : \*Leaching\* of \*glyphosate\*  
and amino-methylphosphonic acid from danish agricultural field sites  
\*2005\*

34/6/225 (Item 225 from file: 55)  
17407681 BIOSIS NO.: 200300366400  
Vegetation management and \*ecosystem\* disturbance: Impact of \*glyphosate\*  
herbicide on plant and animal diversity in terrestrial systems.  
\*2003\*

34/6/226 (Item 226 from file: 55)  
17816952 BIOSIS NO.: 200400184638  
As the worm turns: Eisenia fetida avoids \*soil\* contaminated by a  
\*glyphosate\*-based herbicide.  
\*2004\*

34/6/227 (Item 227 from file: 55)  
17252827 BIOSIS NO.: 200300211546  
The 5-enolpyRoundupvylshikimate-3-phosphate synthase of \*glyphosate\*-tolerant  
soybean expressed in Escherichia coli shows no severe allergenicity.  
\*2003\*

34/6/228 (Item 228 from file: 55)  
18351483 BIOSIS NO.: 200510045983  
5-EnolpyRoundupvylshikimate-3-phosphate synthase from Staphylococcus aureus  
is  
insensitive to \*glyphosate\*  
\*2005\*

S35        697    S31 NOT S33  
 S36        219    S35/2006:2008 (most recent 3 yrs of general hits)

37/6/1        (Item 1 from file: 50)  
 0009366526    CAB Accession Number: 20073246328  
     The absence of \*glyphosate\* \*residues\* in wet \*soil\* and the adjacent  
     watercourse after a forestry application in new bRoundupswick.  
     Publication Year: 2007

37/6/2        (Item 2 from file: 10)  
 4808334 43991334 Holding Library: AGL  
     \*Acute\* and \*chronic\* \*toxicity\* of \*glyphosate\* compounds to glochidia  
     and juveniles of Lampsilis siliquoidea (Unionidae)  
     \*2007\*

37/6/3        (Item 3 from file: 40)  
 00722421    ENVIROLINE NUMBER: 07-19308  
     \*Acute\* and \*Chronic\* \*Toxicity\* of Pesticide Formulations (Atrazine,  
     Chlorpyrifos, and Permethrin) to Glochidia and Juveniles of Lampsilis  
     siliquoidea  
     Oct 07

37/6/4        (Item 4 from file: 154)  
 25219146    PMID: 17716950  
     \*Acute\* effects of \*glyphosate\* herbicide on \*metabolic\* and enzymatic  
     parameters of silver catfish (Rhamdia quelen).  
     Nov \*2007\*

37/6/5        (Item 5 from file: 50)  
 0009432127    CAB Accession Number: 20073281121  
     Adsorption of \*glyphosate\* on clays and \*soils\* from Parana State:  
     effect of pH and competitive adsorption of phosphate.  
     Publication Year: 2007

37/6/6        (Item 6 from file: 154)  
 17094058    PMID: 16785173  
     Agricultural pesticide \*residues\* in farm ditches of the Lower Fraser  
     Valley, British Columbia, Canada.  
     \*2006\*

37/6/7        (Item 7 from file: 10)  
 4628128 43913924 Holding Library: AGL  
     Amphipod Performance Responses to Decaying Leaf Litter of Phragmites  
     Australis and Typha Angustifolia from a Lake Erie Coastal Marsh  
     \*2006\*  
     URL: [http://dx.doi.org/10.1672/0277-5212\(2006\)26\[1079:APRTDL\]2.0.CO;2](http://dx.doi.org/10.1672/0277-5212(2006)26[1079:APRTDL]2.0.CO;2)

37/6/8        (Item 8 from file: 55)  
 0019757573    BIOSIS NO.: 200700417314  
     Applicable control measure against Orobanche ramosa in tomato plants  
     \*2007\*

37/6/9        (Item 9 from file: 50)  
 0009227830    CAB Accession Number: 20073070587

Application of a GIS-AF/RF model to assess the risk of herbicide  
\*leaching\* in a citrus-growing area of the Valencia Community, Spain.  
Publication Year: 2006

37/6/11 (Item 11 from file: 154)

17546264 PMID: 17295264

Assessment of the potential \*toxicity\* of herbicides and their  
\*degradation\* products to nontarget cells using two \*microorganisms\*, the  
bacteria *Vibrio fischeri* and the ciliate *Tetrahymena pyriformis*.

Feb \*2007\*

37/6/12 (Item 12 from file: 154)

25582581 PMID: 17978956

Biodegradation of the herbicide \*glyphosate\* by filamentous fungi in  
platform shaker and batch bioreactor.

Nov \*2007\*

37/6/13 (Item 13 from file: 55)

0019837557 BIOSIS NO.: 200700497298

A bioluminescent signal system: detection of chemical \*toxics\* in water  
\*2007\*

37/6/14 (Item 14 from file: 50)

0009069087 CAB Accession Number: 20063141701

Chlorination kinetics of \*glyphosate\* and its by-products: modeling  
approach.

Publication Year: 2006

37/6/15 (Item 15 from file: 50)

0009091903 CAB Accession Number: 20063171894

The chemical control of the environmental weed basket asparagus (*Asparagus aethiopicus* L. cv. *Sprengeri*) in Queensland.

Publication Year: 2006

37/6/16 (Item 16 from file: 55)

0019554615 BIOSIS NO.: 200700214356

Chemical control of *Prosopis farcta* (Banks and Sol.) M acbride in the Jordan  
Valley

\*2007\*

37/6/17 (Item 17 from file: 55)

0019661984 BIOSIS NO.: 200700321725

Chemical cotton stalk destruction for maintenance of host-free periods  
for

the control of overwintering boll weevil in tropical and subtropical  
climates

\*2007\*

37/6/18 (Item 18 from file: 50)

0009188168 CAB Accession Number: 20073016559

Are chemical or mechanical treatments more sustainable for forest  
vegetation management in the context of the TRIAD?

Publication Year: 2006

37/6/19 (Item 19 from file: 154)

17282654 PMID: 17022425

Changes in juvenile coho \*salmon\* electro-olfactogram during and after

short-term \*exposure\* to current-use pesticides.  
Oct \*2006\*

37/6/20 (Item 20 from file: 55)  
19137488 BIOSIS NO.: 200600482883  
Characterization of 5-enolpyRoundupvylshikimate 3-phosphate synthase gene  
from *Campptotheca acuminata*  
\*2006\*

37/6/21 (Item 21 from file: 55)  
19104254 BIOSIS NO.: 200600449649  
Characterization of 5-enolpyRoundupvylshikimate-3-phosphate synthase from  
*Sclerotinia sclerotioRoundupm*  
\*2006\*

37/6/22 (Item 22 from file: 50)  
0009411658 CAB Accession Number: 20073286762  
Cold weather application of \*glyphosate\* for garlic mustard ( *Alliaria*  
*petiolata* ) control.  
Publication Year: 2007

37/6/23 (Item 23 from file: 55)  
0019711535 BIOSIS NO.: 200700371276  
Cloning, expression, and functional characterization of the *Dunaliella salina*  
5-enolpyRoundupvylshikimate-3-phosphate synthase gene in *Escherichia coli*  
\*2007\*

37/6/24 (Item 24 from file: 55)  
18952798 BIOSIS NO.: 200600298193  
Cultivation of black tRoundupffle to promote reforestation and land-use  
stability  
\*2006\*

37/6/25 (Item 25 from file: 55)  
0019582681 BIOSIS NO.: 200700242422  
Combination effects of herbicides on plants and algae: do species and test  
systems matter?  
\*2007\*

37/6/26 (Item 26 from file: 50)  
0009077304 CAB Accession Number: 20063150473  
Comparison of the behaviour of three herbicides in a field experiment  
under bare \*soil\* conditions.  
Publication Year: 2006

37/6/27 (Item 27 from file: 10)  
4763430 43942844 Holding Library: AGL  
Comparison of Broiler Performance and Carcass Parameters When Fed Diets  
Containing Combined Trait Insect-Protected and \*Glyphosate\*-Tolerant Corn  
(MON 89034 x NK603), Control, or Conventional Reference Corn  
\*2007\*

37/6/28 (Item 28 from file: 10)  
4854853 43982937 Holding Library: AGL



Comparison of Broiler Performance and Carcass Parameters When Fed Diets Containing Soybean Meal Produced from \*Glyphosate\*-Tolerant (MON 89788), Control, or Conventional Reference Soybeans  
\*2007\*

37/6/29 (Item 29 from file: 10)  
4763428 43942842 Holding Library: AGL  
Comparison of Broiler Performance When Fed Diets Containing Grain from Second-Generation Insect-Protected and \*Glyphosate\*-Tolerant, Conventional Control or Commercial Reference Corn  
\*2007\*

37/6/30 (Item 30 from file: 50)  
0009451813 CAB Accession Number: 20083034146  
Comparison of broiler performance when fed diets containing event DP-356<O>43-5 (Optimum GAT), nontransgenic near-isoline control, or commercial reference soybean meal, hulls, and oil.  
Publication Year: 2007

37/6/31 (Item 31 from file: 55)  
0020020662 BIOSIS NO.: 200800067601  
Comparison of broiler performance when fed diets containing event DP-356O43-5 (Optimum GAT), nontransgenic near-isoline control, or commercial reference soybean meal, hulls, and oil  
\*2007\*

37/6/32 (Item 32 from file: 55)  
0019880625 BIOSIS NO.: 200700540366  
Compatibility of selected pesticides with three entomopathogenic fungi of sugarcane pests  
\*2007\*

37/6/33 (Item 33 from file: 50)  
0009420684 CAB Accession Number: 20083003561  
Concentrations and specific loads of \*glyphosate\*, diuron, atrazine, nonylphenol and \*metabolites\* thereof in French urban sewage sludge.  
Publication Year: 2007

37/6/34 (Item 34 from file: 50)  
0009070747 CAB Accession Number: 20063123503  
Controlling speckled alder ( *Alnus incana* ssp. *Roundupgosa* ) invasion in a wetland reserve of Southern Quebec.  
Publication Year: 2006

37/6/35 (Item 35 from file: 55)  
0019796531 BIOSIS NO.: 200700456272  
Cardiovascular effects of herbicides and formulated adjuvants on isolated rat aorta and heart  
\*2007\*

37/6/37 (Item 37 from file: 55)  
0019591867 BIOSIS NO.: 200700251608  
A critical review of the influence of effluent irrigation on the fate of pesticides in \*soil\*  
\*2007\*

37/6/38 (Item 38 from file: 50)  
0009258966 CAB Accession Number: 20073081914  
Cosorption of zinc and \*glyphosate\* on two \*soils\* with different characteristics.  
Publication Year: 2006

37/6/39 (Item 39 from file: 50)  
0009062129 CAB Accession Number: 20063119114  
Defoliation and the war on dRoundupgs in Putumayo, Colombia.  
Publication Year: 2006

37/6/40 (Item 40 from file: 154)  
25560221 PMID: 17958399  
Differential \*inhibition\* of class I and class II 5-enolpyRoundupvylshikimate-3-phosphate synthases by tetrahedral reaction intermediate analogues.  
Nov 20 \*2007\*

37/6/41 (Item 41 from file: 50)  
0009375657 CAB Accession Number: 20073248726  
Direct determination of \*glyphosate\* using hydrophilic interaction chromatography with coulometric detection at copper microelectrode.  
Publication Year: 2007

37/6/42 (Item 42 from file: 40)  
00695291 ENVIROLINE NUMBER: 06-05814  
Dormant Season Vegetation Management in Broadleaved Transplants and Direct Sown Ash (*Fraxinus excelsior* L.) Seedlings  
Feb 06

37/6/44 (Item 44 from file: 154)  
17753834 PMID: 17426049  
Detection of cytogenetic and DNA damage in peripheral erythrocytes of goldfish (*Carassius auratus*) \*exposed\* to a \*glyphosate\* formulation using the micronucleus test and the comet assay.  
Jul \*2007\*

37/6/45 (Item 45 from file: 50)  
0009226662 CAB Accession Number: 20073079461  
Determination of \*glyphosate\* using off-line ion exchange preconcentration and capillary electrophoresis-laser induced fluorescence detection.  
Publication Year: 2007

37/6/47 (Item 47 from file: 50)  
0009200845 CAB Accession Number: 20073055683  
Desorption and time-dependent sorption of herbicides in \*soils\*.  
Publication Year: 2007

37/6/48 (Item 48 from file: 71)  
03678989 2007099358  
Ecological fitness of a \*glyphosate\*-resistant *Lolium rigidum* population:  
Growth and seed production along a competition gradient

PUBLICATION DATE: May 7, 2007

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0009448557 CAB Accession Number: 20083024709  
Influence of complexation phenomena with multivalent cations on the analysis of \*glyphosate\* and aminomethyl phosphonic acid in water.  
Publication Year: 2007

37/6/50 (Item 50 from file: 50)  
0009193203 CAB Accession Number: 20073025506  
The effect of conservation farming on the abundance of earthworms on eroded \*soils\*.  
Publication Year: 2006

37/6/51 (Item 51 from file: 50)  
0009411650 CAB Accession Number: 20073286772  
Influence of cotton height on injury from flumioxazin and \*glyphosate\* applied POST-directed.  
Publication Year: 2007

37/6/52 (Item 52 from file: 55)  
0019804397 BIOSIS NO.: 200700464138  
Effects of cover crop \*residue\* and preplant herbicide on early leaf spot of peanut  
\*2007\*

37/6/53 (Item 53 from file: 50)  
0009358965 CAB Accession Number: 20073196287  
Effects of dredging an agricultural drainage ditch on water column herbicide concentration, as predicted by fluvarium techniques.  
Publication Year: 2007

37/6/54 (Item 54 from file: 55)  
0020085613 BIOSIS NO.: 200800132552  
Effects of Fakel herbicide on vital activity of Ceriodaphnia affinis in \*acute\* and \*chronic\* experiments  
\*2007\*

37/6/55 (Item 55 from file: 10)  
4740621 43981564 Holding Library: AGL  
Effects of the \*Glyphosate\* Active Ingredient and a Formulation on Lemna gibba L. at Different \*Exposure\* Levels and Assessment End-Points  
\*2007\*  
URL: <http://dx.doi.org/10.1007/s00128-007-9277-5>

37/6/56 (Item 56 from file: 55)  
0020061006 BIOSIS NO.: 200800107945  
The effects of \*glyphosate\* isopropylamine and trifluralin on the carbon mineralization of olive tree \*soils\*  
ORIGINAL LANGUAGE TITLE: Zeytin Topraklarinin Karbon Mineralizasyonuna \*Glyphosate\* Isopropylamine ve Trifluralin'in Etkileri  
\*2007\*

37/6/57 (Item 57 from file: 50)  
0009274575 CAB Accession Number: 20073141131

The effect of the \*glyphosate\* , 2,4-D, atrazine and nicosulfuron herbicides upon the edaphic Collembola (Arthropoda: Ellipura) in a no tillage system.

Publication Year: 2007

37/6/58 (Item 58 from file: 50)  
0009414963 CAB Accession Number: 20073295839

Influence of herbicides as growth regulators on growth and yield of baby corn ( Zea mays L.).

Publication Year: 2007

37/6/59 (Item 59 from file: 50)  
0009347419 CAB Accession Number: 20073194262

Effect of some herbicides on the biomass production of Trichoderma and Gliocladium spp.

Publication Year: 2007

37/6/60 (Item 60 from file: 50)  
0009473808 CAB Accession Number: 20083035326

Effect of herbicides on Fusarium pallidoroseum - a potential biocontrol agent of water hyacinth [ Eichhornia crassipes (Mart.) Solms].

Publication Year: 2007

37/6/61 (Item 61 from file: 50)  
0009263810 CAB Accession Number: 20073095256

Effect of some herbicides on the growth and spoRounduplation of two fungal biocontrol agents.

Publication Year: 2006

37/6/62 (Item 62 from file: 50)  
0009467268 CAB Accession Number: 20083047339

Effect of herbicides on mitosis of Hibiscus cannabinus Linn.

Publication Year: 2007

37/6/63 (Item 63 from file: 50)  
0009467266 CAB Accession Number: 20083047344

Effect of herbicides on meiosis of Hibiscus cannabinus Linn.

Publication Year: 2007

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4809719 44007223 Holding Library: AGL

Effects of the herbicide \*roundup\* on freshwater microbial communities: a mesocosm study

\*2007\*

37/6/65 (Item 65 from file: 154)  
16848770 PMID: 16317487

Effects of the herbicides \*Roundup\* and Avans on Euglena gracilis.  
Feb \*2006\*

37/6/66 (Item 66 from file: 76)  
0001962733 IP ACCESSION NO: 7258204  
Effect of the herbicide Avans 330 SL on the liver pathomorphology of clinically healthy carp (Cyprinus carpio L.) and carp infected by

Ichthyophthirius multifiliis  
PUBLICATION DATE: \*2006\*

37/6/67 (Item 67 from file: 55)  
0019516345 BIOSIS NO.: 200700176086  
Effect of the herbicide Avans 330 SL and Azoprim 50 WP on \*skin\*  
pathomorphology of healthy and patient carp with ichthyophthiriasis  
\*2006\*

37/6/68 (Item 68 from file: 50)  
0009078955 CAB Accession Number: 20063129307  
Effect of heavy metals and herbicides on immune capacities in Pacific  
oyster, Crassostrea gigas .  
Publication Year: 2006

37/6/69 (Item 69 from file: 50)  
0009107194 CAB Accession Number: 20063163304  
Effects of husbandry factors and harvest method and timing on oil  
content and chlorophyll retention in rapeseed.  
Publication Year: 2006

37/6/70 (Item 70 from file: 50)  
0009303591 CAB Accession Number: 20073168722  
Effect of lactofen application timing on yield and isoflavone  
concentration in soybean seed.  
Publication Year: 2007

37/6/71 (Item 71 from file: 55)  
19139579 BIOSIS NO.: 200600484974  
Effects of alternative management systems on weed populations in hazelnut  
(Corylus avellana L.)  
\*2006\*

37/6/72 (Item 72 from file: 154)  
24880041 PMID: 16456628  
Effectiveness of management interventions to control invasion by  
Rhododendron ponticum.  
Apr \*2006\*

37/6/73 (Item 73 from file: 50)  
0009502544 CAB Accession Number: 20083070258  
The influence of meteorological conditions on the growth and yielding of  
leek cultivated in living mulches.  
Publication Year: 2007

37/6/74 (Item 74 from file: 154)  
17246585 PMID: 16977524  
Effect of mixtures of pesticides used in the direct seeding technique on  
nontarget plant seeds.  
Aug \*2006\*

37/6/75 (Item 75 from file: 55)  
0019973597 BIOSIS NO.: 200800020536  
Effects induced by agrochemical on epithelial morphology on gills of guppy  
(Poecilia vivipara)  
\*2007\*

37/6/76 (Item 76 from file: 50)  
0009128644 CAB Accession Number: 20063198239  
Effect of integrated weed-management practices on growth and yield of wet-seeded rice ( *Oryza sativa* ) and their residual effect on succeeding pulse crop.  
Publication Year: 2006

37/6/77 (Item 77 from file: 55)  
19294012 BIOSIS NO.: 200600639407  
Effect of in vivo pollutant \*exposure\* and pathogen injection on phagocytosis gene expression in the pacific oyster, *Crassostrea gigas*  
\*2006\*

37/6/78 (Item 78 from file: 154)  
26563824 PMID: 17822816  
Effects of pesticides on community composition and activity of sediment microbes--responses at various levels of microbial community organization.  
Apr \*2008\*

37/6/79 (Item 79 from file: 154)  
17148090 PMID: 16862293  
Effect of pesticides on nitrification in \*aquatic\* sediment.  
May \*2006\*

37/6/80 (Item 80 from file: 10)  
4740619 43981562 Holding Library: AGL  
Effect of Pesticides on the \*Reproductive\* Output of *Eisenia fetida*  
\*2007\*  
URL: <http://dx.doi.org/10.1007/s00128-007-9269-5>

37/6/81 (Item 81 from file: 55)  
0019912993 BIOSIS NO.: 200700572734  
Effects of post-emergent herbicides on *Trichoderma harzianum*, a potential biocontrol agent against *Sclerotinia sclerotiorum* in soybean cropping  
\*2007\*

37/6/82 (Item 82 from file: 50)  
0009451426 CAB Accession Number: 20083034573  
Effect of RRS on nitrogen transition and related bacteria in rhizosphere  
\*soil\*.  
Publication Year: 2007

37/6/83 (Item 83 from file: 50)  
0009200511 CAB Accession Number: 20073055992  
Effects of weed management practices on orchard \*soil\* biological and fertility properties in southeastern China.  
Publication Year: 2007

37/6/84 (Item 84 from file: 40)  
00708230 ENVIROLINE NUMBER: 07-00525  
Influence of Watershed System Management on Herbicide Concentrations in Mississippi Delta Oxbow Lakes  
Nov 1, 06

37/6/85 (Item 85 from file: 10)  
4710422 43939195 Holding Library: AGL  
Effect of external or internal fecal contamination on numbers of bacteria  
on prechilled broiler carcasses  
\*2007\*

37/6/86 (Item 86 from file: 50)  
0009185816 CAB Accession Number: 20073038175  
Effects of sublethal \*glyphosate\* rates on fresh market tomato.  
Publication Year: 2007

37/6/87 (Item 87 from file: 154)  
26524182 PMID: 18453404  
Effects of \*soil\* phosphoRoundups status on environmental risk assessment  
of  
\*glyphosate\* and glufosinate-ammonium.  
May-Jun \*2008\*

37/6/88 (Item 88 from file: 55)  
0019838201 BIOSIS NO.: 200700497942  
Effect of solarization and cowpea cover crop on plant-parasitic nematodes,  
pepper yields, and weeds  
\*2007\*

37/6/89 (Item 89 from file: 50)  
0009178118 CAB Accession Number: 20073006655  
Effects of surface sorption on microbial \*degradation\* of \*glyphosate\*.  
Publication Year: 2006

37/6/90 (Item 90 from file: 154)  
26530529 PMID: 18155747  
Environmental fate and non-target impact of \*glyphosate\*-based herbicide  
(\*Roundup\*) in a subtropical wetland.  
Mar \*2008\*

37/6/91 (Item 91 from file: 50)  
0009328247 CAB Accession Number: 20073199982  
Environmental impacts of transgenic herbicide-resistant crops.  
Publication Year: 2007

37/6/92 (Item 92 from file: 50)  
0009323215 CAB Accession Number: 20073158144  
Environmental risk from using \*glyphosate\* on hard surfaces.  
Publication Year: 2006

37/6/93 (Item 93 from file: 50)  
0009290078 CAB Accession Number: 20073132555  
Enzymatic activity of \*soil\* contaminated with triazine herbicides.  
Publication Year: 2007

37/6/94 (Item 94 from file: 50)  
0009303913 CAB Accession Number: 20073168412  
Evaluation of herbicides against dodder ( *Cuscuta reflexa* ) infesting  
the hedges of bougainvillea ( *Bougainvillea purpurea* ) and cleridendron ( *Cleridendron splendena* ).  
Publication Year: 2007

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0001883962 IP ACCESSION NO: 6889975  
Evaluation of Herbicide Impact on Periphyton Community Structure Using  
the  
Matlock Periphytometer  
PUBLICATION DATE: \*2006\*

37/6/96 (Item 96 from file: 41)  
0000302321 IP ACCESSION NO: 7439497  
Evaluation of Animal Poisoning \*Exposure\* Inquiries to the New Zealand  
National Poisons Centre During 2005  
PUBLICATION DATE: \*2007\*

37/6/97 (Item 97 from file: 50)  
0009181163 CAB Accession Number: 20073033229  
Evaluation of the in vitro effect of glyphosate-based herbicide on  
bovine lymphocytes using chromosome painting.  
Publication Year: 2006

37/6/98 (Item 98 from file: 55)  
0019498205 BIOSIS NO.: 200700157946  
Evaluation of soybean cultivars with the Rps1k gene for partial resistance  
or field \*tolerance\* to Phytophthora sojae  
\*2006\*

37/6/99 (Item 99 from file: 50)  
0009192152 CAB Accession Number: 20073044758  
Exploring improved pesticide management in sub-tropical environments  
with GIS-supported fate modeling.  
Publication Year: 2006

37/6/100 (Item 100 from file: 50)  
0009087350 CAB Accession Number: 20063166465  
Expression of CP4 EPSPS in microspores and tapetum cells of cotton (*Gossypium hirsutum*) is critical for male \*reproductive\* development in  
response to late-stage \*glyphosate\* applications.  
Publication Year: 2006

37/6/101 (Item 101 from file: 154)  
26308616 PMID: 17971090  
Do escaped transgenes persist in nature? The case of an herbicide  
resistance transgene in a weedy Brassica rapa population.  
Mar \*2008\*

37/6/102 (Item 102 from file: 76)  
0001969157 IP ACCESSION NO: 7168505  
Establishment of transgenic herbicide-resistant creeping bentgrass  
(*Agrostis stolonifera* L.) in nonagronomic habitats  
PUBLICATION DATE: \*2006\*

37/6/103 (Item 103 from file: 40)  
00699916 ENVIROLINE NUMBER: 06-13112  
Faba Bean Nitrogen Fixation in a Wheat-Based Rotation Under Rainfed  
Mediterranean Conditions: Effect of Tillage System  
Aug-Sep 06



37/6/104 (Item 104 from file: 50)  
0009447072 CAB Accession Number: 20083026456  
Facilitated transport of diuron and \*glyphosate\* in high copper vineyard  
\*soils\*.  
Publication Year: 2007

37/6/105 (Item 105 from file: 55)  
0019484236 BIOSIS NO.: 200700143977  
Field study on the occurrence of ground beetles and spiders in genetically  
modified, herbicide-tolerant corn in conventional and conservation tillage  
systems  
\*2006\*

37/6/107 (Item 107 from file: 50)  
0009407131 CAB Accession Number: 20073209521  
Forest floor plant community response to experimental control of the  
invasive biennial, *Alliaria petiolata* (garlic mustard).  
Publication Year: 2007

37/6/108 (Item 108 from file: 50)  
0009509909 CAB Accession Number: 20083103461  
Fate and behavior of chlorpyrifos and \*glyphosate\* at a field level in  
Apalta catchment I. Experimental phase.  
Book Title: Environmental fate and ecological effects of pesticides  
Publication Year: 2007

37/6/109 (Item 109 from file: 50)  
0009344344 CAB Accession Number: 20073225073  
Photodegradation of \*glyphosate\* in the ferrioxalate system.  
Publication Year: 2007

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4823620 44034748 Holding Library: AGL  
Fate of \*glyphosate\* in \*soil\* and the possibility of \*leaching\* to  
ground and surface waters: a review  
\*2008\*  
URL: <http://dx.doi.org/10.1002/ps.1512>

37/6/111 (Item 111 from file: 50)  
0009049521 CAB Accession Number: 20063122457  
Fate of the herbicides \*glyphosate\*, glufosinate-ammonium, phenmedipham,  
ethofumesate and metamitron in two Finnish arable \*soils\*.  
Publication Year: 2006

37/6/112 (Item 112 from file: 50)  
0009290542 CAB Accession Number: 20073131069  
Phosphate and \*glyphosate\* adsorption by hematite and ferrihydrite and  
comparison with other variable-charge minerals.  
Publication Year: 2007

37/6/113 (Item 113 from file: 50)  
0009205413 CAB Accession Number: 20073060244  
Phosphate and \*glyphosate\* mobility in \*soil\* columns amended with  
\*roundup\*.  
Publication Year: 2007

37/6/114 (Item 114 from file: 50)  
0009223173 CAB Accession Number: 20063082369  
\*Glyphosate\* in small private water supply systems.  
Third Danish Plant Production Congress, Denmark, 10-11 January, 2006  
Publication Year: 2006

37/6/115 (Item 115 from file: 50)  
0009466401 CAB Accession Number: 20083049170  
\*Glyphosate\*-resistant cotton response to \*glyphosate\* applied in  
irrigated and nonirrigated conditions.  
Publication Year: 2007

37/6/116 (Item 116 from file: 50)  
0009435833 CAB Accession Number: 20083016215  
\*Glyphosate\* translocation from plants to \*soil\* - does this constitute  
a significant proportion of \*residues\* in \*soil\*?  
Publication Year: 2007

37/6/117 (Item 117 from file: 55)  
0019655816 BIOSIS NO.: 200700315557  
GMOs: building the future on the basis of past experience  
\*2006\*

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0009124773 CAB Accession Number: 20063182803  
Genetic analysis of \*glyphosate\* \*tolerance\* in *Halomonas variabilis*  
strain HTG SUB 7 .  
Publication Year: 2006

37/6/119 (Item 119 from file: 50)  
0009138149 CAB Accession Number: 20063227287  
Genetic stRoundupcture and activity of the nitrate-reducers community in  
the  
rhizosphere of different cultivars of maize.  
Publication Year: 2006

37/6/120 (Item 120 from file: 55)  
18849289 BIOSIS NO.: 200600194684  
Growth performance and organ development in Atlantic \*salmon\*, *Salmo salar*  
L. parr fed genetically modified (GM) soybean and maize  
\*2006\*

37/6/121 (Item 121 from file: 50)  
0009205759 CAB Accession Number: 20073058961  
Herbicide effects on plant disease.  
Publication Year: 2007

37/6/122 (Item 122 from file: 55)  
18970895 BIOSIS NO.: 200600316290  
Herbicidal inhibitors of amino acid biosynthesis and herbicide-tolerant crops  
\*2006\*

37/6/123 (Item 123 from file: 76)  
0002044377 IP ACCESSION NO: 8013133  
Herbicide and Native Grass Seeding Effects on Sulfur Cinquefoil (*Potentilla*

Recta) - Infested Grasslands  
PUBLICATION DATE: \*2008\*

37/6/124 (Item 124 from file: 55)  
19265325 BIOSIS NO.: 200600610720  
Herbicidal \*tolerance\* of Trichoderma spp - a potential biocontrol agent of  
\*soil\* borne plant pathogens  
\*2006\*

37/6/125 (Item 125 from file: 50)  
0009323216 CAB Accession Number: 20073158143  
How pesticides used on hard surfaces end up in drinking water.  
Publication Year: 2006

37/6/126 (Item 126 from file: 10)  
4575453 43878403 Holding Library: AGL  
Histological, digestive, \*metabolic\* , hormonal and some immune factor  
responses in Atlantic \*salmon\*, Salmo salar L., fed genetically modified  
soybeans  
\*2007\*  
URL: <http://dx.doi.org/10.1111/j.1365-2761.2007.00782.x>

37/6/127 (Item 127 from file: 50)  
0009466387 CAB Accession Number: 20083049186  
Impact of fall and early spring herbicide applications on insect injury  
and \*soil\* conditions in no-till corn.  
Publication Year: 2007

37/6/128 (Item 128 from file: 71)  
04029149 2008079895  
Impact of \*glyphosate\*-tolerant soybean and glufosinate-tolerant corn  
production on herbicide losses in surface \*Roundupnoff\*

37/6/129 (Item 129 from file: 55)  
18804772 BIOSIS NO.: 200600150167  
Improved resistance management for durable disease control: A case study of  
phoma stem canker of oilseed rape (Brassica napus)  
\*2006\*

37/6/130 (Item 130 from file: 50)  
0009375561 CAB Accession Number: 20073248822  
In-capillary derivatization and laser-induced fluorescence detection for  
the analysis of organophosphoRoundups pesticides by micellar  
electrokinetic chromatography.  
Publication Year: 2007

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16856450 PMID: 16444581  
\*Inhibition\* of adenosine kinase by phosphonate and bisphosphonate  
derivatives.  
Feb \*2006\*

37/6/132 (Item 132 from file: 50)  
0009195750 CAB Accession Number: 20073051739  
An intercomparison study of the determination of \*glyphosate\* ,  
chlormequat and mepiquat \*residues\* in wheat.  
Publication Year: 2007

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19150209 BIOSIS NO.: 200600495604  
Interactions between chemical herbicides and the candidate bioherbicide  
*Microsphaeropsis amaranthi*  
\*2006\*

37/6/134 (Item 134 from file: 50)  
0009101395 CAB Accession Number: 20063159163  
The interaction between seven-year-old *Pinus patula* trees, competition  
from *Roundupbus cuneifolius* and herbicides in KwaZulu-Natal.  
Publication Year: 2006

37/6/135 (Item 135 from file: 55)  
0019457938 BIOSIS NO.: 200700117679  
Interactions of *Colletotrichum tRoundupncatum* with herbicides for control of  
scentless chamomile (*Matricaria perforata*)  
\*2006\*

37/6/136 (Item 136 from file: 55)  
0019659460 BIOSIS NO.: 200700319201  
Interactions of alternate hosts, postemergence grass control, and  
rootworm-resistant transgenic corn on western corn rootworm (Coleoptera :  
Chrysomelidae) damage and adult emergence  
\*2007\*

37/6/137 (Item 137 from file: 10)  
4687771 43839499 Holding Library: AGL  
Interference to hardwood regeneration in northeastern North America:  
assessing and countering ferns in northern hardwood forests  
\*2006\*

37/6/138 (Item 138 from file: 55)  
19364842 BIOSIS NO.: 200700024583  
In vivo P-31 and H-1 HR-MAS NMR spectroscopy analysis of the unstarved  
*Aporrectodea caliginosa* (Lumbricidae)  
\*2006\*

37/6/139 (Item 139 from file: 71)  
03559337 2006340751  
In vivo SUP31P and SUP1H HR-MAS NMR spectroscopy analysis of the unstarved  
*Aporrectodea caliginosa* (Lumbricidae)

37/6/140 (Item 140 from file: 154)  
17138082 PMID: 16845715  
Invasion and control of water hyacinth (*Eichhornia crassipes*) in China.  
Aug \*2006\*

37/6/141 (Item 141 from file: 55)  
0019693452 BIOSIS NO.: 200700353193  
Isolation and \*mutation\* of recombinant EPSP synthase from pathogenic  
bacteria *Pseudomonas aeRoundupginosa*  
\*2007\*

37/6/142 (Item 142 from file: 50)

0009451342 CAB Accession Number: 20083034649  
 Juneberry growth is affected by weed control methods.  
 Publication Year: 2008

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 0009299102 CAB Accession Number: 20073162616  
 Laboratory studies on \*glyphosate\* transport in \*soils\* of the Maresme  
 area near Barcelona, Spain: transport model parameter estimation.  
 Publication Year: 2007

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 0020184182 BIOSIS NO.: 200800231121  
 Long-term orchard groundcover management systems affect \*soil\* microbial  
 communities and apple replant disease severity  
 \*2008\*

37/6/146 (Item 146 from file: 71)  
 03994611 2008050490  
 Long-term orchard groundcover management systems affect \*soil\* microbial  
 communities and apple replant disease severity

37/6/147 (Item 147 from file: 50)  
 0009096488 CAB Accession Number: 20063157835  
 Late-season redroot pigweed control in sugarbeet with over-the-top  
 \*glyphosate\*.  
 Publication Year: 2006

37/6/148 (Item 148 from file: 55)  
 18920500 BIOSIS NO.: 200600265895  
 Live shearing free-ranging guanacos (Lama guanicoe) in Patagonia for  
 sustainable use  
 \*2006\*

37/6/149 (Item 149 from file: 50)  
 0009019986 CAB Accession Number: 20063070153  
 Microbiological parameters of \*soil\* set aside before and after  
 desiccation.  
 Publication Year: 2006

37/6/150 (Item 150 from file: 55)  
 19076346 BIOSIS NO.: 200600421741  
 MicroTom-a high-throughput model transformation system for functional  
 genomics  
 \*2006\*

37/6/151 (Item 151 from file: 154)  
 17075406 PMID: 16532367  
 Molecular identification and expression of differentially regulated genes  
 of the European flounder, *Platichthys flesus*, submitted to pesticide  
 \*exposure\*.  
 May-Jun \*2006\*

37/6/152 (Item 152 from file: 50)  
 0009404170 CAB Accession Number: 20073278737  
 Management of cotton grown under overhead sprinkle and sub-surface drip  
 irrigation.  
 Publication Year: 2006

37/6/153 (Item 153 from file: 154)  
16986026 PMID: 16586140  
Managing tree-of-heaven (*Ailanthus altissima*) in parks and protected areas: a case study of Rondeau Provincial Park (Ontario, Canada).  
Jun \*2006\*

37/6/154 (Item 154 from file: 55)  
18956108 BIOSIS NO.: 200600301503  
Metabonomic strategy for the investigation of the mode of action of the phytotoxin (5S,8R,13S,16R)-(-)-pyrenophorol using H-1 nuclear magnetic resonance fingerprinting  
\*2006\*

37/6/155 (Item 155 from file: 50)  
0009479900 CAB Accession Number: 20083063128  
Measurement and modelling of \*glyphosate\* fate compared with that of herbicides replaced as a result of the introduction of \*glyphosate\* - resistant oilseed rape.  
Publication Year: 2008

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0019544537 BIOSIS NO.: 200700204278  
Non-target impact of deltamethrin on \*soil\* arthropods of maize fields under conventional and no-tillage cultivation  
\*2007\*

37/6/157 (Item 157 from file: 154)  
26596976 PMID: 18320130  
Occurrence of \*glyphosate\* in surface waters of southern ontario.  
Apr \*2008\*

37/6/158 (Item 158 from file: 50)  
0009291033 CAB Accession Number: 20073125570  
Study on the photocatalytic \*degradation\* of \*glyphosate\* by TiO SUB 2 photocatalyst.  
Publication Year: 2007

37/6/159 (Item 159 from file: 10)  
4735910 43975889 Holding Library: AGL  
Oviposition site selection: pesticide avoidance by gray treefrogs  
\*2007\*

37/6/160 (Item 160 from file: 50)  
0009080493 CAB Accession Number: 20063139522  
Plant biotechnology: ecological case studies on herbicide resistance.  
Publication Year: 2006

37/6/161 (Item 161 from file: 55)  
0020121879 BIOSIS NO.: 200800168818  
Production of cloned blastocysts using epithelial cells cultured from bovine semen  
\*2008\*

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0009138214 CAB Accession Number: 20063227229  
Preferential flow estimates to an agricultural tile drain with  
implications for \*glyphosate\* transport.  
Publication Year: 2006

37/6/163 (Item 163 from file: 55)  
0020052413 BIOSIS NO.: 200800099352  
A preliminary investigation into the use of biosensors to screen stomach  
contents for selected poisons and dRoundupgs  
\*2007\*

37/6/164 (Item 164 from file: 55)  
18831171 BIOSIS NO.: 200600176566  
Prevalence and numbers of bacteria in broiler crop and gizzard contents  
\*2006\*

37/6/166 (Item 166 from file: 55)  
0019936303 BIOSIS NO.: 200700596044  
Potential for sediment-applied acetic acid for control of invasive *Spartina alterniflora*  
\*2007\*

37/6/167 (Item 167 from file: 50)  
0009358321 CAB Accession Number: 20073201139  
Putative porin of *Bradyrhizobium* sp. ( *Lupinus* ) bacteroids induced by  
\*glyphosate\*.  
Publication Year: 2007

37/6/168 (Item 168 from file: 55)  
0019839745 BIOSIS NO.: 200700499486  
Pesticides in the Rhone river delta (France): Basic data for a field-based  
\*exposure\* assessment  
\*2007\*

37/6/169 (Item 169 from file: 55)  
19229602 BIOSIS NO.: 200600574997  
Pesticides in Southwest Florida waterways - A report card  
\*2006\*

37/6/170 (Item 170 from file: 71)  
03696165 2007115901  
Pesticide usage on the Southern High Plains and \*acute\* \*toxicity\* of four  
chemicals to the fairy shrimp *Thamnocephalus platyurus*  
(CRoundupstacea: Anostraca)

37/6/171 (Item 171 from file: 50)  
0009171951 CAB Accession Number: 20073004840  
Quantifying the effect of \*soil\* moisture on the aerobic microbial  
mineralization of selected pesticides in different \*soils\*.  
Publication Year: 2006

37/6/172 (Item 172 from file: 55)  
19331949 BIOSIS NO.: 200600677344  
Quantifying potential \*tolerance\* of selected cotton cultivars to  
*Belonolaimus longicaudatus*  
\*2006\*

37/6/173 (Item 173 from file: 55)  
19420269 BIOSIS NO.: 200700080010  
Quantifying the relation between adhesion ligand-receptor bond formation and cell phenotype  
\*2006\*

37/6/174 (Item 174 from file: 50)  
0009196884 CAB Accession Number: 20073049315  
Recently patented and commercialized formulation and adjuvant technology.  
Publication Year: 2007

37/6/175 (Item 175 from file: 154)  
16878466 PMID: 16469313  
Reconstitution of the enzyme AroA and its \*glyphosate\* \*tolerance\* by fragment complementation.  
Feb 20 \*2006\*

37/6/176 (Item 176 from file: 50)  
0009466388 CAB Accession Number: 20083049185  
Reduced-input, postemergence weed control with \*glyphosate\* and residual herbicides in second-generation \*glyphosate\*-resistant cotton.  
Publication Year: 2007

37/6/177 (Item 177 from file: 50)  
0009416600 CAB Accession Number: 20073294186  
The role of disturbance in habitat restoration and management for the eastern regal fritillary ( *Speyeria idalia idalia* ) at a military installation in Pennsylvania.  
Publication Year: 2007

37/6/178 (Item 178 from file: 76)  
0001956338 IP ACCESSION NO: 7110327  
Relative fitness of transgenic vs. non-transgenic maize x teosinte hybrids: A field evaluation  
PUBLICATION DATE: \*2006\*

37/6/179 (Item 179 from file: 55)  
19413724 BIOSIS NO.: 200700073465  
The role of indole and other shikimic acid derived maize volatiles in the attraction of two parasitic wasps  
\*2006\*

37/6/180 (Item 180 from file: 50)  
0009485080 CAB Accession Number: 20083055355  
\*Roundup\* ready flex and the critical period for weed control.  
Publication Year: 2008

37/6/181 (Item 181 from file: 50)  
0009263268 CAB Accession Number: 20073098420  
Reproducibility of binary-mixture \*toxicity\* studies.  
Publication Year: 2007

37/6/182 (Item 182 from file: 71)



03806239            2007225264  
 Revegetating Roundupssian knapweed (*Acroptilon repens*) infestations using  
 morphologically diverse species and seedbed preparation

37/6/183            (Item 183 from file: 50)  
 0009509898        CAB Accession Number: 20083103471  
                   \*Residue\* determination of \*glyphosate\* and aminomethyl-phosphonic acid  
 in surface and groundwater by SPE-LC-MS/MS.  
                   Book Title: Environmental fate and ecological effects of pesticides  
                   Publication Year: 2007

37/6/184            (Item 184 from file: 76)  
 0002012155            IP ACCESSION NO: 7631195  
 Risk assessment of xenobiotics in stormwater discharged to HarrestRoundupp A,  
 Denmark  
 PUBLICATION DATE: \*2007\*

37/6/185            (Item 185 from file: 10)  
 4576700 43879853    Holding Library: AGL  
                   Response of Phragmites to environmental parameters associated with  
 treatments  
                   \*2007\*  
                   URL: <http://dx.doi.org/10.1007/s11273-006-9013-7>

37/6/186            (Item 186 from file: 55)  
 0020049725        BIOSIS NO.: 200800096664  
 Response of wheat root pathogens to crop management in eastern Saskatchewan  
 \*2007\*

37/6/187            (Item 187 from file: 10)  
 4693026 43932184    Holding Library: AGL  
                   Restoring forest in wetlands dominated by reed canarygrass: the effects  
 of pre-planting treatments on early \*survival\* of planted stock  
                   \*2007\*  
                   URL: [http://dx.doi.org/10.1672/0277-5212\(2007\)27\[24:RFIWDB\]2.0.CO;2](http://dx.doi.org/10.1672/0277-5212(2007)27[24:RFIWDB]2.0.CO;2)

37/6/188            (Item 188 from file: 76)  
 0002018343            IP ACCESSION NO: 7722758  
 Restoring Native Vegetation to an Urban Wet Meadow Dominated by Reed  
 Canarygrass (*Phalaris aRoundupndinacea* L.) in Wisconsin  
 PUBLICATION DATE: \*2007\*

37/6/190            (Item 190 from file: 154)  
 26381605        PMID: 18399488  
                   Sublethal effects of two \*neurotoxican\* insecticides on *Araneus pratensis*  
 (*Araneae: Araneidae*).  
 \*2007\*

37/6/191            (Item 191 from file: 50)  
 0009193052        CAB Accession Number: 20073042627  
                   Shikimate accumulation in sunflower, wheat, and proso millet after  
 \*glyphosate\* application.  
                   Publication Year: 2007

37/6/192            (Item 192 from file: 50)  
 0009421947        CAB Accession Number: 20083002023  
                   Selected stormwater priority pollutants - a European perspective.

Publication Year: 2007

37/6/193 (Item 193 from file: 10)  
4673743 43913184 Holding Library: AGL  
\*Soil\* microbial biomass, functional diversity and enzyme activity in  
\*glyphosate\* -resistant wheat-canola rotations under low-disturbance direct  
seeding and conventional tillage  
\*2007\*  
URL: <http://dx.doi.org/10.1016/j.soilbio.2006.12.038>

37/6/194 (Item 194 from file: 55)  
18832269 BIOSIS NO.: 200600177664  
\*Soil\* arthropod abundance under conventional and no tillage in a  
Mediterranean climate  
\*2006\*

37/6/195 (Item 195 from file: 10)  
4545431 43858077 Holding Library: AGL  
Simultaneous substitution of Gly96 to Ala and Ala183 to Thr in  
5-enolpyRoundupvylshikimate-3-phosphate synthase gene of E. coli (k12)  
and transformation of rapeseed (Brassica napus L.) in order to make  
\*tolerance\*  
to \*glyphosate\*  
\*2007\*  
URL: <http://dx.doi.org/10.1007/s00299-006-0208-4>

37/6/196 (Item 196 from file: 50)  
0009272808 CAB Accession Number: 20073109701  
A simplified approach to the determination of N -nitroso \*glyphosate\* in  
technical \*glyphosate\* using HPLC with post-derivatization and  
colorimetric detection.  
Publication Year: 2007

37/6/197 (Item 197 from file: 50)  
0009411670 CAB Accession Number: 20073286749  
Suppression of Caucasian old world bluestem with split application of  
herbicides.  
Publication Year: 2007

37/6/198 (Item 198 from file: 50)  
0009029890 CAB Accession Number: 20063100841  
Sorption, desorption and mineralisation of the herbicides \*glyphosate\*  
and MCPA in samples from two Danish \*soil\* and subsurface profiles.  
Publication Year: 2006

37/6/199 (Item 199 from file: 71)  
03631985 2007047393  
Sorption of \*glyphosate\* and phosphate by variable-charge tropical \*soils\*  
from Tanzania  
PUBLICATION DATE: FebRoundupary 15, 2007

37/6/203 (Item 203 from file: 55)  
19229546 BIOSIS NO.: 200600574941  
Statistical analysis of outcrossing between adjacent maize grain production  
fields

\*2006\*

37/6/204 (Item 204 from file: 55)  
0020047511 BIOSIS NO.: 200800094450  
Synthesis, cytotoxicity and clastogenicity of novel alpha-aminophosphonic acids  
\*2007\*

37/6/205 (Item 205 from file: 55)  
19092843 BIOSIS NO.: 200600438238  
Timing of cut-stump herbicide applications for killing hardwood trees on power line rights-of-way  
\*2006\*

37/6/206 (Item 206 from file: 50)  
0009186533 CAB Accession Number: 20073037476  
Trace element mobilization in \*soils\* by \*glyphosate\*.  
Publication Year: 2006

37/6/207 (Item 207 from file: 55)  
18951868 BIOSIS NO.: 200600297263  
Transformation of a muskmelon 'Galia' hybrid parental line (Cucumis melo L. var. reticulatus Ser.) with an antisense ACC oxidase gene  
\*2006\*

37/6/208 (Item 208 from file: 71)  
03453495 2006225717  
Transgenic plants expressing bacterial genes as a model system for plant functional genomics

37/6/211 (Item 211 from file: 55)  
0019668250 BIOSIS NO.: 200700327991  
\*Toxicity\* of pesticides used in peach production on the egg parasitoids Trichogramma atopovirilia Oatman & Platner, 1983 (Hymenoptera : Trichogrammatidae)  
\*2007\*

37/6/212 (Item 212 from file: 154)  
17635919 PMID: 17292447  
\*Toxicity\* evaluation with Vibrio fischeri test of organic chemicals used in aquaculture.  
Jun \*2007\*

37/6/213 (Item 213 from file: 10)  
4550140 43863107 Holding Library: AGL  
\*Toxicity\* of Three Polyethoxylated Tallowamine Surfactant Formulations to Laboratory and Field Collected Fairy Shrimp, Thamnocephalus platyurus Roundups  
\*2007\*  
URL: <http://dx.doi.org/10.1007/s00244-006-0151-y>

37/6/214 (Item 214 from file: 55)  
19299155 BIOSIS NO.: 200600644550  
Tissue culture studies for shoot multiplication and herbicide \*tolerance\* in certain grain legumes  
\*2006\*

37/6/215 (Item 215 from file: 50)

0009489666 CAB Accession Number: 20083062140

An updated liquid chromatographic assay for the determination of  
\*glyphosate\* in technical material and formulations.

Publication Year: 2008

37/6/216 (Item 216 from file: 50)

0009115988 CAB Accession Number: 20063166793

Urban contributions of \*glyphosate\* and its degradate AMPA to streams in  
the United States.

Publication Year: 2006

37/6/217 (Item 217 from file: 71)

03662167 2007081520

Variation in the initial success or seeded native bunchgrasses in the  
rangeland foothills of Yolo County, California

37/6/218 (Item 218 from file: 50)

0009049382 CAB Accession Number: 20063122575

Weed control and response to herbicides during Tifton 85 bermudagrass  
establishment from rhizomes.

Publication Year: 2006

37/6/219 (Item 219 from file: 50)

0009493407 CAB Accession Number: 20083080853

Zinc adsorption on goethite as affected by \*glyphosate\*.

Publication Year: 2008

## Appendix N-3. Terrestrial Residue Exposure Model Output Data

**Table N-51. Avian Estimated Food Consumption from TREX model**

| Avian Class | Body Weight (g) | Ingestion (F dry) (g bw/day) | Ingestion (F wet) (g/day) | % body wt consumed | FI (kg-diet/day) |
|-------------|-----------------|------------------------------|---------------------------|--------------------|------------------|
| Small       | 20              | 5                            | 23                        | 114                | 2.28E-02         |
| Mid         | 100             | 13                           | 65                        | 65                 | 6.49E-02         |
| Large       | 1000            | 58                           | 291                       | 29                 | 2.91E-01         |

**Table N-52. Avian Adjusted Acute Toxicity Dose from TREX model**

| Avian Body Weight (g) | Adjusted LD50 (mg/kg-bw) |
|-----------------------|--------------------------|
| 20                    | 1440.86                  |
| 100                   | 1834.29                  |
| 1000                  | 2591.00                  |

**Table N-53. Avian Dose-based Estimated Environmental Concentration (EEC) from TREX model**

| Dose-based EECs (mg/kg-bw)      | Avian Classes and Body Weights |        |        |
|---------------------------------|--------------------------------|--------|--------|
|                                 | small                          | mid    | large  |
|                                 | 20 g                           | 100 g  | 1000 g |
| Short Grass                     | 1102.93                        | 628.94 | 281.58 |
| Tall Grass                      | 505.51                         | 288.26 | 129.06 |
| Broadleaf plants/Small Insects  | 620.40                         | 353.78 | 158.39 |
| Fruits/pods/seeds/Large insects | 68.93                          | 39.31  | 17.60  |

**Table N-54. Mammalian Estimated Food Consumption from TREX model**

| Mammalian Class          | Body Weight | Ingestion (Fdry) (g bwt/day) | Ingestion (Fwet) (g/day) | % body wt consumed | FI (kg-diet/day) |
|--------------------------|-------------|------------------------------|--------------------------|--------------------|------------------|
| Herbivores/ insectivores | 15          | 3                            | 14                       | 95                 | 1.43E-02         |
|                          | 35          | 5                            | 23                       | 66                 | 2.31E-02         |
|                          | 1000        | 31                           | 153                      | 15                 | 1.53E-01         |
| Grainvores               | 15          | 3                            | 3                        | 21                 | 3.18E-03         |
|                          | 35          | 5                            | 5                        | 15                 | 5.13E-03         |
|                          | 1000        | 31                           | 34                       | 3                  | 3.40E-02         |

**Table N-55. Mammalian Adjusted Endpoints from TREX model**

| <b>Mammalian</b>                    | <b>Body</b>   | <b>Adjusted</b> | <b>Adjusted</b> |
|-------------------------------------|---------------|-----------------|-----------------|
| <b>Class</b>                        | <b>Weight</b> | <b>LD50</b>     | <b>NOAEL</b>    |
| <b>Herbivores/<br/>insectivores</b> | <b>15</b>     | 9494.63         | 384.62          |
|                                     | <b>35</b>     | 7682.17         | 311.20          |
|                                     | <b>1000</b>   | 3322.77         | 134.60          |
| <b>Grainvores</b>                   | <b>15</b>     | 9494.63         | 384.62          |
|                                     | <b>35</b>     | 7682.17         | 311.20          |
|                                     | <b>1000</b>   | 3322.77         | 134.60          |

**Table N-56. Mammalian Dose-Based Estimated Environmental Concentration (EEC) from TREX model**

| <b>Dose-Based EECs<br/>(mg/kg-bw)</b>  | <b>Mammalian Classes and Body weight</b> |             |               |                   |             |               |
|----------------------------------------|------------------------------------------|-------------|---------------|-------------------|-------------|---------------|
|                                        | <b>Herbivores / insectivores</b>         |             |               | <b>Granivores</b> |             |               |
|                                        | <b>15 g</b>                              | <b>35 g</b> | <b>1000 g</b> | <b>15 g</b>       | <b>35 g</b> | <b>1000 g</b> |
| <b>Short Grass</b>                     | 923.31                                   | 638.13      | 147.95        |                   |             |               |
| <b>Tall Grass</b>                      | 423.19                                   | 292.48      | 67.81         |                   |             |               |
| <b>Broadleafplants/Small Insects</b>   | 519.36                                   | 358.95      | 83.22         |                   |             |               |
| <b>Fruits/pods/seeds/Large insects</b> | 57.71                                    | 39.88       | 9.25          | 12.82             | 8.86        | 2.05          |

## Appendix N-4.      Glyphosate-Resistant Weeds and Effective Herbicides to Control These Weeds

**Table N-57. Glyphosate-Resistant Weeds and Effective Herbicides to Control These Weeds**

| Resistant Weed Species                                   | Herbicides Recommended for Use                                                                                                                                               | Citation/Reference                                                                                                                                                                                                                                                                                                                                                                                       |
|----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Weeds with Recently Acquired Glyphosate Tolerance</b> |                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b><i>Amaranthus palmeri</i></b><br>Palmer Amaranth      | <ol style="list-style-type: none"> <li>1. Flumioxazin</li> <li>2. Fomesafen</li> </ol>                                                                                       | USDA. Cooperative State Research, Education and Extension Service. (2007). Pigweed Poses Challenge to Transformed Herbicide Industry. Last Accessed on June 27, 2008.<br><a href="http://www.csrees.usda.gov/newsroom/impact/2007/lgu/8241_resistant_pigweed.html">http://www.csrees.usda.gov/newsroom/impact/2007/lgu/8241_resistant_pigweed.html</a>                                                   |
| <b><i>Amaranthus rudis</i></b><br>Common Waterhemp       | <ul style="list-style-type: none"> <li>▪ Sulfentrazone</li> </ul>                                                                                                            | Hager, A.G., Wax, L.M., Bollero, G.A. et al. (2002). Common waterhemp ( <i>Amaranthus rudis</i> Sauer) management with soil-applied herbicides in soybean ( <i>Glycine max</i> (L.) Merr.). Crop Protection. Volume 21, Issue 4, May 2002, Pages 277-283.                                                                                                                                                |
| <b><i>Ambrosia artemisiifolia</i></b><br>Common Ragweed  | <ol style="list-style-type: none"> <li>1. Fomesafen</li> </ol>                                                                                                               | Ontario Ministry of Agriculture, Food and Rural Affairs. (2005). Control Options for Group II Resistant Weeds in Soybeans -ongoing research project. Last Accessed on June 27, 2008.<br><a href="http://www.omafr.gov.on.ca/english/crops/field/news/croptalk/2005/ct_1105a3.htm#rag">http://www.omafr.gov.on.ca/english/crops/field/news/croptalk/2005/ct_1105a3.htm#rag</a><br>Roundup Original® Label |
| <b><i>Ambrosia trifida</i></b><br>Giant Ragweed          | <ol style="list-style-type: none"> <li>1. Cloransulam-methyl</li> <li>2. Fomesafen</li> <li>3. Lactofen</li> </ol>                                                           | Purdue University. College of Agriculture. AG Answers. (2006). Giant ragweed added to GT list. Last Accessed on June 27, 2008.<br><a href="http://www.agriculture.purdue.edu/AgAnswers/story.asp?storyID=4374">http://www.agriculture.purdue.edu/AgAnswers/story.asp?storyID=4374</a><br>Roundup Original® Label                                                                                         |
| <b><i>Conyza bonariensis</i></b><br>Hairy Fleabane       | <ol style="list-style-type: none"> <li>1. Isoxaben - during the nonbearing period</li> </ol>                                                                                 | Shrestha, A. and Hembree, K.J. (2007). UC IPM Pest Management Guidelines: Pistachio. UC ANR Publication 3461.<br><a href="http://www.ipm.ucdavis.edu/PMG/r605700211.html">http://www.ipm.ucdavis.edu/PMG/r605700211.html</a><br>Roundup Original® Label                                                                                                                                                  |
| <b><i>Conyza canadensis</i></b><br>Horseweed             | <ol style="list-style-type: none"> <li>1. 2,4-dichlorophenoxyacetic acid (2,4-D)</li> <li>2. Cloransulam-methyl</li> </ol>                                                   | Purdue Weed Science. (2003). Glyphosate Resistant Horseweed/Marestail. Last Accessed on June 27, 2008.<br><a href="http://www.btny.purdue.edu/weedScience/2003/Articles/horse7-14-03.pdf">http://www.btny.purdue.edu/weedScience/2003/Articles/horse7-14-03.pdf</a><br>Roundup Original® Label                                                                                                           |
| <b><i>Lolium multiflorum</i></b><br>Italian Ryegrass     | <ol style="list-style-type: none"> <li>1. Clethodim</li> <li>2. Glufosinate</li> <li>3. Mesosulphuron</li> <li>4. Nicosulfuron + Rimsulfuron</li> <li>5. Paraquat</li> </ol> | USDA. Agricultural Research Service. Weed Biology and Ecology, and Development of Sustainable Integrated Weed Management Systems for Cotton, Soybean, Corn. Last Accessed on June 27, 2008.<br><a href="http://www.ars.usda.gov/research/projects/projects.htm?ACCN_NO=409484">http://www.ars.usda.gov/research/projects/projects.htm?ACCN_NO=409484</a>                                                 |

| Resistant Weed Species                                                                                                                                                                                                                                             | Herbicides Recommended for Use                                                                                                                                                                                                                                                                                                    | Citation/Reference                                                                                                                                                                                                                                                                                                                         |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b><i>Lolium rigidum</i></b><br>Rigid Ryegrass                                                                                                                                                                                                                     | <ol style="list-style-type: none"> <li>1. Glufosinate</li> <li>2. Quizalafop</li> <li>3. Rimsulfuron + Thifensulfuron</li> </ol>                                                                                                                                                                                                  | Simarmata, M., Michael, J. and Penner, D. (2006). HERBICIDES FOR THE CONTROL OF GLYPHOSATE RESISTANT RYEGRASS. North Central Weed Science Society Proceedings 61:60<br><a href="http://www.ncwss.org/proceed/2006/abstracts/60.pdf">http://www.ncwss.org/proceed/2006/abstracts/60.pdf</a>                                                 |
| <b><i>Sorghum halepense</i></b><br>Johnsongrass                                                                                                                                                                                                                    | <ol style="list-style-type: none"> <li>1. (+) isomer (fluazifop-P-butyl)</li> <li>2. Clethodim</li> <li>3. Fenoxaprop – may be cancelled by EPA</li> <li>4. Nicosulfuron</li> <li>5. Primisulfuron-methyl</li> <li>6. Quizalofop P-Ethyl</li> <li>7. Sethoxydim</li> </ol> <p>(All these herbicides work post emergence only)</p> | North Carolina State University. Integrated Pest Management Publication. Last Accessed on June 27, 2008.<br><a href="http://ipm.ncsu.edu/soybeans/weeds/weed_manage/weed_management6.html">http://ipm.ncsu.edu/soybeans/weeds/weed_manage/weed_management6.html</a>                                                                        |
| <b>Weeds Historically Resistant to Glyphosate</b>                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                            |
| <ol style="list-style-type: none"> <li>1. <b><i>Erodium spp</i></b> (Filaree)*</li> <li>2. <b><i>Malva parviflora</i></b> (Cheeseweed)*</li> <li>3. <b><i>Portulaca oleracea</i></b> (Purslane)</li> <li>4. <b><i>Urtica urens</i></b> (Burning nettle)</li> </ol> |                                                                                                                                                                                                                                                                                                                                   | Deynze, A.V., Putnam, D.H., Orloff, S. et al. (2004). Roundup Ready Alfalfa: An Emerging Technology. University of California, Division of Agriculture and Natural Resources Publication 8153.<br><a href="http://anrcatalog.ucdavis.edu/Alfalfa/8153.aspx">http://anrcatalog.ucdavis.edu/Alfalfa/8153.aspx</a><br>Roundup Original® Label |



## **Appendix O. Colony Collapse Disorder and Glyphosate-Tolerant Alfalfa**

# Colony Collapse Disorder and Glyphosate-Tolerant Alfalfa

## 1.0 Introduction

### 1.1 Overview of the Biology and Culture of Alfalfa

The biological and cultural characteristics of alfalfa are summarized by a Council for Agricultural Science and Technology Task Force Special Publication (CAST, 2008). Briefly, alfalfa (*Medicago sativa* L.) is an herbaceous short-lived perennial forage legume (CFIA, 2005; Lesins and Lesins, 1979). Introduced to the Americas it is the most important forage crop species in Canada and the U.S. and is widely adapted and grown in all 50 U.S. states. The three states with the largest amount of alfalfa hay acreage are South Dakota, Montana, and Wisconsin, according to the 2007 Census of Agriculture. Hybridization is restricted to certain species in the Genus *Medicago* and the crop relies on a variety of bee species for pollination (CAST, 2008). Alfalfa is self-incompatible and predominately outcrossing and is not capable of natural hybridization with any other species found in North America (CFIA 2005). Alfalfa grows optimally in fertile, well-drained soils but it can also survive as feral plants growing outside of cultivation (Kendrick et al., 2005). In the U.S., the vast majority of alfalfa is harvested as forage for use as animal feed. Forage is harvested as dry hay, haylage, and greenchop and grazed in pastures, which will be collectively referred to herein as “hay” or “forage”. In 2007, approximately 23.5 million acres of alfalfa were grown in the U.S. (USDA-NASS, 2007). Only about 122,000 acres (0.5%) of the total U.S. alfalfa production acreage is harvested for seed production (USDA-NASS, 2007). Approximately 70% of all alfalfa seed grown in the U.S. is used for the establishment of domestic hay fields, with the balance sold in export markets (CAST, 2008; Putnam, 2006). Because weeds and pests consistently reduce the yield of pure alfalfa and negatively affect forage nutritional quality, virtually all alfalfa planting seed produced in the U.S. is grown using insecticides and or herbicides (Peters and Linscott, 1988) which precludes its use for organic or sprouting (i.e., food) purposes.

### 1.2 Alfalfa Forage Production

In North America, alfalfa can be sown when there is available moisture and a sufficient frost-free growth period. Most alfalfa is predominately sown in the spring, except in the western and southern U.S. where fall planting is more common (Hower et al., 1999). Once alfalfa seedlings are established, the hay fields are harvested two to ten times per year depending upon location and seasonal climate. Following forage cutting, re-growth is from buds associated with the perennial root structure (the crown) or the lower stem nodes. Flower bud initiation requires long day length. Alfalfa forage production fields remain economically viable for approximately three to five years after initial planting.

Most alfalfa fields in the U.S. are harvested in the pre-flower (vegetative) or early bloom stages of maturity to optimize forage yield and feeding quality. Mature alfalfa stems with open flowers or seed result in poor feed quality and significantly reduced market value (Sheaffer et al., 1988). Accordingly, most alfalfa forage producers have a strong economic disincentive to allow extensive flowering or mature seed set in hay production. Since forage production practices periodically remove the entire plant canopy where flowers, pollen or seed might form, greater than 98% of alfalfa in the U.S. is without flowers (vegetative) or in an early stage of flower development (CAST, 2008; Sheaffer et al., 1988; Putnam, 2006; Putnam, 2007) at any given time. Alfalfa fields in flower are thus infrequent and sporadic. Exceptions are most notable in alfalfa seed production (seed increase) fields of the Western U.S. and in non-irrigated, low-input forage production fields in the Plains States wherein a combination of drought and the short growing season often limit forage yield and quality potential (McCaslin, 2007).

### 1.3 Alfalfa Seed Production -- The Role of Bees

Alfalfa seed production is a distinct commercial practice from forage production (Hanson et al., 1988). Alfalfa seed production requires a long growing season with very warm temperatures and very low humidity during seed ripening. Alfalfa seed yield is highly influenced by grower inputs, weeds, insect pests and seasonal weather fluctuations. Due to the limited number of skilled growers and suitable acres, U.S. alfalfa seed production occurs exclusively in niche areas of the western U.S. on approximately 100,000 to 120,000 acres that are of high value, intensively managed, and irrigated (USDA-NASS, 2007).

Alfalfa cultivars are developed by plant breeders using a combination of phenotypic and or genotypic recurrent selection to identify parent plants. Seeds of the cultivar (or variety) are produced commercially in spatial isolation from other cultivars (AOSCA, 2003). Cultivars are, with few exceptions, open-pollinated varieties. Alfalfa is not wind pollinated and it is very rarely self-pollinated (Teuber, 2007b; Viands et al., 1988). Cultivated (seed producing) alfalfa is exclusively bee cross-pollinated (CFIA, 2005; Olmstead and Wooten, 1987). Most professional seed producers use cultured bees and specialized equipment associated with bee culturing. The cost and availability of cultured pollinator bees is highly variable (many cultured bees are imported from western Canada). As seed is not desired on managed forage fields, pollination and bees are of no direct consequence or value to the hay crop, *per se*.

Alfalfa seed production fields are usually planted in the fall and mowed in late spring so that subsequent bloom within the field is uniform, synchronous and optimally timed for the warm dry season and optimal bee pollinator activity. Weed and in-crop volunteer plants are controlled using herbicides and cultivation prior to the start of pollination or after seed harvest. Insecticides, primarily for *Lygus spp.* control, and other pesticides are applied prior to bee release to avoid insecticide damage to bees (Hower et al., 1999). Flowering begins approximately in mid June. At approximately 50% flower (ca. early to mid July), cultured bees (discussed below) are gradually moved with their domicile or hive for local shelter into the seed field for pollination. The bees are allowed to pollinate the plants for approximately one month, the seeds are allowed to ripen for approximately four to six more weeks, and then, chemically desiccated or swathed several days prior to combining the seed. At the end of the pollination period and several weeks prior to field desiccation, the pollinating generation of bees is either at the end of

its lifecycle (leafcutter or alkali bees), or, in the case of honey bees, transported by the bee keeper to a different location to forage on fall-flowering plant species. Post-pollination, it takes approximately four to six weeks for the alfalfa seed to ripen and become physiologically mature under optimal seed production conditions (Bass et al., 1988). High winds and or drought stress may induce flowers to mechanically auto-pollinate; however, the resulting self-pollination (inbreeding) most commonly results in no seed or few seeds with inferior vigor (Viands et al., 1988). Seed is harvested in mid August to late September, depending on geography.

As mentioned earlier, alfalfa seed production is entirely dependent upon several different bee species to “trip” flowers (discussed in more detail below) and release pollen for ovule fertilization and seed production. Teuber et al. (2005) developed an extensive literature review on honey bee pollination in alfalfa. A general recent review of principles of bee pollination may be found in *Crop Pollination by Bees* (Delaplane and Mayer, 2000). A low frequency of feral solitary bee species may visit blooming alfalfa fields to collect pollen or nectar (Hammon et al. 2006); however in most alfalfa seed-growing areas, naturally occurring populations of alfalfa-pollinating bees are either nonexistent or at levels insufficient for adequate pollination (Arnett, 2002). Most professional seed producers use prudent, cultured bee management to control the bee species, bee hive field placement, bee stocking date(s) and bee stocking rate(s) and they are careful to apply bee compatible insecticides in their seed fields.

Honey bees (*Apis mellifera* L.) are used primarily in the irrigated valleys of the Desert Southwest (California, Arizona, etc.) and cultured alfalfa leafcutting bees, *Megachile rotundata* (F.), are used primarily in the cooler Pacific Northwest. In certain niche geographies where suitable climate and soil beds exist (e.g., southern Washington), permanent colonies of the ground-nesting alkali bee, *Nomia melanderi* Cockerell, contribute significantly to commercial alfalfa pollination, and are estimated to contribute 20% pollination for alfalfa seed fields proximal to an alkali bee bed. However, alkali bee pollination is often augmented by adding cultured leafcutter bees. Occasionally, some seed producers use a blend of two managed cultured bee species for pollination to increase the rate of seed set or shorten the pollination period. Feral honey bees and native bees including *Bombus* spp, *Osmia* spp, *Agapostomen* spp. and *Megachile* spp. can also be found visiting alfalfa flowers in varying numbers. These species may sometimes pollinate alfalfa flowers but their importance in alfalfa pollination is minor (Hammon et al., 2006; Arnett, 2002). Hammon et al. (2006) identified nine native bee species visiting alfalfa flowers in Colorado. In the northern, central and southern plains where a small portion of the U.S. alfalfa seed tonnage is produced, seed yield and grower inputs per acre are very low. In these marginal seed growing geographies, seed producers typically do not augment bee populations and typically rely on feral and native bee populations. Other non-bee insect pollinators are not effective pollinators of alfalfa; thus, some authors have estimated that about 60% of all pollinators in alfalfa hay and seed fields are honey bees (Morse and Calderone, 2000; Johnson, 2007).

Bee pollinator activity is required to simultaneously deposit non-self pollen onto the alfalfa flower’s stigma surface, rupture the protective stigmatic cuticle, and effect pollination (Teuber, 2007b; Viands et al., 1988). This process is called “tripping” and is triggered by bees visiting the flower to collect nectar or pollen. After it is tripped, the stigma of the flower becomes lodged into the groove of the standard petal of the flower. Because of the nonreversible tripping

mechanism within the alfalfa flower, each alfalfa flower may be pollinated only a single time by a single pollinating bee. Honey bees are hit in the head by this violent tripping process, which they learn to avoid by sipping nectar slantwise from the flower (Milius, 2007). Accordingly, honey bees demonstrate a strong behavioral aversion to foraging for nectar in flowering alfalfa (Arnett, 2002; Pitts-Singer, 2007; Teuber, et al., 2005). Because honey bees avoid the tripping mechanism they also are less efficient commercial alfalfa pollinators (Arnett, 2002; Cane, 2002). Indeed, Cane (2002) determined that honey bees only pollinate (“trip”) about 22 percent of the alfalfa flowers they visit. In non-seed production areas flowering weeds or other crop species are more important sources of nectar and pollen for honey bees (Arnett, 2002; Pitts-Singer, 2007; Teuber, et al., 2005). Researchers are working to improve honey bee pollination through selection of useful honey bee traits such as increased hive pollen storage, where in a typical honey bee hive only a small portion of the workers actually collect pollen instead of nectar (for honey). The hope is that bees selected for high pollen storage will also be good alfalfa pollen collectors, thus making them better pollinators (Mueller, 2008). Because of these shortcomings of the honey bee and competition from other crops for pollinating hives (e.g., almonds), alfalfa seed producers have increasingly used the alfalfa leafcutter bee for alfalfa pollination.

The leafcutter bee (*M. rotundata*) was accidentally introduced into North America from Eurasia in the 1930s and by the 1950s, entomologists recognized the bee as a superior pollinator of alfalfa (Greer, 1999; Bosch and Kemp, 2005). Currently, alfalfa leafcutting bees are the preferred bee pollinator for more than two-thirds of all alfalfa seed production acres in North America (Bosch and Kemp, 2005). In the 1970’s, leafcutter bee keepers started experiencing difficulty in maintaining leafcutter bee populations. Population losses (the difference between parental adults released and live progeny recovered) of 50% are now common in the Pacific Northwest. Leafcutter bees are increasingly being introduced from Canada to maintain adequate pollination for seed production. Chalkbrood, a disease caused by pathogenic fungus, *Ascosphaera* spp., is thought to be a major contributing factor negatively affecting leafcutter bee populations.

All bees have a limited range over which they will search to collect pollen. The maximum foraging radius for each of the three commercially available bee species *A. mellifera*, *M. rotundata*, and *N. melanderi* depends heavily on the abundance (or dearth) of nectar and pollen resources. Leafcutter bees have the shortest routine foraging radius (<1/4 mile), followed by the honey bee, and alkali bee (ca. 1 to 3 miles) (Arnett, 2003; Gathmann and Tschardt, 2002; Hammon et al., 2006; Teuber et al., 2005). Honey bees may infrequently transport alfalfa pollen and effect pollination up to 3 miles from the source (St. Amand et al., 2000; Teuber et al., 2004; Hammon et al. 2006). Accordingly, managed bee colonies are placed either in or in very close proximity to the crops they are intended to pollinate. Therefore, it is a common practice for certified and many non-certified seed producers to mitigate cross-pollination by unknown alfalfa pollen by using spatial field isolation and stocking their fields with recommended rates of cultured bees to synchronously and quickly pollinate the field and make it less attractive to feral bees. Likewise, conventional seed producers that have concerns regarding biotechnology-derived crops may use isolation and prudent bee management strategies to help mitigate cross-pollination to external alfalfa.

## 1.4 Hazard Assessment of Biotechnology-derived Crops and Associated Technologies on Honey Bees

Before commercialization, biotechnology-derived crops, including glyphosate-tolerant (GT) alfalfa and other GT crops, undergo extensive testing and evaluation as part of an environmental assessment to determine if there are any potential environmental effects. In particular, potential effects on non-target organisms (NTO) are considered. These potential effects are addressed via a science-based tiered assessment approach (Mendelsohn et al., 2003; Romeis et al., 2006, 2008; USDA/APHIS, 1997; U.S. EPA, 2007). A key component of that process is a problem formulation step that defines protection endpoints and management goals from which risk hypotheses are developed to evaluate risk. For biotechnology-derived crops expressing the herbicide-tolerance trait, a petition must be submitted to USDA/APHIS that addresses effects on NTO among other relevant factors. In most cases, EPA must be provided with information to support an amendment to the relevant herbicide label demonstrating that application of the herbicide to the herbicide-tolerant crop will not cause unreasonable adverse effects on the environment. For biotechnology-derived crops expressing insecticidally active proteins (termed PIPs or Plant Incorporated Protectants by the U.S. EPA), extensive evaluation including testing for potential effects on NTOs such as the honey bee have been conducted. The results of those analyses show that there are no negative effects of PIP-containing crops or their expressed proteins on honey bees (Mendelsohn et al., 2003; O'Callaghan et al., 2005; OECD, 2007; Rose et al., 2007; U.S. EPA Biopesticides Registration Action Documents) or bumble bees (*Bombus* spp.) (Babendreier et al., 2008). A recent meta-analysis by Duan and coworkers concluded that there was no evidence for any negative effects from use of registered PIPs on honey bees (Duan et al., 2008). It should be noted that GT alfalfa does not contain a PIP.

## 1.5 EPSPS Protein Specificity and Mode of Action

The EPSPS (5-enolpyruvylshikimate-3-phosphate synthase (EPSPS: EC2.5.1.19)) family of enzymes is ubiquitous in plants and microorganisms and their properties have been extensively studied (Dill, 2005). EPSPS proteins catalyze the transfer of the enolpyruvyl group from phosphoenol pyruvate (PEP) to the 5-hydroxyl of shikimate-3-phosphate (S3P), thereby yielding inorganic phosphate and shikimic acid-3-phosphate (5-enolpyruvylshikimate-3-phosphate), the penultimate product of the shikimic acid pathway (Alibhai and Stallings, 2001; Dill, 2005). EPSPS enzymes have extreme substrate specificity and bind only PEP and glyphosate, an EPSPS inhibitor. Shikimic acid is a substrate for the biosynthesis of aromatic amino acids (Phe, Trp and Tyr) as well as many secondary metabolites, such as tetrahydrofolate, ubiquinone and vitamin K. The shikimate pathway and, hence, EPSPS proteins, are absent in mammals, fish, birds, reptiles and insects including bees (Alibhai and Stallings, 2001).

The *cp4 epsps* gene is an *epsps* homolog isolated from *Agrobacterium* sp. strain CP4, a common soil-borne bacterium, (Padgett et al., 1996a, b). The *cp4 epsps* gene encodes the CP4 EPSPS protein. The CP4 EPSPS protein expressed in glyphosate-tolerant plants is functionally identical to endogenous plant EPSPS enzymes with the exception that CP4 EPSPS naturally displays reduced affinity for glyphosate, the active ingredient in Roundup® agricultural herbicides (Padgett et al., 1996a, b). In conventionally bred plants, glyphosate binds to the endogenous

plant EPSPS enzyme and blocks the biosynthesis of 5-hydroxyl of shikimate-3-phosphate, thereby starving plants of essential amino acids and secondary metabolites (Steinrücken and Amrhein, 1980; Haslam, 1993). In GT plants, the production of aromatic amino acids and other metabolites that are necessary for normal growth and development are met by the continued action of the glyphosate-tolerant CP4 EPSPS enzyme (Padgett et al., 1996a, b; Cerdeira and Duke, 2006, 2007). This difference in the glyphosate binding affinity is the basis for glyphosate tolerance in crops that produce CP4 EPSPS (Franz et al., 1997).

## 1.6 Safety Assessment of CP4 EPSPS on Arthropods

Safety assessments of GT crops, such as GT alfalfa, have shown that insertion of the *cp4 epsps* gene and the glyphosate-tolerant CP4 EPSPS protein does not alter the levels of nutrients and anti-nutrients in glyphosate treated and untreated plants (Heck et al., 2005; Nida et al., 1996; Padgett et al., 1996a; and Ridley et al., 2002; Nickson and Hammond, 2002; Cerdeira and Duke, 2006; U.S. FDA, 2008). For GT alfalfa, compositional analyses were performed for 35 nutritional components including proximates (protein, fat, ash and moisture), acid detergent fiber (ADF), neutral detergent fiber (NDF), amino acids, minerals, and carbohydrates (McCann et al., 2006; U.S. FDA, 2004). The values for all of the biochemical components assessed were similar to those of the conventional alfalfa grown in the trials or were within the range observed for conventional alfalfa. In addition, the levels of naturally occurring toxicants and anti-nutrients were addressed. Specifically, the levels of lignin (an anti-nutritional factor affecting digestibility), coumestrol (an estrogenically active phytoestrogen), as well as saponins and soluble forage proteins (both are associated with frothy bloat in ruminants), were all shown to fall within the ranges that occur in conventional alfalfa varieties (OECD, 2005). These data support substantial equivalence components of the risk assessment and establish that there should be no unintended effects of GT alfalfa, due to its equivalence with conventional alfalfa, on non-target organisms (Romeis et al., 2008).

Given the specificity of the EPSPS family of enzymes and their absence of demonstrated impacts in mammals, fish, birds, reptiles and insects (including bees), there is no known scientific basis to justify direct testing of this protein on specific non-target organisms such as bees (Cerdeira and Duke, 2006, 2007; Romeis et al., 2008). CP4 EPSPS containing crops, including alfalfa, canola, cotton, maize, and soybean have now been grown on many hundreds of thousands of hectares in excess of 10 years without any suggestion of negative effects on non-target organisms (Cerdeira and Duke, 2006; Dill et al., 2008). It may be noted that most of these crops serve as occasional nectar and or pollen sources for foraging honey bees. Even though the likelihood of hazard is low for the CP4 EPSPS protein, a number of researchers conducted laboratory and field investigations with different types of arthropods and other non-mammalian organisms exposed to GT crops containing the CP4 EPSPS protein, as discussed below.

Representatives of pollinators, soil organisms, beneficial arthropods and pest species were exposed to tissues from GT crops that contain the CP4 EPSPS protein<sup>52</sup>. These studies vary in design; some for relatively short duration and others for multiple generations (*Collembola*). Precise estimates of exposure of the test animals to the CP4 EPSPS protein in most of these test

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<sup>52</sup> See document entitled "Food safety and environmental impact of the CP4 EPSPS protein.

systems were not assessed. Importantly, no toxicity was observed in arthropods exposed to these GT crops, reinforcing the conclusion of minimal hazard.

The risk assessment for CP4 EPSPS protein in GT crops reveals no evidence of unreasonable risk to NTOs because minimal hazard is predicted based on widespread occurrence of the EPSPS proteins and no scientifically plausible mechanism of toxicity. Although minimal ecological risk is predicted in the formal risk assessment process, several field-monitoring studies were conducted for GT crops to reinforce the conclusion and address any potential uncertainties in the risk assessment process. Plots were monitored for arthropod abundance in Roundup Ready 2 Corn, Roundup Ready Soybeans, Roundup Ready Sugar Beet and Roundup Ready Canola. Results of these studies are consistent with the predictions of the ecological risk assessment in that there is no evidence of unreasonable risk demonstrated in these studies. These results support the argument that the CP4 EPSPS expressed in GT crops such as GT alfalfa do not negatively affect non-target organisms such as honey bees.

## 1.7 Safety Assessment of Glyphosate on Arthropods

Glyphosate (N-(phosphonomethyl) glycine) is a non-selective systemic herbicide, first commercialized in 1974. Glyphosate herbicide is now one of the most widely used herbicides in the world (Franz et al. 1997; Giesy et al. 2000). Formulations of glyphosate have been extensively tested for a wide range of potential environmental effects and have proven safe for a wide range of organisms, including honey bees (extensively reviewed by Giesy et al., 2000 and see especially Agriculture Canada, 1991; U.S.EPA, 1993a; WHO, 1994). Regarding honey bees Giesey et al., 2000, states:

“Honey bees are not affected by glyphosate formulations, either by ingestion or direct overspray, at maximum use rates. The majority of other beneficial arthropods are unaffected by Roundup. Although screening tests under extreme exposure conditions indicate toxicity of glyphosate formulations to some beneficial arthropods, at the maximum use rates these effects were reduced or eliminated when more realistic exposure conditions were used. These data demonstrate minimal risk to beneficial arthropods in areas adjacent to treated fields. Within treated fields, vegetation changes resulting from herbicide use can lead to significant changes in beneficial arthropod populations.”

## 1.8 Exposure Assessment of Glyphosate-Tolerant Alfalfa and Honey Bees

### 1.8.1 *Exposure in Glyphosate-Tolerant Alfalfa Seed Production*

As of 2002, there were an estimated 2.4 million bee colonies in the U.S., of which the majority belong to commercial migratory (managed) beekeepers (Johnson, 2007). About one-third of these colonies are in California and Florida. Another 7% are found in the Dakotas and 5% are each located in Texas and Montana. Minnesota, Idaho, Michigan, Washington, Wisconsin, Oregon, and New York, collectively account for an additional 20%. Commercial migratory honey bee providers may move their hives two to five times per growing season. Estimates show that the majority of rented hives are used in apple and almond production, followed by



clover seed, cherry, and pear producers. Collectively, across all alfalfa cropping practices (seed and hay) it has been estimated that about 60% of all alfalfa pollinators are honey bees (Johnson, 2007; Morse and Calderone, 2000) but the number of acres with pollinating bees varies widely by crop purpose (seed vs. hay) and by geography. Therefore, the 60% estimate is not informative for the estimation of exposure since pollinators are not typical in hay crop production (99.5% of the U.S. alfalfa acres) and the choice of bee pollinator species in alfalfa seed production is highly dependent on geography and seed grower management.<sup>53</sup> A worst-case exposure estimate can be generated based on alfalfa seed production acreage (USDA-NASS, 2007) and typical pollinator species for the geography (CAST, 2008).

Forage Genetics International (FGI) is the sole seed-producing licensee of GT (Roundup Ready®) alfalfa (FGI, 2007, 2008). As such FGI contractually specifies which seed growers, field sites and under what protocols the GT alfalfa seed crop can be produced (i.e., licensed for variety increase). Of the growers in the eleven (11) western U.S. states that are eligible to grow GT alfalfa for seed<sup>54</sup>, only those in the Desert Southwest States (CA, AZ, etc.) rely predominately on commercially managed honey bees as pollinators. In other geographies where wild or commercial honey bees may be present (e.g. the Dakotas) GT alfalfa seed increase will either not be licensed<sup>2</sup> and/or seed producers stock non-*Apis* bee species. There are approximately 44,000 acres of alfalfa seed in the southwestern U.S., of which approximately 30,000 acres (CAST, 2008; McCaslin, 2007) is produced for export—this is a market sector that is sensitive to biotechnology-derived traits and unlikely to adopt GE varieties at this time (McCaslin, 2007; CAST, 2008). Therefore, only the domestic market acres (ca. 14,000 acres) under honey bee pollination are projected as likely candidates for licensed seed increase for GT alfalfa varieties. For exposure calculation purposes, 14,000 acres and 44,000 acres will be used as the likely and high acreage exposure estimates, respectively, and per Mueller (1989), the maximum hive stocking rate will be three colonies per acre. Using these data, the following worst-case exposure estimates were made (table O-1). These estimates show that the exposure of managed honey bee colonies to GT alfalfa seed production fields in the U.S. would range from 1.75% (projected) to potentially 5.50% (worst case) of the total managed honey bee population in a given year.

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<sup>53</sup> Data cited by Johnson, 2007, reference Morse and Calderone, 2000. Morse and Calderone, 2000, provide a table entitled: "The Value of Honey Bees as Pollinators of U.S. Crops in 2000," that shows that for both seed and alfalfa hay production about 60% of all alfalfa pollinators are honey bees (Johnson, 2007; Morse and Calderone, 2000). While honey bees are used in the production of alfalfa seed, they are not used for alfalfa hay production. The attribution by the authors of 60% of the value of alfalfa hay to honey bees was meant to capture the indirect value honey bees contribute to the production of alfalfa hay and not to imply that honey bees are used or required for the production of hay once the grower has purchased alfalfa seed (Calderone, pers. comm.).

<sup>54</sup> FGI will limit the contracting of Roundup Ready alfalfa seed production acres to 11 western states--AZ, CA, CO, ID, MT, NV, OR, TX, UT, WA and WY, under terms of an industry coexistence consensus plan sponsored by The National Alfalfa & Forage Alliance (NAFA 2008). Seed production requires that Roundup agricultural herbicide be applied to the seed field. Such supplemental labeling is only available in these 11 states plus OK and NM where contracts have/will not be issued.

**Table O-1. Projected Likely and Highest (“Worst Case”) Exposure Estimates for Managed Honey Bee Colonies in Glyphosate-Tolerant Alfalfa Seed Production**

| Honey Bee Colonies in U.S. | Alfalfa Seed Production Acres, Total U.S. | Acres Pollinated by Honey Bees in Southwest U.S. | Acres Licensed for GT Alfalfa Seed Increase & Pollinated by Honey Bees | Colonies per Acre | Colonies Pollinating GT Alfalfa Seed Acres | Percent of Colonies Pollinating GT Alfalfa Seed Acres |
|----------------------------|-------------------------------------------|--------------------------------------------------|------------------------------------------------------------------------|-------------------|--------------------------------------------|-------------------------------------------------------|
| 2,400,000                  | 120,000                                   | 44,000                                           | Highest potential; all acres (44,000)                                  | 3                 | 132,000                                    | 5.50 %                                                |
| 2,400,000                  | 120,000                                   | 44,000                                           | Non-exported acres; likely potential (14,000)                          | 3                 | 42,000                                     | 1.75 %                                                |

## 1.9 Exposure in Honey Production

As stated above, although bees serve no direct agronomic (pollination) purpose in hay production fields, some alfalfa hay growers opt to allow their late-summer hay crop to flower extensively, precluding the harvest of maximum hay quality or yield. Working with honey bee keepers, these non-irrigated hay growers may allow their hay crop to flower and be used as an intentional source of honey bee forage instead of cutting for other livestock feeding purposes. In this situation, the bees are not “pollinators” used to produce the alfalfa crop *per se*; rather they are placed there as “foragers” to produce a honey crop and bee progeny (not seed).

While it is theoretically possible for exposure of honey-producing bees to GT alfalfa flowers found in fields where harvesting was delayed due to weather or on unmanaged feral plants to occur intermittently in some geographies, because of factors of scale, hay harvest routines and the seed purchase license restrictions, the extent and duration of any unintentional exposure is expected to be minor in comparison to intentional seed crop pollination use (see CAST, 2008; Kendrick et al., 2005). Hay growers that elect to plant GT alfalfa must sign a Technology/Stewardship Agreement that contractually obligates them to read and follow applicable sections of the Monsanto’s Technology Use Guide (TUG). For GT alfalfa, the TUG includes information on hay and forage management practices to promote high forage quality (i.e. before 10% bloom) and to prevent seed development.

Unintended exposure to GT alfalfa flowers can be further minimized by beekeepers if they opt to selectively place their hives near only conventional alfalfa variety fields rather than growers using GT alfalfa. The hay growers who purchase GT alfalfa will do so as a means to more efficiently produce high yielding, high quality forage alfalfa; these higher management alfalfa producers are unlikely to currently host bee hives because delayed harvest is incompatible with optimal forage harvest cycles. Such intensively managed pure-stand alfalfa is not needed by beekeepers and it is not optimal for fields used in honey production. Instead, honey producers

are more likely to work with a conventional alfalfa grower using marginal lands or lower inputs in geographies such as the upper plains states where extensive bloom is common (and geographically, growers are not eligible for GT seed production contracts). When alfalfa flowers are used as a source of nectar, the alfalfa may be grown mixed with clover. GT alfalfa varieties will not be grown in clover mixtures because clover is not glyphosate tolerant. Other flowers may also occur in the vicinity, decreasing the amount of foraging on alfalfa flowers. The majority of honey bees in a colony selectively collect nectar (not pollen) for honey production and only about 25% of honey bees actually forage for pollen (Arnett, 2002; Mueller, 1989). Because of the numerous biological and cultural mitigation factors, and the non-preference of alfalfa as a nectar source, exposure of honey bees outside of GT alfalfa seed producing areas is expected to be minimal.

Accurate estimates for the acreage of alfalfa devoted to honey production are not available, nor are there data for the number of pounds of alfalfa honey produced per year or the amount of honey produced per acre of alfalfa forage. Extension publications contain general references of “one-third of honey produced is from alfalfa” but verifiable numbers are not collected (Hannaway and Larson, 2004; Mulder, 2008). Honey production per acre of alfalfa is difficult to estimate since production is dependent on a number of abiotic and biotic factors including plant variety, geography, management practices and weather. However, a conservative worst-case estimate can be made by assuming that, if approximately one-third of the U.S. honey production is predominately alfalfa-based, then approximately one-third of honey bees are foraging predominately on alfalfa (table O-2). Therefore, of the 2.4 million colonies in the U.S. (Johnson, 2007), approximately 800,000 potentially forage on alfalfa. Using a stocking rate estimate of two to three colonies per acre (Mueller, 1989), then, it may be calculated that approximately 266,667 to 400,000 full-bloom alfalfa acres are used to support 800,000 colonies. The total acreage of alfalfa grown in the U.S. for hay and or seed production was nearly 24 million in 2007 (USDA, 2007). Therefore, approximately 1.2 to 1.8 percent of the total U.S. alfalfa (hay and seed) acreage is potentially used to support honey bee colonies during the longer days of summer when alfalfa has sufficient photoperiod to bloom and it remains unclipped.

As discussed above, due to the prohibitions in the Monsanto Technology Use Guide and the negative economic impacts of extensive flowering on forage quality and yield, optimally managed alfalfa hay fields (e.g., GT varieties) are very unlikely host fields for honey bee keepers. It is therefore likely that honey bees will only be intentionally placed on GT alfalfa when it is grown for seed increase (not forage), and then, only when the seed acres are planted in the irrigated desert valleys of California and Arizona where honey bees are the pollinator of first choice. In total, there are approximately 44,000 acres of alfalfa seed production in the Desert Southwest States (McCaslin, 2007; USDA, 2007) of which approximately 30,000 seed acres would be unlikely to plant GT alfalfa because they produce conventional seed for the export market (CAST, 2008; McCaslin, 2007). One possible conservative exposure scenario for honey production would be to assume that all of the remaining seed production acres in these southwestern geographies (i.e., ca. 14,000 acres) are planted to GT alfalfa seed production, honey bees are used as the sole pollinator species and honey is harvested. Under this scenario, the following conservative exposure estimates can be developed (table O-2):

- 0.06% of the total alfalfa acres in the U.S. would be GT *and* intentionally used to host honey bee colonies producing honey (i.e., 14,000 of 24 million acres);
- 3.5 to 5.3% of the current acres used to support alfalfa honey production acres (i.e., 14,000 of the 266,667 to 400,000 acres, overall) would encounter a change from conventional alfalfa flowers as bee forage to GT alfalfa flowers and all of these acres would be under seed producer variety increase contracts and license.
- Likewise, 3.5 to 5.3% of all U.S. alfalfa honey production would encounter a change from conventional alfalfa flowers as bee forage to GT alfalfa flowers and, essentially all of these bee keepers (and bees) would be working in close association as a pollinating service for a contracted, licensed GT alfalfa seed producer. Relative to this figure, only minimal additional exposure would be likely from delayed harvest forage fields or dispersed feral plants.
- 1.2 to 1.8% of all U.S. commercial honey bee colonies would be intentionally foraged on GT alfalfa flowers for the stocking rates of three and two colonies per acre on 14,000 acres, respectively (i.e., 28,000 to 42,000 of the 2.4 million bee colonies would be intentionally foraged on the GT alfalfa, inclusive of all hay and seed uses). Over 98 percent of cultured honey bee colonies would have little or no intentional foraging exposure to GT alfalfa.
- Assuming that one-third of this honey is sourced from alfalfa and exposure is estimated to be 1.2 to 1.8% of all honey bee colonies annually, a worst case estimate for honey sourced from GT alfalfa is 2.2% of the U.S. honey production.

**Table O-2. Post-Commercialization Exposure Estimates for the 2.4 Million U.S. Bee Colonies**

|                                                             | 3 colonies/acre |        | 2 colonies/acre |        |
|-------------------------------------------------------------|-----------------|--------|-----------------|--------|
| <b>Alfalfa acreage supporting honey bees (seed and hay)</b> | 266,667         |        | 400,000         |        |
| Acres of conventional alfalfa                               | 252,667         | 94.70% | 386,000         | 97.50% |
| Acres of GT alfalfa                                         | 14,000          | 5.30%  | 14,000          | 3.50%  |
| <b>Colonies supported by alfalfa flowers (seed and hay)</b> | 800,000         |        |                 |        |
| # colonies on GT alfalfa                                    | 42,000          | 5.30%  | 28,000          | 3.50%  |
| # colonies kept on conventional alfalfa                     | 758,000         | 94.70% | 772,000         | 97.50% |
| Estimated colonies kept on GT alfalfa flowers               | 42,000          | 1.80%  | 28,000          | 1.20%  |
| Estimated colonies kept on all other sources of flowers     | 2,358,000       | 98.20% | 2,372,000       | 98.80% |

### 1.10 Honey Bees and Colony Collapse Disorder

Honey bees are the major bee species used for crop pollination worldwide and in 2000 their contribution to U.S. agriculture, including alfalfa production, was valued at \$14.6 billion

(Greenleaf & Kremen, 2006). Currently, approximately 2.4 million managed honey bee colonies are used to pollinate crops in the U.S. (Johnson, 2007). This number represents a significant decrease from the estimated 4 million managed honey bee colonies present in 1981. This downward trend continues in both the U.S. and Europe. The National Research Council's (NRC) "Status of Pollinator's Committee" report (USDA-CCD, 2007) detailed the following problems facing the beekeeping industry including:

- Catastrophic problems with invasive parasitic mites (and resistance to pesticides meant to control them);
- Africanized honey bees which are aggressive and poor honey producers;
- The bacterial American foulbrood disease (and resistance to the antibiotic used to control it);
- The small hive beetle;
- A variety of viruses, bacteria, and fungi (including microsporidia);
- Insecticides with known toxicity to honey bees used in production agriculture; and
- Increased production costs and competition from cheap imported honey.

As listed above, honey bees face a number of abiotic and biotic stressors that can seriously disrupt or destroy a hive (Flottum, 2008a; MAAREC, 2007; USDA-CCD, 2007; Williams, 2008). Cultural practices by managed bee keepers can also potentially affect honey bee health. These include immune-suppressing stress from poor nutritional forage sources, apiary overcrowding, a lack of pollen or nectar, air pollution, drought, and migratory stress from long-distance transport of hives for pollination services (Endres, 2008; McFrederick et al., 2008; Williams, 2008). Crowding can also increase pathogen transmission. More recently Colony Collapse Disorder (CCD) has emerged (or possibly re-emerged) as a potential and poorly understood threat. Because of the importance of honey bees to U.S. agriculture, the U.S. Department of Agriculture (USDA) formed an ad hoc CCD Working Team comprised of academic, private, and Federal scientists to determine causes contributing to, and potential mitigation plans for, CCD (USDA-CCD, 2007).

CCD describes a phenomenon first reported in the U.S. in 2006-2007 in which honey bee colonies (*A. mellifera*) apparently disappear without a trace. A similar phenomenon has been observed in Europe (Belgium, Canada, France, the Netherlands, Germany, Greece, Italy, Portugal, Spain, Switzerland and the United Kingdom, West Africa, and Taiwan (Dupont, 2007; Flottum, 2008c; Kievits, 2007; Molga, 2007; Steinberger 2007). Large scale disappearances of honey bees are not new and are recorded as far back as 950 and 992 in Ireland, and more recently in the U.S. in the 1880s, the 1920s and the 1960s (Oldroyd, 2007). Isolated disappearances occurred in the Cache Valley of Utah in 1903 and in Pennsylvania in 1995-1996 (USDA-CCD, 2007). These disappearances have been variously named autumn collapse, disappearing disease, fall dwindle disease, May disease, and spring dwindle (Oldroyd, 2007). It is unknown whether these losses were related to the causal agent(s) of CCD or to some other stressor(s). Some experts argue, for example, that the case definition for CCD is ambiguous and that CCD may not be a new disorder because the symptoms for CCD are indistinguishable from those of other the normal diseases, such as winter colony collapse (Anderson and East, 2008; see also Oldroyd, 2007). At this time, however, most experts are classifying CCD as a unique disease (USDA-CCD, 2007) the symptoms of which include:

- Sudden loss of the colony's adult bee population with very few bees found near the dead colonies;
- Several frames with healthy, capped brood and low levels of parasitic mites which indicates that colonies were relatively strong shortly before the loss of adult bees and that the losses cannot be attributed to a recent infestation of mites;
- Food reserves that have not been robbed, despite active colonies in the same area, suggesting avoidance of the dead colony by other bees;
- Minimal evidence of wax moth or small hive beetle damage; and
- A laying queen often present with a small cluster of newly emerged attendants.

Some scientists believe that these symptoms are consistent with a disease or disease/pathogen interaction, perhaps aggravated by other sub-optimal cultural practices (CCD-USDA, 2007; Flottum, 2008a, 2008b, 2008d; Cox-Foster, 2008; Williams, 2008). Leading candidates are *Nosema* infections, mites and viruses.

*Nosema apis* and *Nosema ceranae* are microsporidian diseases of the western (*A. mellifera*) and eastern honey bee (*A. cerana*), respectively (Klee et al., 2007). In 2007, Klee and co-workers confirmed the presence of virulent *N. ceranae* in the western honey bee, first in Spain and Taiwan, and now world wide. Colonies can be simultaneously infected with both *Nosema* species. Symptoms of *Nosema* infection can be somewhat non-specific and thus confused with other diseases. They generally involve diarrhea and loss of female workers, which appear to be the most susceptible. *Nosema* infection shortens worker lifespan and can seriously weaken the colony leading to loss of hives.

Mite infestations of honey bees generally involve either the tracheal mite (*Acarapis woodi*) or the Varroa mite (*Varroa destructor*). A resistant strain of honey bee, as well as cultural controls, has been developed to control the tracheal mite. The Varroa mite is an obligate external parasite of both eastern and western honey bees (*A. cerana* and *A. mellifera*). Besides the visual presence of mites, other symptoms of mite infestation include the presence of dead bees in the hive and invasion of the hive by other pests as the hive weakens. Because mites feed on the hemolymph of bees and move between brood and adults, they are also capable of vectoring viruses such as the Deformed Wing Virus, a major pathogen affecting honey bee colonies (Lanzi et al., 2006).

A number of different viruses can infect honey bees (Chen et al, 2006). Many of the symptoms of CCD are consistent with a pathogen infection; therefore, viruses are likely candidates for the disease (Stokstad, 2007). For example, some investigators found that sanitation via irradiation of CCD affected combs allowed successful repopulation of the combs by honey bees (Williams et al., 2008). To try to identify a potential pathogen(s) as a causal agent of CCD, Cox-Foster and colleagues (2007) used an unbiased metagenomic approach to survey microflora in CCD hives, normal hives, and imported royal jelly. Their results showed a strong correlation of the incidence of CCD with the Israeli Acute Paralysis Virus (IAPV), which is either a new viral species or an unclassified virus possibly related to Kashmir bee virus (KBV) (Cox-Foster et al., 2007; Chen et al., 2007). IAPV is a single-stranded RNA virus in the family Dicistroviridae (genus *Iflavirus*) that can be vectored by the Varroa mite. IAPV is one of the top candidates as

the causal agent of CCD. Although the CCD Working Group is developing new recommendations regarding data collection to identify the cause of CCD, one conclusion reached very quickly for the CCD Working Group (USDA-CCD. 2007; MAAREC, 2007) was that:

*“Several other factors have been suggested as causal mechanisms of CCD, for example, the use of genetically modified (GMO) crops. However, large bee die-offs have also occurred in Europe, where GMO crops are not widely grown. Also, in the United States, the patterns of CCD-affected colonies do not appear to correlate with the distribution of GMO-crops such as Bt-corn. Furthermore, extensive laboratory and field testing has indicated a lack of acute and sub-lethal effects on bees exposed to GMO-pollen.”*

The CCD working group further stated that it is not currently investigating GMO crops because *“Some GMO crops, specifically Bt Corn, have been suggested as a potential cause of CCD. While this possibility has not been ruled out, CCD symptoms do not fit what would be expected in Bt affected organisms. For this reason GMO crops are not a “top” priority at the moment.”* (MAAREC, 2007)

## **2.0 Conclusion**

CCD is a serious threat to honey bee populations worldwide. Although the exact cause(s) of CCD is unknown, diseases and colony stress have been proposed as possible candidates. The temporal and geographic distribution of CCD, as well as the pathology associated with the disorder, are factors cited by the CCD working group. These factors limit the likelihood that any glyphosate-tolerant crop, including GT alfalfa, might be involved in CCD. A causal link between CCD and GT crops such as GT alfalfa is unlikely due to the limited exposure of honey bees to GT alfalfa and the lack of hazard associated with the CP4 EPSPS protein. In addition, the currently approved Bt crops referenced by the CCD working group occupy much of the same general agricultural acreage as GT crops, including the acreage that GT alfalfa is expected to occupy. Given the dynamics of GT alfalfa seed and forage production, the current worst case exposure estimates of commercial honey bee colonies to GT alfalfa flowers are 1.2 to 1.8%. Safety assessments and field observations, based on the mode of action of the CP4 EPSPS protein, suggest no potential negative effects on any animal including honey bees. Given the pathology and distribution of CCD and the lack of hazard or exposure of GT alfalfa to commercial honey bees, we conclude that there will be no negative impact on honey bees from the deregulation and commercial production of GT alfalfa.



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## **Appendix P.      FDA Submission**



U.S. Food and Drug Administration



Department of  
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CFSAN/Office of Food Additive Safety December 8, 2004

## Biotechnology Consultation

### Note to the File

BNF No. 000084

**Date:** December 8, 2004

**Subject:** Glyphosate-tolerant (Roundup Ready®) Alfalfa Event J101 and Event J163

**Keywords:** alfalfa, *Medicago sativa* L., glyphosate (N-phosphonomethylglycine), glyphosate-tolerant, herbicide-tolerant, CP4 5-enolpyruvylshikimate-3-phosphate synthase (CP4 EPSPS), *Agrobacterium* sp. strain CP4, Roundup Ready®

### 1.0 Background

In a submission dated October 6, 2003, Monsanto Company (Monsanto) and Forage Genetics Incorporated (Forage Genetics) (jointly the notifiers) provided summary data and information supporting their safety assessment of two glyphosate-tolerant alfalfa (*Medicago sativa* L.) lines. One line contains the transformation event designated J101, and the second line contains the event designated J163. The notifiers intend to combine event J101 and event J163 through conventional breeding to produce commercial glyphosate-tolerant alfalfa seed. Monsanto and Forage Genetics submitted additional information in a submission dated June 15, 2004. Monsanto has successfully completed prior consultations with the agency on other glyphosate-tolerant plants expressing CP4 EPSPS protein.

### 2.0 Intended Effect

The intended effect of this genetic modification is to confer tolerance to the herbicide glyphosate, which is the active ingredient in Roundup®. The notifiers achieved this by transforming the parent alfalfa R2336 with a 5-enolpyruvylshikimate-3-phosphate synthase gene (*cp4 epsps*) from *Agrobacterium* sp. CP4 strain. The 5-enolpyruvylshikimate-3-phosphate synthase protein (CP4 EPSPS) encoded by this gene provides tolerance to glyphosate herbicide.

## 3.0 Method of Development

### 3.1 Genetic Modifications

Glyphosate-tolerant alfalfa events J101 and J163 were generated by *Agrobacterium*-mediated transformation of *Medicago sativa* L. line R2336 callus with the binary T-DNA vector PV-MSHT4. Transformant cells were identified through selection for glyphosate tolerance. The T-DNA segment of the PV-MSHT4 vector contains a single *cp4 epsps* expression cassette with the following elements intended for transfer to the recipient plant line during transformation.

| Name             | Description                                                                                         |
|------------------|-----------------------------------------------------------------------------------------------------|
| RB               | Right border                                                                                        |
| P-eFMV           | 35S promoter of the Figwort Mosaic Virus with duplicated enhancer region                            |
| HSP70-Leader     | The petunia heat shock protein 70 5' untranslated leader sequence                                   |
| CTP2             | Chloroplast transit peptide coding sequence derived from the <i>Arabidopsis thaliana epsps</i> gene |
| <i>cp4 epsps</i> | <i>cp4 epsps</i> gene derived from <i>Agrobacterium</i> sp. strain CP4                              |
| E9 3'            | Terminator sequence from the pea ribulose-1,5-bisphosphate carboxylase, small subunit E9 gene       |
| LB               | Left border                                                                                         |

The transformation vector PV-MSHT4 contains the *ori-322* origin of DNA replication, which allows the replication of the vector in the intermediate host *E. coli*, and the streptomycin adenyltransferase (*aad*) gene, which encodes a protein conferring resistance to the antibiotics streptomycin and spectinomycin. The *ori-322* and *aad* genes are located on the vector backbone, outside of the T-DNA border sequences; therefore, the genes are not intended for transfer to the recipient plant line during transformation.

### 3.2 Insert Characterization and Stability

The notifiers characterized events J101 and J163 using restriction endonuclease digestion and Southern blot analysis. According to the notifiers, the results of their characterization support the conclusion that, for events J101 and J163, a single, intact copy of the *cp4 epsps* gene cassette (of the PV-MSHT4 vector T-DNA) was incorporated into *Medicago sativa* L. line R2336, and that, for each event, the *cp4 epsps* gene cassette was incorporated at a different locus. The notifiers also used Southern blot analysis to conclude that the integrity of the *cp4 epsps* gene cassette was maintained and that alfalfa events J101 and J163 do not contain any detectable backbone sequence from the PV-MSHT4 vector.

2.1 The notifiers assessed the genetic stability of the insertions in J101, in J163, and in a population resulting from the conventional breeding of J101 and J163 (dihomogenic

population). The notifiers explained that, for the single event populations, both chi square analysis of phenotype segregation and Southern blot analysis of genotype segregation indicate a stable, one-locus Mendelian inheritance pattern and that, for the dihomogenic populations, chi square analysis of the Syn1 generation indicates normal Mendelian inheritance for the two independent loci.

The notifiers stated that alfalfa is an outcrossing autotetraploid plant with eight sets of chromosomes and that varieties of alfalfa are composed of a heterogeneous group of individuals. As a consequence of the genetics associated with conventional breeding of the J101 and J163 alfalfa lines, the *cp4 epsps* gene copy number is variable with advancing generations, ranging from zero to eight, for populations carrying both events.

## **4.0 Introduced Protein**

### **4.1 Identity and Function**

The expressed gene product in events J101 and J163 is a protein, CP4 EPSPS, derived from *Agrobacterium* sp. strain CP4. It is a single polypeptide 455 amino acids long and structurally and functionally similar to native plant EPSPS enzymes. Naturally occurring plant EPSPS, which catalyzes an essential step in aromatic amine synthesis essential to plant viability, is inhibited by the herbicide glyphosate. Compared to alfalfa EPSPS, the CP4 EPSPS protein has a much lower affinity for glyphosate, the active component of Roundup herbicide. Consequently, plant cells producing CP4 EPSPS are tolerant to glyphosate treatment.

The notifiers purified the CP4 EPSPS protein from the forage tissue of alfalfa plants containing either event J101 or event J163 and characterized the introduced protein using N-terminal sequence analysis, matrix assisted laser desorption ionization time of flight (MALDI-TOF) mass spectrometry, sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE), Western blot analysis, and glycosylation analysis.

### **4.2 Expression Level**

The notifiers estimated the expression level of the CP4 EPSPS protein in J101 and in J163 by enzyme-linked immunosorbent assay (ELISA). They determined that the mean levels of CP4 EPSPS protein in forage from alfalfa plants containing event J101 and plants containing event J163, collected across two seasons and from six field sites, were 257 and 270 g/g of tissue fresh weight (tfw), respectively.

## **5.0 Safety Assessment of the Introduced Protein**

The notifiers presented data and information to support the safety of the CP4 EPSPS protein for human and animal consumption. They provided the following arguments in support of CP4 EPSPS protein safety:

*Agrobacterium* species are not known for human or animal pathogenicity; *Agrobacterium* sp. *cp4 epsps* has a history of use as a genetic donor in numerous glyphosate-tolerant crops, which humans and animals have consumed since 1996.

The CP4 EPSPS protein is functionally equivalent to native plant EPSPS protein except for its affinity for glyphosate.

Based on an amino acid homology search of several toxin databases, the CP4 EPSPS protein does not have biologically relevant structural similarities to protein toxins known to cause adverse health effects in humans or animals.

CP4 EPSPS protein is present at low levels: it represents only a relatively small portion of the total protein (0.49 percent in J101 and 0.52 percent in J163) in alfalfa. Fresh alfalfa forage contains 5.2 percent total protein levels and dried alfalfa contains approximately 20 percent protein by weight.

No treatment-related adverse effects were observed in an acute toxicity test in which mice were gavaged with doses of up to 572 milligrams of CP4 EPSPS1 per kilogram of body weight. According to the notifiers, this represents a safety factor for cows of approximately 26 and 27, for J101 and for J163 respectively, given a 630 kg cow consuming 13 kg of alfalfa dry matter per day.

The notifiers also assessed the allergenic potential for CP4 EPSPS protein produced from events J101 and J163. They concluded that the CP4 EPSPS protein from glyphosate-tolerant alfalfa lines J101 and J163 does not pose a significant allergenic risk based on 1) the absence of known reports of allergies to *Agrobacterium* species, which is the source of the *cp4 epsps* coding sequence transferred to the recipient plant lines, 2) the absence of immunologically relevant sequences, as determined by comparison of the amino acid sequence of the CP4 EPSPS protein to sequences in several allergen databases, and 3) the susceptibility of CP4 EPSPS protein to rapid proteolytic digestion in simulated gastric fluid.

## **6.0 Compositional Assessment**

The notifier states that alfalfa has a long history as a feed source for many animal species, but its greatest use is for dairy and beef cattle. Greater than 95 percent of alfalfa is used as animal feed on farms and is consumed as pasture, greenchop, silage, or dried forage. A small amount of alfalfa is sold and fed as dehydrated pellets. Human food uses of alfalfa are minor and are consumed as compressed leaf material for dietary supplements and herbal teas or as fresh sprouts.

### **6.1 Justification of Comparable Lines**

In their submission, the notifiers stated that, because alfalfa is an outcrossing autotetraploid, seed generated through self-pollination of a single genotype of alfalfa is not of adequate vigor for use in safety assessment studies. Consequently, they used a control population of null segregants (segregants lacking both the glyphosate-tolerant phenotype and the *cp4 epsps* genotype) from the

transformation protocol. The notifiers described how these "near isogenic" null segregants were developed in parallel with J101 and J163 and, in turn, were used to develop control alfalfa populations for use in compositional equivalence evaluations. Statistically significant differences between the transgenic and control alfalfa populations were declared at the 5 percent level of significance (i.e., where the p-value is less than 0.05).

## 6.2 Compositional Analysis

The notifiers compared the composition of simplex (single copy, single event) glyphosate-tolerant alfalfa lines J101 and J163 to the null segregant control line, using second cutting forage samples grown at five replicated field sites across the alfalfa-producing regions of the United States and harvested at the early to late bloom stage. A randomized complete block design with four blocks at each location was used. Twelve commercially available conventional alfalfa varieties, used to establish commercial compositional ranges, were grown at these sites, with four varieties grown at each of the five field sites. Forage samples were analyzed for 35 nutritional components including proximates (protein, fat, ash and moisture), acid detergent fiber (ADF), neutral detergent fiber (NDF), amino acids, various minerals and carbohydrates (by calculation).

The notifiers developed a tolerance interval using twelve different varieties of commercially available, conventional alfalfa to establish comparable ranges for compositional constituents. Using these ranges, the notifiers calculated the tolerance interval to contain, with 95 percent confidence, 99 percent of the values contained in the population of commercial alfalfa varieties. The notifiers used this 99 percent tolerance interval to determine if the test range was within the variance of a population of reference alfalfa varieties.

The notifiers stated that statistically significant differences were observed for the level of some analytes in comparison to the control population. For line J101, the mean level of cystine was greater than, and the mean levels of glutamic acid and tyrosine were less than, the null segregant controls. For line J163, the mean levels of cystine, acid detergent fiber (ADF), and neutral detergent fiber (NDF) were greater than, and the mean levels of histidine, lysine, and tyrosine were less than, the null segregant controls. However, the notifiers further noted that while the analyte levels were different, these levels were still within Monsanto's and Forage Genetics' commercial compositional ranges and their tolerance interval derived from data on conventional species grown at the same sites, and comparable to published literature values. The notifiers stated that the mean levels of iron and ash for the control and all varieties were unusually high but that these high mean levels could be attributed to high levels measured at one site. Consequently, repeat measurements were made for iron and ash the following year, resulting in levels similar to other sites and values found in the literature. The notifiers also found several differences in the level of nutrients within the locations, but except for the nutrients already cited, these were not consistent across locations. The notifiers therefore, concluded that these differences are unlikely to be biologically meaningful.



### 6.3 Levels of Naturally Occurring Toxicants and Anti-nutrients

The notifiers cited lignin, an insoluble amorphous macromolecule, as a key anti-nutritional factor in alfalfa where high lignin concentrations decrease alfalfa digestibility. The notifiers measured lignin levels in the forage of plants containing either event J101 or J163 as well as null segregant and commercial varieties. From these measurements, they concluded that the levels of lignin in J101-containing alfalfa were not statistically different from the levels of lignin in the control alfalfa population. The notifiers observed a statistically significant increase in the levels of lignin in J163-containing alfalfa when compared to the levels in control alfalfa. However, the notifiers noted that these levels were within their tolerance interval, established using data derived from conventional species and similar to published literature values. In summary, the notifiers concluded that the lignin levels in glyphosate-tolerant alfalfa are comparable to lignin levels in conventional alfalfa.

The notifiers reviewed the literature and concluded that coumestrol is the most estrogenically active phytoestrogen in alfalfa. The notifiers conducted field trials to measure coumestrol at four locations using a randomized complete block design with four replicates at each location. The combined statistical analysis of all the data showed no statistically significant differences. There were some location differences, but these were not consistent across all locations. The notifiers concluded that coumestrol levels in alfalfa lines J101 and J163 are equivalent to those in the null segregant controls and conventional alfalfa forage.

Digestive bloat constitutes a high health risk to cattle grazing on lush alfalfa pastures or fed fresh greenchop alfalfa. Saponins and soluble forage proteins are suggested as contributing agents to frothy bloat (ruminal tympany) in ruminants. The notifier concluded that a search of the literature did not reveal evidence showing that these compounds are the causative agents for bloat. Further, there are no reliable methods or databases on the level of saponins and soluble forage proteins in alfalfa.

In conclusion of their assessment, the notifiers state that alfalfa event J101 and event J163, and the feeds and foods derived from them, are as safe and nutritious as current commercial varieties of alfalfa and the comparable feeds and foods derived from them.

## 7.0 Conclusions

Monsanto and Forage Genetics have concluded that their glyphosate-tolerant alfalfa event J101 and event J163, and the feeds and foods derived from them, are not materially different in safety, composition, or any other relevant parameter from alfalfa now grown, marketed, and consumed. At this time, based on Monsanto's and Forage Genetics' description of its data and information, the Agency considers this consultation on alfalfa event J101 and event J163 to be complete.

<sup>(1)</sup>The CP4 EPSPS protein used in this study was produced in *E. coli*. Monsanto and Forage Genetics note that the CP4 EPSPS protein produced in *E. coli* is biologically, chemically, and functionally equivalent to the CP4 EPSPS protein produced in plants.

FDA/Center for Food Safety & Applied Nutrition  
Hypertext updated by [jmf/rxm](#) February 2, 2005

**Appendix Q.      Presence of Glyphosate-Tolerant  
Alfalfa in Human Food and Animal  
Feed**

# Presence of Glyphosate-Tolerant Alfalfa in Human Food and Animal Feed

## Executive Summary

Alfalfa (*Medicago sativa*) is the fourth most widely grown and third most valuable forage crop cultivated in the United States. This insect (bee) pollinated crop generally has a high yield, high protein and low fiber content, making it an ideal livestock feed (primarily dairy cattle and horse, but also used for beef cattle, sheep, and goats). Alfalfa is also consumed by humans as sprouts, herbal supplements or teas; the consumption in humans is smaller than that observed in livestock. In 2004, Monsanto Company and Forage Genetics International (FGI), jointly developed glyphosate-tolerant (GT) alfalfa, designated as events J101 and J163 that were genetically engineered for tolerance to the herbicide glyphosate (Roundup®). Since alfalfa is a very important forage crop, introduction of the GT variety for commercialization could lead to transgenic genes or proteins being present in organic or conventional alfalfa; thus warranting a thorough assessment of the potential impacts. This report examines scenarios where GT alfalfa may be found in animal feed and human food and addresses the potential human and livestock health implications of the same.

Glyphosate tolerance in alfalfa is achieved by genetically altering the alfalfa crop to express the soil bacterium, *Agrobacterium* sp. CP4 strain EPSPS (5-enolpyruvylshikimate-3-phosphate synthase) protein. The *Agrobacterium* sp. CP4 strain *cp4 epsps* gene encodes the CP4 EPSPS protein enzyme that has a reduced affinity for glyphosate when compared to the native alfalfa EPSPS enzyme. Glyphosate herbicide functions by inhibiting expression of plant EPSPS that results in the prevention of synthesis of essential aromatic amino acids. However, the CP4 EPSPS protein in the genetically engineered alfalfa is not hindered by glyphosate application.

Alfalfa is a herbaceous, short-lived perennial forage crop species that is predominantly and entirely dependent upon bees for pollination, therefore, gene flow by pollination between different alfalfa fields is probable. This becomes an issue when a proportion of cultivated alfalfa is GT alfalfa, and growers of conventional alfalfa wish to prevent the presence of GT alfalfa in their seed stock and crops. Alfalfa production occurs mainly in the West and Northwest United States where it is cultivated primarily for hay (forage) or seed. Gene flow between and into seed fields is of higher concern than gene flow into hay fields. Pollination of alfalfa is highly dependent on the species of pollinator used (honey bee, alfalfa leafcutter bee, alkali bee). Flower availability, the number of bees, weather, season, time of day, hive placement, plant competition, strength of the colony and disease are some of the other important factors that can potentially impact pollen transport. Feral alfalfa near seed fields can be an additional source of pollen and potential for gene flow if not contained adequately. However, proper adherence to FGI Best Practices and Monsanto's Monsanto Technology/Stewardship Agreement (MTA) has shown the risk of GT alfalfa presence to be well below FGI's goal of less than 0.5 percent unintended presence. Most countries importing organic alfalfa from the United States have a goal of no more than 1.0 percent.

The potential use of the GT crop and the associated use patterns of the herbicide glyphosate, the CP4 EPSPS gene and protein, the *Agrobacterium* utilized in creating GT alfalfa, and the herbicide itself were considered potential issues of concern and have been subsequently investigated. It should be noted at this point that Monsanto, the manufacturer of GT alfalfa does not allow GT alfalfa to be planted for sprouts (Hubbard, 2008); therefore, human direct consumption exposure to GT alfalfa appears to be minimal.

The U.S. FDA in 2004 conducted a safety assessment of the gene product and CP4 EPSPS protein to which the Agency concluded that the soil bacterium used to create GT alfalfa was not an allergen or pathogen and that the CP4 EPSPS gene and protein lacked structural similarities to any known allergens to humans. In humans, CP4 EPSPS protein has been shown to be readily degraded by digestive juices and has been evaluated by researchers to be non-toxic to mice when consumed at dose levels thousands of times higher than the expected human exposure. In addition, the CP4 EPSPS protein has been assessed previously for safety in approved genetically engineered lines that are readily consumed by humans such as canola, soybean, and corn and demonstrated little or no potential for toxicity in humans or animals. In 1996, GT soybeans were deregulated and no adverse health events have been reported for it or other GT food crops. Studies on the persistence of plant-derived recombinant DNA in livestock have indicated that feed ingested DNA fragments do survive in the terminal gastrointestinal (GI) tract and that uptake into the gut epithelium does occur. There is no evidence thus far to indicate that the recombinant DNA would be processed in a manner any different from the endogenous feed-ingested genetic material. Additionally, no deleterious effects of CP4 EPSPS protein or gene consumption by dairy cattle, livestock, or poultry nutritional parameters have been reported. Field observations of events J101 and J163 have revealed no negative effects of the transgene on non-target organisms such as bees and earthworms. No effects have been observed on pollen harvest behavior of worker bees, or on survival and development of honey bee eggs, larvae or pupa post exposure to the CP4 EPSPS protein.

One of the potential outcomes of commercializing GT alfalfa would be increased usage of the herbicide glyphosate. Glyphosate tends to adsorb strongly to soil particles and residues are not expected to leach into groundwater. Monitoring studies indicate that glyphosate and its primary metabolite amino methyl phosphonic acid (AMPA) are more likely to exist in surface waters in the vicinity of agricultural applications. The risk to human and animal health from glyphosate exposure depends on both the toxicity of the glyphosate and the likelihood of people or organisms coming into contact with the herbicide. Humans and animals can be exposed to glyphosate via one of three potential exposure routes: inhalation, dermal, and oral (ingestion). Considering the nature of glyphosate application, farm workers who spray the pesticide may be at most risk of exposure to glyphosate. A bio-monitoring study of pesticide applicators conducted in 2004 indicated that the highest estimated bodily adsorption of glyphosate in farm workers was 400 times less than the Reference Dose (RfD) established for glyphosate. The Reference Dose, established to be 2 mg/kg/day, is the safe level of glyphosate that can be consumed everyday for a lifetime in a human. This same study also indicated that people in the vicinity of farming operations, but not directly involved in glyphosate spraying operations had little detectable exposure to glyphosate (2,500 times less than RfD for children and 50,000 times less than RfD for spouses of farm workers). Considering the similarity of the glyphosate use

pattern and application rates in this study compared to those registered for use on GT alfalfa, bystander exposure attributed to the use of glyphosate on glyphosate-tolerant crops is expected to be negligible.

The toxicological review of the glyphosate herbicide indicates that it does not appear to result in adverse effects on development, reproduction, or endocrine systems in humans and other mammals. Under present and expected conditions of use, glyphosate herbicide does not seem to pose a health risk to humans. There is little evidence of any direct effect of glyphosate on arthropods in the field or in natural environments and the higher toxicity of glyphosate observed in aquatic invertebrates can mainly be attributed to the presence of surfactants used to make glyphosate herbicide products penetrate the leaf cuticle.

The CP4 EPSPS gene and protein, the *Agrobacterium* utilized in creating GT alfalfa and the herbicide glyphosate have been shown to be non hazardous to humans, livestock and non-target animals. The potential for food exposure in humans is considered negligible and concerns of exposure in non food scenarios were mitigated using data from bio-monitoring studies. There is little evidence that the gene, protein, or herbicide have any direct toxic effect on livestock or any deleterious outcome on nutritional parameters. Best Manufacturing Practices and Monsanto's (MTA) agreement are considered sufficient to alleviate concerns regarding cross-fertilization from GT to non-GT seed fields or from hay to seed fields. From the human food and animal feed viewpoint, commercializing of GT alfalfa does not pose a significant risk to human, livestock, and wildlife.

## 1.0 Introduction

The scope of this report covers how glyphosate-tolerant (GT) alfalfa could be present in human food and animal feed and the resulting health impacts of that presence.

Alfalfa an important forage crop in the U.S., farmers use alfalfa to feed their livestock (e.g., dairy cows, sheep, and goats). Alfalfa is an important animal feed because of its high protein and low fiber content. Alfalfa ranks fourth on the list of most widely grown crops, behind corn, soybeans, and wheat, and it is the third most valuable to agriculture. Alfalfa is consumed by humans as alfalfa sprouts, herbal supplement, or as tea; however, these are minor consumption categories comparatively to the amount used as animal forage.

### 1.1 Alfalfa Biology and Usage

Alfalfa (*Medicago sativa* L.) is a short-lived perennial herbaceous legume (Lesins and Lesins, 1979) and is exclusively an insect-pollinated crop that is pollinated by a small number of insect species, all of which are bees. A concise, recent review of several salient features of the biology of alfalfa within the context of gene flow was recently developed by an expert panel assembled by the National Alfalfa & Forage Alliance (Van Deynze et al., 2008), which is discussed in further detail in section 3 of this technical report.

Alfalfa grown for forage is the third-ranked crop in the U.S. by value and fourth ranked by total acreage. The number and location of alfalfa forage acres are closely associated with livestock operations, especially dairy. Alfalfa is highly valued for animal feed because of its high protein content, high intake potential, and digestibility. It can provide the sole plant component in many livestock feeding programs when supplemented with the proper minerals.

In the U.S., the vast majority of alfalfa is harvested as forage for use as animal feed; however, some minor food uses of alfalfa occur such as use of seed for sprout production and the production of dietary supplements or tea. In 2005, alfalfa dry hay produced in the U.S. was valued at over \$7.3 billion with 99 percent of it used on-farm or sold within the U.S. (USDA-NASS, 2006) for animal feed. Alfalfa hay export was valued at approximately \$192 million (USDA-FAS, 2006), representing roughly two percent of the total dry hay crop value. Of the domestic use total, less than one percent of alfalfa hay acres were harvested as organic in 2005 (USDA-NASS, 2006). Five countries (Japan, Republic of Korea, Taiwan, Canada and Mexico) account for 98 percent of the total metric tons exported. Japan imports 74 percent of the alfalfa exports from the U.S. and is consistently the largest annual importer of U.S. alfalfa hay.

### 1.2 Conventional Alfalfa Crop

Conventional alfalfa has been used for animal feed for decades. Alfalfa is also consumed minimally by humans (e.g., sprouts, dietary supplements, and herbal teas). Pollen from alfalfa may be a minor contributor to some respiratory allergic diseases such as asthma, but the risk to human health is minimal. In addition, alfalfa sprouts have been the source of several foodborne outbreaks due to bacterial contamination (US FDA, 1999). Epidemiological investigations suggest that seeds are the likely source in most, if not all, sprout-associated illness outbreaks. Seeds grown for sprouts have more stringent restrictions for chemical applications during

growing since the chemicals must be evaluated as food residues. FDA considers GT alfalfa not materially different from conventional alfalfa; therefore it is permitted for human consumption (US FDA, 2004a). However, Monsanto does not allow GT alfalfa to be planted for sprouts (Hubbard, 2008).

### 1.3 Gene and Gene Product

Production of a genetically engineered (GE) organism involves integration of a novel DNA sequence into the plant's genomic DNA, called a transformation event. The novel DNA construct contains all the genetic information needed to produce the new characteristic or trait and, in most instances, this includes production of a novel protein. The expressed gene product in Roundup Ready® alfalfa is a protein, 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), derived from a soil bacterium, *Agrobacterium* sp. CP4 strain, thus called CP4 EPSPS. The protein is a single polypeptide that is 455 amino acids long and structurally and functionally similar to the native plant EPSPS enzymes. The herbicide glyphosate inhibits an essential step in aromatic amine synthesis in plants. The CP4 EPSPS protein is not inhibited by the herbicide glyphosate; thus any plant with the protein is resistant to glyphosate application.

The U.S. Food and Drug Administration (FDA), the lead U.S. regulatory agency for review of the food and feed safety of GE crops, completed a voluntary consultation with FGI and Monsanto in 2004 regarding the safety of GT alfalfa (US FDA, 2004b). The FDA made the following assertions: the soil bacterium used to create GT alfalfa is not a known allergen or pathogen; the CP4 EPSPS gene and protein lack structural similarities to any allergen; the CP4 EPSPS protein is only a small portion of alfalfa; and while acute toxicity in mice was observed, allergenic responses associated with Roundup Ready® crops have not been reported by farm workers or members of the general population since the commercialization of these crops in 1996. FDA (2004b) did not review studies on dermal or inhalation toxicity of the CP4 EPSPS gene or protein, nor were any available at the time of this analysis.

### 1.4 Herbicides

There are several herbicide products containing glyphosate that are recommended for use on GT alfalfa. These products include: Roundup Original Max®, Roundup Weather Max®, and Roundup Ultra Max II® (Monsanto, 2008). According to Greenbook, an online database that partners with chemical manufacturers such as Monsanto to provide information about agricultural products, Honcho® and Honcho Plus® are also recommended for use on GT alfalfa (Greenbook, 2008). Each of these products contains between 41 and 48 percent glyphosate (Monsanto, 2004; 2007b; 2007d; 2007e; 2007f).

The adoption of GT crops has caused a shift in herbicide usage; generally glyphosate usage has increased while other herbicides have declined resulting in a reduction in total herbicide usage. Several reviews concerning GE crops and herbicide use have supported this conclusion (Brimner et al., 2005; Fernandez-Cornejo, 2006; Gianessi and Reigner, 2006; Kleter et. al., 2007; Sankula, 2006; Johnson et al., 2008). However, in 2004, Charles M. Benbrook asserted that herbicide usage increased based due to the adoption of herbicide-tolerant crops. The data set used to



determine these trends in herbicide usage were from USDA's National Agricultural Statistics Service (NASS), which is not comprehensive and the data differs yearly as to what is reported. For example, different states report glyphosate use from year to year for corn or soybeans. This discrepancy in reporting and data collection causes controversy over the exact amount of national use of herbicides. However, all analyses agreed that the herbicide glyphosate usage increased due to the adoption of GT crop technologies. GT alfalfa is cultivated almost identically to conventional alfalfa except for the use of glyphosate during post emergence.

Bio-monitoring studies confirm that agricultural workers who apply glyphosate to crops internalize some of the chemical (Curwin et al., 2007; Mandel et al., 2005). EPA (1993) determined in its RED for glyphosate that the chemical may be classified as either a Category III (i.e., slightly toxic; slightly irritating) or Category IV (i.e., practically non-toxic; not an irritant) toxicant. Toxicity and occupational exposure data exist for glyphosate, and this assessment utilizes these data to estimate exposure and risk to field workers.

## 1.5 Methodology

A literature search was designed to identify peer review articles and grey literature (e.g., government reports, State Agricultural Extension Office publications) on GT alfalfa and gene flow, toxicity, and occurrence in food or livestock feed (appendix A). Several DIALOG databases were searched. Google and Google Scholar search engines supplemented the DIALOG search. Alfalfa harvest statistics were obtained from USDA's National Agricultural Statistics Service (<http://www.nass.usda.gov/index.asp>). In addition, USDA's Economics, Statistics and Market Information System (ESMIS), which is a collaborative project between Albert R. Mann Library at Cornell University and USDA, provided information on alfalfa harvesting (<http://usda.mannlib.cornell.edu/MannUsda/homepage.do>). USDA's Agricultural Marketing Service also provided information on harvests (<http://www.ams.usda.gov>).

## 2.0 Glyphosate-Tolerant Alfalfa Hazard Identification

Alfalfa (*Medicago sativa* L.) is a perennial herbaceous legume pollinated by bees and cultivated primarily as forage for use as animal feed. Alfalfa is an important animal feed because of its high protein and low fiber content, and is a staple of most livestock diets, especially dairy cows (Martin et al., 2005). Monsanto Company and Forage Genetics International, jointly developed GT alfalfa, designated as events J101 and J163 that were genetically engineered for tolerance to the herbicide glyphosate (Roundup). The possibility of these genetically engineered varieties being present in food and feed supplies and the importance of the alfalfa crop, warrant a thorough assessment of the impacts, if any, of introducing the GT alfalfa crop for commercialization.

### 2.1 Glyphosate-Tolerant Alfalfa Biology

Glyphosate-tolerance in alfalfa was developed using *Agrobacterium*-mediated transformation to incorporate into the alfalfa genome the *cp4 epsps* coding sequence that produces a glyphosate-tolerant form of EPSPS. The protein is a single polypeptide that is 455 amino acids long and structurally and functionally similar to the native plant EPSPS enzymes. The enzyme 5-enolpyruvyl-shikimate-3-phosphate synthase (EPSPS) is inhibited by glyphosate, which prevents the plant from synthesizing the aromatic amino acids phenylalanine, tyrosine, and tryptophan. The CP4 EPSPS protein is not inhibited by the herbicide glyphosate; thus any plant with the protein is resistant to glyphosate application. Several studies have shown that conventional and GT alfalfa are compositionally and nutritionally similar, please refer to technical report *Character and Quality of Glyphosate Alfalfa Traits* (appendix U) for further details. Compositional analyses of the forage samples included proximates (protein, fat, ash and moisture), acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin, amino acids, and minerals (calcium, copper, iron, magnesium, manganese, phosphorous, potassium, sodium and zinc), as well as carbohydrates by calculation. Reviews on the nutritional quality of GE foods conclude there's no significant nutritional difference in conventional versus GE plants for food or animal feed (Flachowsky et al., 2005). Steckel and colleagues (2007) evaluated GT alfalfa for three years with glyphosate treatments ranging from 0.75 to 3 lbs a.e./acre for crop injury and feed quality. Levels up to 9 lb a.e./acre glyphosate over 3 years did not cause a reduction in yield or nutrition. The label rate for glyphosate application to GT alfalfa is no greater than 1.55 lb a.e./acre.

#### 2.1.1 CP4 EPSPS Gene and Protein Occurrence and Exposure

FDA considers GT alfalfa not materially different from conventional alfalfa (US FDA, 2004a). Monsanto does not intend to introduce GT alfalfa into the human food supply, either as compressed leaf material or as sprouts. GT alfalfa will be sold solely in the U.S. to producers of forage for use as animal feed.

##### 2.1.1.1 CP4 EPSPS Gene and Protein Detection Methods

After StarLink corn, a non-human food-use GE corn was found in the food supply, sampling and food surveillance was brought to public attention. Another incident was an accidental shipment of an unapproved GE corn variety for cultivation that occurred between 2001 and 2004 (Alexander et al., 2007). Labeling of products as not containing GE ingredients, such as those products having ‘GE-free’ claims, also bolsters the need for reliable and sensitive detection methods for GE food products. Methods for detecting GE materials range in their limits of detection. In many situations, a test will be required that not only detects the presence of GE material, but also measures the amount of GE content in the sample. All testing methodologies detect either the novel DNA or the novel protein. The major trait-specific or protein detection methods are immunoassays or Enzyme Linked Immunosorbent Assays (ELISAs), and make use of the properties of antibodies. ELISAs are easy to use, robust and cheaper than DNA detection methods but generally less sensitive (Griffiths et al., 2002). The most commonly used DNA amplification method is the Polymerase Chain Reaction (PCR), though there are other amplification methods to suit specific applications.

For each testing method, a Limit of Detection (LOD) is defined to show the sensitivity of the method. For example, a method with an LOD of 1 percent (w/w) for Roundup Ready® soy would be able to detect Roundup Ready® soy in a batch of soy flour when present as 1 percent (w/w) of the total soy flour (Griffiths et al., 2002). It is important to note that this LOD value written in an abbreviated form means the LOD for Roundup Ready® soy is 1 percent (w/w) of total soy flour if the product is comprised of 100 percent soy (Griffiths et al., 2002). For food products containing several ingredients, estimation of the LOD is less reliable. Using the previous example, if the 1 percent (w/w) GE soy flour were used as a baking ingredient in cake, the soy flour may make up only 0.5 percent (w/w) of the total cake ingredients. The GE soy would thus be only 0.005 percent (w/w) of the total sample, which would be well below the LOD for this method (Griffiths et al., 2002). The LOD is normally defined on a percent (w/w) basis, the actual measurement of GE ingredients is based on either DNA or protein and this DNA- or protein-based measurement is not necessarily directly transferable to a percent (w/w) measurement (Griffiths et al., 2002). Efforts are being made through various governments to develop reliable detection methods and monitoring plans. Labeling and traceability of GE foods has spurred the need for reliable detection methods (Alexander et al., 2007), discussed further in section 2.1.1.2. below. Some highly processed foods contain no traces of DNA and/or protein. In these cases, there is no analytical method available to identify whether these products are derived from GE materials.

#### 2.1.1.2 Labeling Standards

The United States does not require labeling of GE products. It is the responsibility of the producer/farmer to verify the absence or presence of GE material if needed through a contractual obligation, and/or to ensure that levels of GE material meet tolerance levels established by an end user. The default standard for certification as GE free has been taken to be zero percent in many cases, although experience shows that meeting such a standard is difficult. There have been proposals for setting maximum allowable levels in the range of 1 to 3 percent (Thomison and Loux, no date).

The labeling legislation is not well harmonized internationally (Griffiths et al., 2002). Whilst Australia has a tolerance level of 1 percent unintended GE material, other countries such as

Japan and Korea currently have a higher tolerance level of 5 percent (Griffiths et al., 2002). The requirement for labeling in the USA is voluntary. On the other hand, the European Commission (EC), on behalf of the European Union (EU), has proposed new legislation to drop the threshold for the presence of unintended GE content from 1 percent to 0.5 percent. The EU is also planning to adopt a process-based rather than the product-based GE food labeling approach, so that any product derived from gene technology would have to be labeled, even if the novel DNA and/or protein were completely removed. The commercial feed producer is required by EU legislation to label feed containing GE feed ingredients. At present, European Market Regulations 2003/1829/EC and 2003/1830/EC govern the use of GE ingredients intended for food, feed, and food additives. Threshold labeling at 9 g/kg (0.9 percent) for the unintended presence of approved GE material and 5 g/kg for GE materials not approved in Europe is required (Bakke-McKellep et al., 2007). In addition, a 0.5 percent labeling threshold has been mandated for GE crops that have been given a favorable risk assessment but are not yet approved within the EU. Unapproved varieties are managed with zero tolerance (Alexander et al., 2007). Products such as milk, meat, and eggs, and that are derived from livestock fed transgenic feeds are exempt from EU-labeling laws. Currently, only the EU and Switzerland have labeling regulations pertaining to GE feed (ISAAA, 2005). Figure Q-1 below illustrates the countries with GE food labeling, thresholds, and date of regulation.

Regulations concerning the labeling of GM food or feed products in select countries<sup>a</sup>

| Country                   | Labeling status                              | Threshold (percent)                               | Date of implementing threshold regulation |
|---------------------------|----------------------------------------------|---------------------------------------------------|-------------------------------------------|
| Australia and New Zealand | Mandatory                                    | 1                                                 | December 2001                             |
| Brazil                    | Mandatory                                    | 4                                                 | December 2001                             |
| Canada                    | Voluntary <sup>b</sup>                       | –                                                 | November 1994                             |
| China                     | Mandatory                                    | 0                                                 | July 2001                                 |
| Czech Republic            | Mandatory                                    | 1                                                 | Not available                             |
| European Union            | Mandatory <sup>c</sup>                       | 0.9, 0.5 food and feed                            | July 2003                                 |
| Hong Kong                 | Voluntary                                    | 5                                                 | February 2001                             |
| Israel                    | Mandatory <sup>d</sup>                       | 1                                                 | Not available                             |
| Japan                     | Mandatory for selected products              | 5                                                 | April 2001                                |
| Korea                     | Mandatory for selected products <sup>d</sup> | 3                                                 | 13 June 2001                              |
| Malaysia                  | Mandatory                                    | 3                                                 | Proposal                                  |
| Russia                    | Mandatory for selected products              | 5                                                 | 1 September 2002                          |
| Switzerland               | Mandatory                                    | 2 or 3 (feed <sup>e</sup> ), 0.5 (imported seeds) | Not available                             |
| Taiwan                    | Mandatory                                    | 5                                                 | Proposal                                  |
| Thailand                  | Mandatory for selected products              | 5                                                 | Proposal                                  |
| United States             | Voluntary                                    |                                                   | January 2001                              |

Data have been converted to SI units.

<sup>a</sup> Data from Jia (2003) and ISAAA (2005).

<sup>b</sup> Labeling required if safety concerns (allergenic, change in nutritional composition) exist.

<sup>c</sup> Labeling required at a 0.9% threshold for approved GM organisms or 0.5% for GM organisms given a favorable risk assessment but not yet approved. Includes both feed and food products.

<sup>d</sup> Labeling required only if recombinant DNA or proteins are detected.

<sup>e</sup> Threshold for feeds containing raw material of a single source is 3%. For mixed feeds, a threshold of 2% exists.

Figure Q-1: Regulations on GE food labeling throughout the world (Alexander et al., 2007)

### 2.1.1.3 Detection in Food Products

There is some literature available on the detection and quantification of GE material in various foods. In an Australian monitoring study (Griffiths et al., 2002), the GT trait was detected in soy flour, soy protein isolate, soy milk, snack foods, biscuits, powdered bread, and corn flour as illustrated in figure Q-2 below.

| Round           | Number  | Test Material                            | Ingredient          | GM Ingredient <sup>a</sup> |                    |                   | Laboratory results |              |        |
|-----------------|---------|------------------------------------------|---------------------|----------------------------|--------------------|-------------------|--------------------|--------------|--------|
|                 |         |                                          |                     | GM Trait                   | % of GM Ingredient | % in Test Product | No. Results        | % of results |        |
|                 |         |                                          |                     |                            |                    |                   |                    | present      | absent |
| 1               | 2301A   | Soy flour                                | Soy flour           | Roundup Ready              | 1                  | 1                 | 85                 | 94           | 6      |
|                 | 2301 B  | Soy flour                                | Soy flour           | Roundup Ready              | 0.2                | 0.2               | 81                 | 89           | 11     |
|                 | 2301 C  | Soy protein isolate                      | Soy protein isolate | -                          | 0                  | 0                 | 91                 | 91           | 9      |
|                 | 2301 D  | Soy protein isolate                      | Soy protein isolate | Roundup Ready              | 1                  | 1                 | 94                 | 99           | 1      |
|                 | 2301 E  | Soy protein isolate                      | Soy protein isolate | Roundup Ready              | 0.5                | 0.5               | 92                 | 98           | 2      |
| 2               | 2302 A  | Maize flour                              | Maize flour         | Bt176                      | 0.75               | 0.75              | 74                 | 97           | 3      |
|                 | 2302 B  | Maize flour                              | Maize flour         | -                          | 0                  | 0                 | 74                 | 26           | 74     |
|                 | 2302 C  | Maize flour                              | Maize flour         | Bt176                      | 1.5                | 1.5               | 74                 | 99           | 1      |
| 3               | 2303 A  | Soy flour                                | Soy flour           | -                          | 0                  | 0                 | 63                 | 16           | 84     |
|                 | 2303 B  | Soy flour                                | Soy flour           | Roundup Ready              | 2                  | 2                 | 63                 | 92           | 8      |
|                 | 2303 C  | Wheat flour/soy flour                    | Soy flour           | Roundup Ready              | 10                 | 0.5               | 63                 | 97           | 3      |
| 4               | 2304 A  | Maize flour                              | Maize flour         | Bt176                      | 0.5                | 0.5               | 98                 | 99           | 1      |
| 5               | GMO-05A | Soy milk powder with soy protein isolate | Soy protein isolate | Roundup Ready              | 1                  | 0.15              | 67                 | 100          | 0      |
| 6               | GMO-06A | Snack Food Crumbs                        | Soy flour           | Roundup Ready              | 0                  | 0                 | 57                 | 14           | 86     |
|                 | GMO-06B | Snack Food Crumbs                        | Soy flour           | Roundup Ready              | 2                  | Unknown           | 58                 | 95           | 5      |
| 7               | GMO-07  | Maize/soy flour mix                      | Soy flour           | Roundup Ready              | 1                  | 0.5               | 78                 | 96           | 4      |
|                 |         |                                          | Maize flour         | Bt176                      | 0.25               | 0.125             | 67                 | 91           | 9      |
|                 |         |                                          | Maize flour         | Bt11                       | 0                  | 0                 | 43                 | 53           | 47     |
| 8               | GMO-08A | Soy-based baked biscuit crumbs           | Soy flour           | Roundup Ready              | 2.5                | 0.05              | 91                 | 98           | 2      |
| 9               | GMO-09A | Soy in canned meat                       | Soy flour           | Roundup Ready              | 5                  | 0.1               | 81                 | 67           | 33     |
| 10 <sup>b</sup> | GMO-10A | Maize flour/wheat flour                  | Soy flour           | Roundup Ready              | 0                  | 0                 | 92                 | 4            | 96     |
|                 |         |                                          | Maize flour         | Bt176                      | 0.5                | 0.025             | 97                 | 86           | 14     |
|                 |         |                                          | Maize flour         | Bt11                       | 0                  | 0                 | 65                 | 6            | 94     |
|                 | GMO-10B | Soya flour/maize flour                   | Soy flour           | Roundup Ready              | 1                  | 0.25              | 107                | 97           | 3      |
|                 |         |                                          | Maize flour         | Bt176                      | 1                  | 0.025             | 91                 | 84           | 16     |
|                 |         |                                          | Maize flour         | Bt11                       | 0                  | 0                 | 65                 | 38           | 62     |
| 11 <sup>b</sup> | GM11A   | Soy flour/ wheat flour                   | Soy flour           | Roundup Ready              | 1.5                | 0.075             |                    | 90           | 10     |
|                 |         |                                          | Maize flour         | Bt176                      | 0                  | 0                 |                    | 8            | 92     |
|                 |         |                                          | Maize flour         | Bt11                       | 0                  | 0                 |                    | 0            | 100    |
|                 | GM11B   | Soy flour/ wheat flour                   | Soy flour           | Roundup Ready              | 0.5                | 0.025             |                    | 82           | 18     |
|                 |         |                                          | Maize flour         | Bt176                      | 0                  | 0                 |                    | 10           | 90     |
|                 |         |                                          | Maize flour         | Bt11                       | 0                  | 0                 |                    | 0            | 100    |
| 12              | GM12    | Powdered bread                           | Soy flour           | Roundup Ready              | 3                  | 0.01              |                    | 81           | 19     |

<sup>a</sup> % of GM ingredient is calculated as % (w/w) GM ingredient in total ingredient. % in Test Product is calculated as % (w/w) GM ingredient in total Test Material.

<sup>b</sup> Results for information only as Bt06M Maize Reference Materials withdrawn due to degradation

**Figure Q-2: Australian detection of genetically engineered material in various foods (Griffiths et al., 2002)**

### 2.1.1.4 Detection of CP4 EPSPS Gene or Protein in Downstream Animals

To date, no recombinant DNA sequences have been found in any organ or tissue sample from animals fed GE plants (Flachowsky et al., 2007). As described by the European Food Safety Authority (EFSA) in 2007 the fate of recombinant DNA from genetically engineered plants or resultant proteins are dependent on the following four factors:

- the fate of the recombinant DNA and protein during the feed processing and ensilaging;
- the fate of the recombinant DNA and protein in the gastrointestinal tract of animals fed with the GE feed;
- the potential absorption of the digested pieces of DNA or protein into animal tissues/products;
- and
- the potential of biological functionality of absorbed DNA and protein fragments.

No study has found that mechanical treatment (e.g. baling, chopping, processing) of animal feed has effect on DNA stability (EFSA, 2007). Digestion in the gut requires DNA and protein to be broken down to the building blocks of fragments and nucleotides; proteins into polypeptides, oligopeptides, and amino acids; the transformation DNA and protein are digested in similar manner to native DNA or proteins. This rapid breakdown in the stomach and upper portions of the small intestine minimizes the chance of adsorption of the transformed DNA or protein. From EFSA:

“In 2006, the Council for Agricultural Science and Technology (CAST) published a paper entitled “Safety of Meat, Milk, and Eggs from Animals Fed Crops Derived from Modern Biotechnology” (CAST, 2006). This report indicates that no intact or immunologically reactive fragments of recombinant plant proteins or DNA have been detected in samples of meat, milk, eggs, lymphocytes, blood, and organ tissue from production animals fed crops modified for agronomic traits using recombinant DNA technology.”

In field tests, CP4 EPSPS was found in GT soybean at 0.1 percent in chicken feed (Ash et al., 2003) by an ELISA method; no detectable amounts of CP4 EPSPS protein were in whole egg, egg albumen, liver, or feces of the chickens fed GT soybeans.

Conventional PCR/Southern Blot and an ELISA method were utilized to determine if transgenic DNA or protein were detectable in pigs fed GT soybeans (Jennings et al., 2003). The routine LOD for the present PCR/Southern blot detection of *cp4 epsps* and *le1* gene fragments was approximately 2.5 pg (extremely sensitive) of purified GT soybean genomic DNA per reaction. The CP4 EPSPS competitive immunoassay had an LOD of approximately 94 ng (1000 fold less sensitive than the PCR/Southern Blot, yet still sensitive) of CP4 EPSPS protein/g of pork loin tissue extract (~94 ppb). There was an absence of detectable levels of fragments of either transgenic DNA or protein, which confirms DNA and proteins undergo degradation in animal digestive tracts (Jennings et al., 2003).

Quantitative real-time PCR and conventional PCR was used to evaluate glyphosate-tolerant canola *cp4 epsps* transgene in the intestines, rumen, or feces of sheep feed canola meal (Alexander et al., 2004). Digestion of plant material and release of transgenic DNA can occur in the small intestine of sheep. The free transgenic DNA is rapidly degraded at neutral pH in small intestine duodenal fluid, thus reducing the likelihood that intact transgenic DNA would be available for absorption through the Peyer’s Patches further down in the distal ileum of the small intestine (Alexander et al., 2004).

The persistence of plant-derived recombinant DNA in sheep and pigs fed genetically engineered (GT) canola was assessed by Sharma et al. (2006) utilizing Polymerase Chain Reaction (PCR) and Southern hybridization analysis of DNA extracted from digesta, gastrointestinal (GI) tract tissues, and visceral organs. This study confirmed that feed-ingested DNA fragments (endogenous and transgenic) do survive to the terminal GI tract and that uptake into gut epithelial tissues does occur. A very low frequency of transmittance to visceral tissue was confirmed in pigs, but not in sheep. There was no evidence to suggest that recombinant DNA would be processed in the gut in any manner different from endogenous feed-ingested genetic material.

### 2.1.2 CP4 EPSPS Gene and Protein Toxicity

The U.S. Food and Drug Administration (FDA), the lead U.S. regulatory agency for review of the food and feed safety of genetically engineered crops, completed a voluntary consultation with FGI and Monsanto in 2004 regarding GT alfalfa (US FDA, 2004b). Specifically, FDA (2004b) made the following conclusions of the gene product, CP4 EPSPS:

the soil bacterium used to create GT alfalfa is not a known allergen or pathogen;  
the CP4 EPSPS gene and protein lack structural similarities to any allergen;  
the CP4 EPSPS protein is only a small portion of alfalfa; and while acute toxicity in mice was observed,  
allergenic responses associated with Roundup Ready® crops have not been reported by farm workers or members of the general population since the commercialization of these crops in 1996.

FDA (2004b) did not review studies on dermal or inhalation toxicity of the CP4 EPSPS gene or protein, nor were any available at the time of this analysis. Immunological response in Sprague-Dawley mice were negative after exposure to purified EPSPS protein (Chang et al., 2003)

## 2.2 Herbicide Glyphosate Use on GT Alfalfa

Glyphosate is among the most widely used pesticides by volume in the United States; glyphosate use data for GT alfalfa were only found for Monsanto products. The only end use herbicide products approved and that have a subsequent proposed maximum use rate for GT alfalfa are the following Monsanto glyphosate herbicide products: Honcho, Honcho Plus, Roundup Original MAX, Roundup WeatherMAX, and Roundup Ultra MAX II. Glyphosate products can be formulated to have different concentrations of glyphosate acid per gallon of product. To improve handling, performance, and concentration, the glyphosate acid is formulated as a salt compound. The term acid equivalent (a.e.) refers to the weight of the glyphosate acid, which is herbicidally active, while the term active ingredient (a.i.) is the weight of the glyphosate acid plus the salt. It is best to refer to a.e. when comparing glyphosate products and rates. For the quantitative ecological Tier 1 risk assessment (*Potential Impacts To Wildlife, Amphibians, Plants And Ecosystems From Increased Glyphosate And Other Chemical Usage*; appendix N), human health risk assessment (*Health And Safety Risks From Increased Glyphosate And Other Chemical Usage On Humans (Exclusive Of Field Workers)*; appendix L), and occupational health risk assessments (*Health And Safety Risks To Field Workers*; appendix M), the maximum use rate of 7.98 lbs a.e./acre year, with a single maximum use rate of 1.99 lb a.e./acre and a minimum reapplication rate of 7 days was used. The values used for this risk assessment are higher than the maximum label rate for glyphosate on GT alfalfa (maximum single use rate is 1.55 lbs a.e./acre, and maximum yearly rate 5.96 lbs a.e./acre for application of glyphosate to GT alfalfa). Each of the technical reports listed previously provide in depth detail on the toxicity, exposure, and quantitative risk assessment of glyphosate usage on GT alfalfa.

### 2.2.1 Glyphosate Occurrence and Exposure



#### 2.2.1.1 Glyphosate Overview of the Chemical Fate and Occurrence

Glyphosate adsorbs strongly to soil and is not expected to move vertically below the six inch soil layer; residues are expected to be immobile in soil (US EPA, 1993, 2006). Glyphosate is primarily degraded by soil microbes in the environment. The major degradate of this process is aminomethyl phosphonic acid (AMPA), which further degrades in the soil to carbon dioxide. The half-life of glyphosate in soil laboratory studies is two days (US EPA, 1993, 2006). In agricultural soils, the disappearance time (DT50) of glyphosate ranges from 1.7 to 197.3 days, but is typically less than 60 days depending upon edaphic and climatic conditions (Giesy et al., 2000). Due to glyphosate and AMPA's strong adsorptive characteristics, they are not likely to leach to groundwater from the soil; however, monitoring data by USGS demonstrates low amounts of glyphosate and AMPA in groundwater, especially in heavy agricultural areas. In a USGS monitoring study of surface water, groundwater, and soil conducted from 2001 to 2006, the metabolite AMPA was observed more frequently than the parent compound glyphosate (Scribner et al., 2007). Glyphosate and its metabolite AMPA were found in surface water more frequently than groundwater. High levels of glyphosate and AMPA were noted in ground and surface waters were observed when samples were taken from an area with close to agricultural areas that had a recent application of glyphosate coinciding with a recent rain event. Glyphosate was found in rain water; however, this was due to glyphosate's association with particulate matter (dust) and not to its existence as vapor. For an in depth discussion environmental levels of glyphosate in the soil, water, and air, refer to the Technical Report *Effects of Changes in Farming Practices on Water, Soil and Air Due to Use of Glyphosate-Tolerant Alfalfa* (appendix J).

#### 2.2.1.2 Glyphosate Exposure

The Technical Reports *Potential Impacts To Wildlife, Amphibians, Plants And Ecosystems From Increased Glyphosate And Other Chemical Usage* (appendix N), *Health And Safety Risks From Increased Glyphosate And Other Chemical Usage On Humans (Exclusive Of Field Workers)* (appendix L), and *Health And Safety Risks To Field Workers* (appendix M) provide greater detail on glyphosate exposure, refer to these technical reports for further details. A brief overview is provided in this section.

People can be exposed to glyphosate in three ways:

- 1) Inhaling glyphosate (inhalation exposure),
- 2) Absorbing glyphosate through the skin (dermal exposure), and
- 3) Ingesting glyphosate (oral exposure).

These exposures are highly dependant on the use of glyphosate. Glyphosate could enter the body by any one or all of these routes. Glyphosate exposures include agricultural (food); home and personal use (several weed killers contain glyphosate); glyphosate applied to agricultural or residential properties that make their way into the drinking water; or occupational exposure for agricultural workers, field workers, or pesticide applicators. The risk to human and animal health from glyphosate exposure depends on both the toxicity of the glyphosate and the likelihood of people or organism coming into contact with it (exposure).

Listed below are the various exposures scenarios for GT alfalfa:

- Inhalation exposure – agricultural or general public inhaling glyphosate spray
  - Glyphosate does not exist as a vapor under normal conditions; therefore, it is inhaled, small droplets in a aerosolized spray can be inhaled or ingested
- Inhalation exposure – animal inhaling glyphosate spray
  - Glyphosate does not exist as a vapor under normal conditions; therefore, it is inhaled, small droplets in a aerosolized spray can be inhaled or ingested
- Dermal exposure – agricultural or general public absorbing glyphosate during application or during a spill
  - Glyphosate is poorly absorbed through the skin
- Dermal exposure – agricultural or general public absorbing glyphosate from recently treated plants
  - Glyphosate is poorly absorbed through the skin
- Dermal exposure – animals absorbing glyphosate from recently treated plants
  - Glyphosate is poorly absorbed through the skin
- Oral exposure – consuming glyphosate-tolerant alfalfa (humans: tea, sprouts, or herbal supplement; animals: consuming alfalfa)
- Oral exposure – agricultural worker or general public accidental ingestion
- Oral exposure – animal accidental ingestion
- Oral exposure – drinking water containing glyphosate consumed by human
- Oral exposure - drinking water containing glyphosate consumed by animal

The US EPA's toxicological database on glyphosate is considered adequate and complete (US EPA, 2006; 1993), and based on these data, glyphosate is considered to be a toxicologically low-risk herbicide (Cerdeira and Duke, 2006). EPA concluded in (US EPA, 1993, 2006a, 2006b) that glyphosate does not pose a significant risk to human and ecological health, as do the three technical reports listed above that support this EIS. EPA's conclusion that glyphosate does not pose a significant risk to farm workers is confirmed with the *Farm Family Exposure Study* (Acquavella, et al. 2004) a biomonitoring study of pesticide applicators. This biomonitoring study determined that the highest estimated bodily adsorption of glyphosate as the result of routine labeled applications of registered glyphosate-based agricultural herbicides to crops, including glyphosate-tolerant crops, was approximately 400 times lower than the reference dose (RfD) established for glyphosate. Reference dose is the safe level of glyphosate that can be consumed everyday for a lifetime in a human. Furthermore, investigators determined that 40 percent of applicators did not have detectable exposure on the day of application, and 54 percent of the applicators had an estimated bodily adsorption of glyphosate more than 1000 times lower than the RfD (Acquavella, *et al.*, 2004). Use patterns and rates for GT alfalfa are similar to most GT agronomic practices, and in some cases the use pattern for GT alfalfa is less intensive because the perennial nature of alfalfa eliminates the need for annual pre-plant burn down applications which are common in most agricultural crop production. Therefore, the deregulation of glyphosate-tolerant alfalfa would not significantly increase the exposure risk to pesticide applicators.

The biomonitoring study also found little evidence of detectable exposure to individuals on the farm who were not actively involved in or located in the immediate vicinity of labeled applications of glyphosate-based agricultural herbicides to crops. Considering the similarity of the use pattern and application rates of the glyphosate products in this study compared to those registered for use on GT alfalfa and GT crops in general, bystander exposure attributed to the use of glyphosate on glyphosate-tolerant crops is expected to be negligible. However, upper estimates of exposure may be detrimental to infants consuming fruit and all age groups consuming vegetables may be at risk of adverse effects associated with acute exposure to glyphosate. It should be noted, though, that the upper estimates of risk are based on highly conservative fruit and vegetable intake rates; thus it is anticipated that only a very small number of individuals will have this magnitude of exposure and therefore be at this level of risk, further detail can be found in technical report *Health And Safety Risks From Increased Glyphosate And Other Chemical Usage On Humans (Exclusive Of Field Workers)* (appendix L).

#### 2.2.1.3 Glyphosate Surfactant Occurrence and Exposure

Various formulations of glyphosate contain POEA at a level of up to approximately 20 percent (200 g/L). Tallow contains a variety of fatty acids (e.g., oleic, palmitic, stearic, myristic, and linoleic acids), as well as smaller amounts of cholesterol, arachidonic, elaidic, and vaccenic acids.

#### 2.2.1.4 Glyphosate Degradate Occurrence and Exposure

Glyphosate is degraded by soil microbes in the environment to primarily form degradate aminomethyl phosphonic acid (AMPA), which further degrades in the soil to carbon dioxide. AMPA has strong adsorptive characteristics and is not likely to leach to groundwater from the soil; however, monitoring data by USGS demonstrates low amounts of glyphosate and AMPA in groundwater, especially in heavy agricultural areas. A USGS monitoring study of surface water, groundwater, and soil conducted from 2001 to 2006 showed that AMPA was observed more frequently than the parent compound glyphosate (Scribner et al., 2007). AMPA was also found more frequently in surface water than groundwater.

### 2.2.2 Glyphosate Toxicity and Exposure

#### 2.2.2.1 Glyphosate Surfactant Toxicity

While surfactants are typically classified as “inert” components in herbicides, they are not toxicologically inert. In many cases, inerts are found to be more toxic than the herbicide itself (USDA, 2003).

A study evaluating the toxicity of the POEA surfactant included a series of teratology tests in rats using glyphosate (98.7 percent purity), POEA used in glyphosate formulations, and the phosphate ester neutralized POEA. Groups of pregnant female rats were dosed with glyphosate at 300, 1,000, or 3,500 mg/kg/day; POEA at 15, 100, or 300 mg/kg/day, or the neutralized POEA at 15, 50, or 150 mg/kg/day on days 6 through 19 of gestation. Results indicated that severe maternal poisoning occurred at the 3,500 mg/mg/day dose of glyphosate, in association with reduced fetal body weight and sternal ossification, as well as fetal death. At a dose of 300

mg/kg/day of POEA and 150 mg/kg/day of neutralized POEA maternal deaths were also reported. Other noteworthy results in dams were signs of mild clinical toxicity and decreased food consumption that occurred at a dose of 100 mg/kg/day POEA surfactant. No fetotoxic effects were reported at any dose level. Based on these results, the recommended NOAELs for glyphosate, POEA, and neutralized POEA were 1000 mg/kg/day, 15 mg/kg/day, and 50 mg/kg/day, respectively (USDA, 2003).

There has been some debate regarding the acute toxicity of POEA and the determination of its LD<sub>50</sub> value compared to glyphosate. It is generally agreed that the acute toxicity of glyphosate formulations (glyphosate and surfactant; LD<sub>50</sub> in rats 5400 mg/kg/day) is almost equivalent to that of glyphosate (LD<sub>50</sub> in rats 5600 mg/kg/day) (USDA, 2003). Additionally, based on drinking water studies on both glyphosate and Roundup® (i.e., glyphosate with POEA), the surfactant does not affect the rapid elimination rate of glyphosate in mammals (NTP, 1992).

#### 2.2.2.2 Glyphosate Degradate Toxicity

Based on toxicological considerations, a committee of the Health Effects Division (HED) at the EPA's Office of Pesticides Program (OPP) has previously determined that AMPA need not be regulated regardless of levels observed in foods or feeds. Consequently, the terminal residue to be regulated in plants and animals is glyphosate *per se* and AMPA is not included in either the tolerance expression or the risk assessment.

### 2.3 Summary of Findings

The incorporation of the CP4 EPSPS gene into the alfalfa genome allows the ability to identify and quantify its presence or absence in food and feed, especially from the viewpoint of farmers wanting to cultivate non-GE alfalfa.

The lack of detectable presence of intact or immunologically reactive fragments of recombinant plant proteins or DNA in samples of meat, milk, eggs, lymphocytes, blood, and organ tissue obtained from production animals fed GE crops may be partly attributable to the lack of sensitivity of detection methods. More sensitive detection methods could shed more light on this issue. The identified presence of feed-ingested DNA fragments (endogenous and transgenic) in the terminal GI tract in a few cases indicates that uptake into gut epithelial tissue is possible. However, it is suggested that recombinant DNA is likely to be processed in the gut in a manner no different from endogenous feed-ingested genetic material. This shows that the CP4 EPSPS is easily metabolized in the gut of humans and livestock animals. Although CP4 EPSPS can be detected to some degree in processed foods it is not expected to have any toxic effect on humans.

Occupational exposure to glyphosate, AMPA and POEA is expected, especially for farm workers but biomonitoring data shows no cause for concern.

### 3.0 Glyphosate-Tolerant Alfalfa and Unintended Presence

Alfalfa seed growers wish to maintain the genetic integrity of their crops, and in order to maintain variety purity, seed crops are grown under conditions that are designed to keep gene flow restricted to individuals grown in the same field. Two factors that influence the severity and likelihood of breakdowns in seed crop integrity are cross-contamination due to equipment carry-over and gene flow due to cross-pollination.<sup>55</sup> This chapter discusses gene flow due to cross-pollination. The Association of Official Seed Certifying Agencies (AOSCA) and the international Organization for Economic Co-operation and Development (OECD) have developed alfalfa seed production practices that enable growers to meet the Federal Seed Act (7 CFR 201) requirements of greater than 99 percent variety purity for certified seeds and greater than 99.9 percent variety purity for foundation seeds.

With the introduction of glyphosate-tolerant (GT) alfalfa, farmers who want to grow seed or hay crops that have no GT traits<sup>56</sup> questioned whether the AOSCA standards are adequate to meet their needs. Different thresholds for percentage of unintended presence are discussed below:

- Zero (GE-free)<sup>57</sup> – Zero is not statistically provable. All testing methods destroy the sample. Therefore, to be useful, the test can only be run on a portion of the lot.
- No transgene DNA detected by PCR – PCR is the most sensitive test available and a negative result is considered to represent zero, even though true zero is not verifiable on a large sample. PCR is expensive (\$250-\$325 each test) and currently needs to be performed in a laboratory (Mueller, 2005).
- No transgene product (protein) detected by antibody strip test – Tests for transgene protein are not as sensitive as DNA tests, however, they can be field portable and much cheaper (\$5-\$10 each) than PCR tests (Mueller 2005). They are also commercially available and are a standard in the field of testing for GM traits. No detection using an antibody strip test is also often referred to as “zero,” even though statistically it is not. Using a standard strip test protocol to test five 600 seed samples from one seed lot, if all five samples test negative for the transgene protein, then there is a 95 percent confidence that any undetected impurity is less than 0.1 percent (FGI 2007).
- Forage Genetics International (FGI) has a company goal of less than 0.5 percent cross-pollination for all their seed concerning the GT trait. Their current Best Practices achieve 0.180 percent or less unintended presence.
- If more than 0.9 percent transgene protein is detected then the lot must be labeled “genetically modified organism” (GMO) in the European Union.
- If more than one percent transgene protein is detected, then the lot must be labeled GMO in Australia and Brazil.
- If more than three percent transgene protein is detected, then the lot must be labeled GMO in Korea.

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<sup>55</sup> Intentional presence due to sabotage is also possible, but is not discussed in this report. Inadvertent seed spread due to losses during production and transportation (leaky handling system) are also not addressed in this report (Mallory-Smith and Zapiola, 2008).

<sup>56</sup> “GT trait” refers to both the DNA and the protein it encodes which result in the glyphosate tolerant phenotype. Transgene refers to the DNA, except when followed by “product” or “protein.”

<sup>57</sup> Genetically modified (GM), genetically modified organism (GMO), and genetically engineered or genetically enhanced (GE) are all roughly synonymous terms.

- If more than five percent transgene protein is detected, then the lot must be labeled GMO in Japan.
- In the U.S. National Organic Program (NOP), “certified organic” crops are grown without any intentional inclusion of transgenic seed. Testing for transgene DNA or protein is not required.

Table Q-1 presents nine possible scenarios of gene flow. Each of these scenarios are discussed in this appendix, but are summarized in table Q-1. These nine scenarios are discussed further in section 3.8. The likelihood of viable seed production from each of these scenarios depends on:

- the level of flowering (percent bloom, amount of pollen present),
- the timing of flowering (synchronized flowering),
- bee activity, bee species,
- distance between fields, and
- whether the pollinated flower is cut before seed is produced.

**Table Q-1. Relative Potential for Gene Flow Between Populations of Alfalfa (requires that viable seed is produced) (adapted from Van Deynze et al., 2008)**

| Pollen Donor                   | Pollen Acceptor                                                                                                                                                                                                                                      |                                                                                                                    |                                                                                                                                                                                                  |
|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                | Seed field                                                                                                                                                                                                                                           | Hay field                                                                                                          | Feral and other alfalfa                                                                                                                                                                          |
| <b>Seed field</b>              | Without distance between fields, cross pollination between fields would occur at an undesirable rate (if flowering time overlapped). FGI Best Practices that include distance between fields can manage cross-pollination to below 0.5 percent.      | Lowest risk of gene flow because hay is cut before seed is produced.                                               | Feral populations should be controlled near seed fields to preserve seed purity. However, if feral plants are present, they will likely be cross-pollinated by seed field pollen.                |
| <b>Hay field</b>               | The percent bloom at harvest will influence how much pollen could potentially be transported to seed fields. Mowing hay prior to 10 percent bloom and distance (350 to 600 feet) from seed fields can manage cross-pollination to below 0.01 percent | Lowest risk of gene flow out of the nine scenarios. Even in fields that bloom, hay is cut before seed is produced. | The percent bloom at harvest will influence how much pollen could potentially be transported to feral populations. Mowing hay prior to 10 percent bloom can reduce pollen availability.          |
| <b>Feral and other alfalfa</b> | Feral populations need to be controlled near seed fields, or variety purity can be compromised. (Or the seed field edges can be harvested as a separate crop.)                                                                                       | Lowest risk of gene flow because hay is cut before seed is produced.                                               | Gene flow between feral individuals that are close to each other is likely. Gene flow between feral populations depends on proximity, pollinators, flowering timing, and environmental stresses. |

There are different ways to define “populations” of alfalfa. The three population definitions used in this appendix and in table Q-1 are as follows (based partly on Bagavathiannan and Van Acker 2008):

- Hay field population – agricultural field that is intentionally planted with alfalfa and is harvested for hay (may also include some grazing).
- Seed field population – agricultural field that is intentionally planted with alfalfa and is harvested as seed stock.
- Feral and other alfalfa –
- Feral – alfalfa growing on any non-agricultural land (including roadsides, fences, waste lots) that reproduces without intentional human inputs, including reseeding. This is considered the “naturalized” population in the U.S. because alfalfa was introduced to the continent at least 200 years ago (Putnam et al., 2001).
- Habitat/rehabilitation/erosion control – alfalfa that is intentionally sown (most likely in a seed mix), but is not managed after planting.
- Rangeland – seed may be sporadically sown for grazing, but land is not mowed for regular hay harvest, populations are mostly self sustaining.
- Volunteer – alfalfa growing out of rotation in an agricultural field with another crop (e.g., corn).
- Escaped volunteer – alfalfa from seed that escaped from an agricultural field (this is the first generation of a feral population). Escaped volunteers may not persist past a generation or two, depending on conditions.

Key information necessary for evaluating the likelihood of gene flow between populations includes:

- Distribution and quantity of pollen from seed, hay, and feral sources
- Geographic distribution of seed and hay fields, and feral populations
- Temporal distribution of flowers within seed and hay fields, and feral populations
- Seed purity standards and how those standards are achieved and monitored
- Bee behavior and data on bee facilitated cross pollination

### 3.1 Alfalfa Reproduction

Alfalfa is a perennial crop that requires cross-pollination for fertilization, which is performed by insect pollinators. The primary insect pollinators are alfalfa leafcutter bees (*Megachile rotundata*), honey bees (*Apis mellifera*), and alkali bees (*Nomia melanderi*). Alfalfa must bloom, be cross-pollinated by insects, set fruit, and then dehisce seed in order to have offspring. Alfalfa requires at least four weeks of appropriate environmental conditions (temperature, sunlight, nutrients, and water) before forming reproductively mature floral buds, and then four to six weeks after that to form mature seeds after pollination (Rogan and Fitzpatrick, 2004). Viable seeds that fall near adult alfalfa have a harder time growing because they must compete for nutrients with the already established adults, and adult alfalfa plants secrete an autotoxic substance into the soil that inhibits root growth in seedlings (Xuan et al., 2005). In fact, reseeding fields to fill gaps from dead plants is not recommended, as the new plants do not compete efficiently enough to survive (Orloff et al., 1997). However, alfalfa does have a hard

seed that can persist in the environment for several years and alfalfa can shatter and spread seed before harvest (Mallory-Smith and Zapiola, 2008).

Gene flow occurs between populations when genetic information from one population is expressed in the offspring of another population. In plants this can occur through outcrossing, or mating between two different individuals. Some plants primarily self-pollinate, which minimizes gene flow because in those cases, under most conditions, genetic information is rarely exchanged between individuals. Other plants, like alfalfa, mostly outcross, and therefore face the possibility of gene flow between populations. It very rarely self pollinates because of self-incompatibility through failed germination of viable pollen or abnormal pollen tube growth (Bauchan et al., 1990), and instead relies on insects for pollination.

### 3.2 Genetic Integrity

As mentioned above, for alfalfa, pollination and thus gene flow is required for seed production. Alfalfa seed farmers would like to keep pollen flowing within a field, but not between fields. This presents problems when the most common alfalfa pollinators, bees, do not respect farmer field boundaries. Therefore, controlling how pollen is distributed within and among alfalfa fields is dependent on knowledge of bee behaviors and ability to design seed production systems that regulate pollen flow within certain areas, and at the same time restrict pollen flow to other unintended areas. It should be noted that pollen flow and gene flow are not synonymous terms even though they are sometimes used interchangeably. For example, pollen may land on a flower and pollinate it, but if the plant is mowed before seed sets, then gene flow has not occurred.

### 3.3 Pollen from Alfalfa Hay

As noted in table Q-1, the degree to which alfalfa hay can be a source of pollen depends on percentage bloom at harvest. Alfalfa grown for hay will be mowed before setting seed, except in exceptional circumstances which are not explored in this report (e.g., extreme weather events such as tornados that might devastate a local community). Therefore hay fields are the least likely pollen-accepting population of alfalfa. There are numerous citations that claim that alfalfa hay is typically mowed before 10 percent bloom (table Q-2). Because alfalfa hay comprises the majority of the geographic footprint of alfalfa, this assumption (harvest at <10 percent bloom) and possible exceptions to this assumption are explored in this appendix. Key information for estimating potential pollen flow from alfalfa hay is how much the field blooms before it is harvested. Monsanto requires that farmers sign a Monsanto Technology/Stewardship Agreement (MTA) which stipulates that farmers must harvest GT alfalfa hay prior to 10 percent bloom (Monsanto, no year). Presumably farmers that prefer to harvest later would not adopt GT alfalfa or would change their harvesting time. No information on farmer compliance with the MTA was found. The discussion in this section investigates the premise that alfalfa hay is only rarely harvested later than 10 percent bloom. The discussion does not apply to GT alfalfa if farmers comply with the MTA.



### 3.3.1 *Recommended Harvest Timing*

Some of the factors that influence farmers' timing of hay field harvests include:

- Predicted quality – Younger plants have higher forage digestibility and protein content, therefore hay from young plants receives the highest grades (and highest price per ton).
- Predicted yield – Yield is based on the biomass of the harvested portion of the plant. Alfalfa reaches its greatest biomass and therefore greatest yield potential at full bloom. During seed set yield decreases. A full bloom field may produce the highest tonnage, but the hay receives a lower grade based on digestibility and protein content.
- End hay user needs (self or buyer) – The highest grade hay is best for dairy cattle because it maximizes milk production and merits its higher price. Heifers (immature dairy cattle), beef cattle, horses, and other livestock do not benefit from the highest grade hay in a way that provides economic gain to farmers; therefore lower grades are acceptable and even desirable for these animals.
- Stand health – Mowing patterns can influence stand health and longevity.
- Root reserves – Stand life can be reduced if alfalfa is repeatedly cut before root reserves are restored. In regions that experience harsh winters adequate root reserves are essential for plant survival. Root reserves are at their lowest during the bud stage and are at their highest from full bloom to seed set (Shroyer et al., 1984; Hesterman and Durling, 1991; Howley and Wright, 1991).
- Weed control – In fields with severe weed problems, early mowing can rescue a stand (Orloff et al., 1997).
- Pest control – Mowing can reduce insect pests (Lee et al., no year).
- Weather – Wet weather can delay mowing and impact drying (for baled hay).

The factors presented above are illustrated by examples in table Q-2. Most of the sources of information in table Q-2 are state university Agricultural Extension publications. There is general agreement that the best balance between high quality and yield is to harvest at or before 10 percent bloom (table Q-2; Undersander and Pinkerton, 1989).

**Table Q-2. Alfalfa Dry Hay Harvest Statistics and Recommendations**

| State        | Growing Region              | Percent of Harvest Acres (2005) | Percent of Organic Harvest Acres (2005) | Harvest Advice                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Source                |
|--------------|-----------------------------|---------------------------------|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| South Dakota | North Central               | 10.70                           | 6.82                                    | Alfalfa for hay is harvested in generally one to four cuttings per year, depending on location within the state. Western areas of the state often receive only one cutting per year due to low rainfall, whereas southeast South Dakota usually can support four and occasionally five cuttings per year. Highest quality hay is taken when alfalfa plants are in pre-bud to early bud.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Wilson, no year       |
| Montana      | Winter Hardy Inter-mountain | 7.80                            | 2.60                                    | Alfalfa plants are injured or weakened if cut when the root reserves are low—usually three weeks after growth begins or after cutting. Harvest timing is most critical in the fall. Alfalfa plants must be able to make sufficient fall growth to store large quantities of carbohydrates in the roots. These reserves help to prevent winterkill and provide rapid spring growth. To assure adequate food reserves in the roots, the alfalfa plants should have at least 30 days of regrowth before being killed by frost. Determine when the first killing frost for your area occurs, and make your last cutting 30 days before that date. Alfalfa regrowth should not be harvested or pastured in the fall until several killing frosts cause the plants to become dormant. Average dates of killing frosts for most areas of Montana are available and should be considered when scheduling the last hay harvest. Harvesting at the early-bloom stage will reduce leaf and stem shatter and cut the losses. Harvesting the forage as silage can save considerable feed value. Weather forecasts should be watched closely, since it is better to delay cutting than to suffer excessive rain damage. | Baldrige et al., 1985 |

| State        | Growing Region | Percent of Harvest Acres (2005) | Percent of Organic Harvest Acres (2005) | Harvest Advice                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Source               |
|--------------|----------------|---------------------------------|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|
| North Dakota | North Central  | 7.35                            | 10.09                                   | <p>NEW PLANTINGS--Alfalfa harvested during the establishment year should grow to the 10 to 25 percent bloom growth stage before harvesting the first cutting to enable the young plants to become well established, although earlier harvest has not been detrimental to stands in high-moisture areas. Alfalfa seeded with a companion crop usually does not grow tall enough after removing the companion crop for an economical forage harvest. If sufficient growth is obtained, it usually occurs in September, and harvest should be delayed until air temperatures have dropped low enough to restrict regrowth, or until just prior to or immediately after the first killing frost.</p> <p>ESTABLISHED STANDS--should be harvested using a combination of growth stage and calendar date to determine the best harvest date. The first cutting must usually be taken before mid-June to allow time for three cuttings prior to August 20-25 in an average year. The first crop should be harvested by the 10 percent bloom stage (late bud to early bloom), especially in the Red River Valley area or under irrigation where three annual cuttings usually are obtained. Delayed harvest lowers the quality of the first harvest the most. Advantages of an early harvest are that a near maximum yield of quality forage is obtained, root reserves for regrowth have been adequately replenished, and soil water usually remains to initiate new growth. Forage quality of second and third-cut alfalfa is less affected by delayed harvest. Harvesting third cutting at 10 to 50 percent bloom will allow buildup of root reserves to aid in overwintering, and forage will be of high quality.</p> | Meyer and Helm, 1994 |
| Wisconsin    | North Central  | 6.91                            | 14.38                                   | <p>There is no simple alfalfa cutting schedule recipe or rule of thumb that will apply every year or for every farm. However, for an alfalfa enterprise to be profitable, producers must optimize forage yield, quality, and stand persistence. Estimating first cut forage quality before the crop is actually harvested is now possible with the availability of scissor cut results on an area basis and making PEAQ estimates on an on-farm basis. Use these tools to make first cut harvest decisions. Summer cuts will typically be made at 35 to 40 day intervals unless environmental factors deviate significantly from normal. Plan to be out of alfalfa fields by about August 25th and make late fall cutting decisions based upon forage need under the realization that stand persistence and subsequent plant vigor will be put at risk</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Rankin, no year      |

| State      | Growing Region                                  | Percent of Harvest Acres (2005) | Percent of Organic Harvest Acres (2005) | Harvest Advice                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Source                                       |
|------------|-------------------------------------------------|---------------------------------|-----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| Minnesota  | North Central                                   | 6.02                            | 10.44                                   | In stands which are in the first season of production (the seeding year), one fourth of growers take no cuttings, one quarter take one, one quarter take two, and one quarter take three cuttings. In established stands, a majority of Minnesota growers (about 70 percent) take three cuttings per year. About one-fourth take two cuttings per year, and a fourth cutting is taken by about 10 percent of growers. Most growers harvest alfalfa when the stand is at 10 percent bloom; if four cuttings are made, a greater percentage of growers harvest when the stand is at pre-bloom. Mid-August through mid-September is when almost all Minnesota growers take the last cutting of the season.                                                                                                                                                                                         | Nelson, 2000                                 |
| Iowa       | North Central                                   | 5.57                            | 4.50                                    | For maximum yields, it is important to have 20-30 plants per square foot during the seedling year for protection against weed competition. Do not harvest alfalfa seeded in late summer until the following spring. Allow new seedlings to start to bloom before the first harvest. Cut alfalfa three-four times a year when stand is 25 percent flowered.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Welter Seed, no year                         |
| California | Moderate Winter Hardy Inter-mountain/ Southwest | 4.63                            | 6.48                                    | In the Intermountain Region, it takes 3 to 4 weeks to restore root reserves and another 7 to 10 days to add surplus carbohydrates to the roots so the plant is ready for another cutting. Hay intended for this [dairy] market must be cut early (late-bud stage at the latest) for the necessary quality to be achieved. Conversely, hay intended for beef cattle or horses can be cut later, at 10- to 30-percent bloom, to maximize yields with acceptable quality for these classes of livestock.                                                                                                                                                                                                                                                                                                                                                                                           | Orloff and Putnam, 2007; Orloff et al., 1997 |
| Michigan   | East Central                                    | 4.01                            | 0.35                                    | (1) Schedule your cuttings based upon alfalfa stage of growth and your goals for forage production. Harvest at the early bloom stage of growth to maximize nutrient yield per acre and ensure that root reserves have been restored to a reasonably high level. Harvesting earlier maximizes forage quality but does not ensure adequate levels of stored root reserves. Harvesting later maximizes yield and stored root reserve levels but forage quality is lowered. (2) Offset the risk of winter injury by selecting multiple disease resistant, winter hardy varieties, maintaining young stands, keeping soil fertility levels high, growing alfalfa on well drained soils, and retaining snow in the winter if possible. (3) Delay the first cutting of winter-injured stands until full bloom. If alfalfa plants were frost heaved, cut above the normal height to avoid crown injury. | Hesterman and Durling, 1991                  |

| State    | Growing Region              | Percent of Harvest Acres (2005) | Percent of Organic Harvest Acres (2005) | Harvest Advice                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Source                |
|----------|-----------------------------|---------------------------------|-----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Kansas   | Great Plains                | 3.79                            | 0.32                                    | On established stands the first cutting should be made when regrowth at the crown is observed; subsequent cuttings can be made at one-tenth bloom or 28-30 day intervals if weather conditions allow. Severe leaf loss may initiate cutting to salvage the hay crop and maintain stands. If this occurs the next cutting should be delayed to allow the root reserves to be replenished. Cutting at the pre-bud and bud stage produces a higher quality forage than at later stages, but repeatedly cutting at early stages reduces root reserves which results in poor stands and lower yields. Cutting when regrowth at the crown appears and at one-tenth bloom maximizes forage yield, quality and benefits stand longevity. The last cutting before fall dormancy should allow four to five weeks of growth so that root reserves are replenished. | Shroyer et al., 1984  |
| Colorado | Winter Hardy Inter-mountain | 3.57                            | 4.38                                    | If highest quality is the primary consideration, harvest at the bud stage during each regrowth cycle. Many growers, however, produce alfalfa hay that is sold or fed on the basis of less than premium quality standards. For these producers, the optimum growth stages for harvest are mid- to late bloom, because higher yields can be obtained and quality is still acceptable.<br>Alfalfa grown in Colorado below 7,000 feet can be harvested in late summer or early fall with little concern for timing relative to the first killing frost (28 degrees F). Regardless of the amount of regrowth at the time of frost, fall conditions almost always are mild enough to allow for adequate recharge of reserves. Above 7,000 feet, it generally is best not to cut within four weeks of the average date of the first killing frost.             | Smith et al., 1998    |
| Wyoming  | Winter Hardy Inter-mountain | 2.67                            | 0.84                                    | Alfalfa should be harvested at the late bud to early bloom (10 percent bloom) stage for premium hay. Delaying harvest will reduce the hay quality. Taking the first cutting early will control weevil problems. In fall-planted alfalfa, first harvest occurs in late May to June, depending on the region and time of planting. Subsequent harvests are approximately every 28 days, as long as the late bud to early bloom stage of development has been reached (second harvest usually in July, third harvest September 1 - 15). The last harvest of the season should be at least two weeks before the first killing frost. At high elevations, 8 - 14 drying days are needed between cutting and baling the hay.                                                                                                                                  | McDonald et al., 2004 |

| State        | Growing Region | Percent of Harvest Acres (2005) | Percent of Organic Harvest Acres (2005) | Harvest Advice                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Source                        |
|--------------|----------------|---------------------------------|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| Ohio         | East Central   | 2.27                            | 0.50                                    | When harvests are made at late bud-early bloom stage of development, the fall cutting schedule is important for stand maintenance. Make the last regular harvest by the calendar: northern Ohio, September 1 to 7; central Ohio, September 3 to 12; southern Ohio September 5-15. This means that on those fields with an intensive cutting schedule, no harvest should be taken from early-mid September to mid-October. At least 30 days between the last regular harvest and killing frost are needed to adequately restore root and crown reserves.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Myers and Van Keuren, no year |
| Pennsylvania | East Central   | 2.27                            | 0.60                                    | During the year of establishment, seedlings need a high level of energy reserves in order to persist through the winter. For spring seedings made without a companion crop, two harvests can generally be made the first year, provided the crop has adequate rainfall and optimum levels of soil nutrients. The first harvest can be made before flowers begin to appear, but waiting for the alfalfa to flower will ensure greater energy reserves in the roots. Alfalfa will generally reach this stage of development between 60 and 70 days after emergence. The second harvest should either be made before September 1, to ensure an adequate buildup of energy reserves for winter, or be delayed until after the first killing frost (24°F) in the fall or after mid-October. Occasionally, when the second harvest is made before September and there are good fall growing conditions, a third harvest may be made after a definite killing frost. When mid-October or later harvests are made, a high stubble (6 inches) should be left for ground cover to protect the crowns and to catch snow for added insulation. | Bosworth et al., no year      |
| Missouri     | East Central   | 2.01                            | 0.58                                    | For spring-seeded established stands in the seeding year, take the first harvest at the mid- to full-bloom stage. Make following harvests as flowers begin to appear. For established stands, take the first (May 10 to 20) and second (June 15 to 25) cuttings when the plants are just beginning to bloom. For persistence of the stand, make two more harvests at about 35-day intervals before Sept. 15. Harvesting alfalfa in the bud stage produces five cuttings of high-quality hay before Sept. 15. This practice, however, reduces stand life to three or four years.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Henning and Nelson, 1993      |

| State      | Growing Region     | Percent of Harvest Acres (2005) | Percent of Organic Harvest Acres (2005) | Harvest Advice                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Source                    |
|------------|--------------------|---------------------------------|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| New York   | East Central       | 2.01                            | 0.16                                    | As a general guideline, all perennial forages should be harvested at early stages of maturity when both palatability and nutrient content are high. For alfalfa, the neutral detergent fiber (NDF) value should be approximately 40 percent. This occurs at a late bud stage for the spring harvest of alfalfa. Early harvest also allows time for regrowth and subsequent harvests during the growing season. Alfalfa can be harvested two to four times a year in New York, depending on the growing season and soil type. Alfalfa stands will persist longer if there is a forty- to forty-five-day interval between harvests. All studies comparing various harvest schedules indicate that four harvests per year decrease the long-term persistence of stands compared to three harvests per year. Frequent harvests, with a shorter interval between, may be more advantageous in short rotations, where stands of alfalfa are only kept down for two to three years. | Cherney et al., 2001      |
| Washington | PNW-Inter-mountain | 2.01                            | 0.56                                    | High-quality dairy hay, which brings the highest price, is harvested during the late bud stage of growth before any sign of bloom. Growers can discern bud stage by simply walking through the field and feeling the terminals of the tallest stems. Buds about to open have a hard lump inside the terminal growth point. Dairy-quality hay is harvested on an average of every 30 days, starting in late May or early June and continuing through September. Alfalfa hay for the horse market requires lower protein and higher fiber. More mature hay with up to 50 percent bloom can be desirable for this market. This growth stage is attained by delaying harvest to 35- to 37-day intervals. In the southern growing areas, 4 to 5 harvests are taken, while in the northern areas 3 to 4 harvests are taken each year.                                                                                                                                              | Kugler and Woodward, 2006 |
| Oklahoma   | Great Plains       | 1.43                            | 0.04                                    | The best time to harvest will vary, depending on projected use of hay. If hay will be sold as high-quality forage (for dairy cattle), alfalfa should be cut at bud stage or earlier (28 day cycle or less). If alfalfa is being used as feed for a cow-calf operation where high quality is not as critical, it should be cut at 25-50 percent bloom stage (35-42 day cycle) to maximize yield.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Caddel et al., 2001       |
| Kentucky   | East Central       | 1.16                            | 0.01                                    | Once established, the crop is harvested at 30 to 38 day intervals between May 1 and September 15.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Townsend et al., 2002     |

| State      | Growing Region                                  | Percent of Harvest Acres (2005) | Percent of Organic Harvest Acres (2005) | Harvest Advice                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Source                  |
|------------|-------------------------------------------------|---------------------------------|-----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| Arizona    | Moderate Winter Hardy Inter-mountain/ Southwest | 1.16                            | 0.24                                    | In general, cutting alfalfa when half of the regrowth buds are three-quarters of an inch or longer is a good compromise between yield and quality and will help maintain an adequate stand.                                                                                                                                                                                                                                                                                                                             | Tickes and Ottman, 2008 |
| New Mexico | Moderate Winter Hardy Inter-mountain            | 1.07                            | 0.33                                    | Late bud to first flower for first cutting, first flower to one-tenth bloom for second and later cuttings.                                                                                                                                                                                                                                                                                                                                                                                                              | McWilliams et al., 2005 |
| Virginia   | East Central                                    | 0.49                            | 0.14                                    | Harvesting usually occurs at late bud to 1/4 bloom, except the first cutting. The first cutting should be made in (hay or silage) bud stage or when orchard grass begins to head. Alfalfa may be cut 3-5 times/year at 30- to 40-day intervals, depending upon location in the state and average rainfall. Make the last cutting three to four weeks before average date of first killing frost in fall or in time to allow 6-8 inches of regrowth. Allow at least one harvest to reach 1/10 bloom to help persistence. | Schooley et al., 2004   |
| Tennessee  | East Central                                    | 0.16                            | 0.00                                    | New spring seedlings should be harvested when they reach full bloom. All other harvests should be made when 10 percent of the plants are blooming. Fall seeded and established stand may be harvested at the bud stage for the first cutting, and then at the 10 per cent bloom stage for all later cuttings. Last harvest should be made before mid-September.                                                                                                                                                         | Bates, 1998             |
| New Jersey | East Central                                    | 0.11                            | 0.00                                    | Usually, when following cutting intervals closely, the alfalfa will be in the pre-bud to bud stage, which is ideal for harvesting, providing the highest nutrient levels and greatest digestible content for livestock. Farmers are encouraged to harvest the crop early rather than use pesticides if pest populations are over thresholds.                                                                                                                                                                            | Lee et al., no year     |



| State         | Growing Region | Percent of Harvest Acres (2005) | Percent of Organic Harvest Acres (2005) | Harvest Advice                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Source        |
|---------------|----------------|---------------------------------|-----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| Massachusetts | East Central   | 0.06                            | 0.00                                    | Careful management of new seedlings is especially important in the seeding year to ensure a long-lived productive stand. New seedlings should not be harvested until plants have come to at least the one-half bloom stage to ensure adequate storage of total nonstructural carbohydrates (TNC) in the roots. This management should be followed for all harvests in the seeding year. Established stands of alfalfa can survive earlier harvesting in the spring than that recommended for new seedlings. Removal of first cuttings at the full bud stage in the spring does not reduce the annual forage yields appreciably. It may even be necessary to spread the harvest period of each cut or may be desirable to improve forage quality and to prevent over-mature hay crops. Because the effects of early cutting are accumulative, the practice of cutting at early growth stages should be rotated among alfalfa fields. Alfalfa stand will not be reduced from a single cut at the bud stage, provided successive cuttings are permitted to reach at least the one-tenth bloom stage of maturity. | Herbert, 1996 |

### 3.3.2 *Quality of Hay is Dependent on Timing of Harvest*

Quality of hay can be measured by several different variables. Although quality can be partially predicted by time of harvest based on percentage of bloom, many buyers require nutrient testing (Robinson et al., 2007). USDA has both narrative and numeric criteria for grading hay. USDA Agricultural Marketing Service (AMS) Market News uses the following visual physical descriptions for quality (<http://www.ams.usda.gov/mnreports/lamllgr311.pdf>):

- Supreme: Very early maturity, pre bloom, soft fine stemmed, extra leafy. Factors indicative of very high nutritive content. Hay is excellent color and free of damage.
- Premium: Early maturity, i.e., pre-bloom in legumes and pre head in grass hays, extra leafy and fine stemmed-factors indicative of a high nutritive content. Hay is green and free of damage.
- Good: Early to average maturity, i.e., early to mid-bloom in legumes and early head in grass hays, leafy, fine to medium stemmed, free of damage other than slight discoloration.
- Fair: Late maturity, i.e., mid to late-bloom in legumes, head-in grass hays, moderate or below leaf content, and generally coarse stemmed. Hay may show light damage.
- Utility: Hay in very late maturity, such as mature seed pods in legumes or mature head in grass hays, coarse stemmed. This category could include hay discounted due to excessive damage and heavy weed content or mold. Defects will be identified in market reports when using this category.

The stages of maturity mentioned in the list above are defined as follows (Bagg, 2003):

Late vegetative – No visible buds, stem at least 12 inches tall.

Early bud – Visible flower buds on at least 1 stem.

Mid bud – 50 percent of stems have at least 1 bud.

Late bud – 75 percent of stems have at least 1 bud, no visible flowers

First bloom – Flowers on at least 1 stem.

1/10 bloom (Early bloom) – 10 percent of stems have at least 1 flower.

Mid bloom – 50 percent of stems have at least 1 flower.

Full bloom – 75 percent of stems have at least 1 flower.

Hay is tested by certified laboratories for acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP), and dry matter (DM). Total digestible nutrients (TDN) is calculated from ADF. Table Q-3 presents the numeric criteria for these hay quality components. Note that only 10 percent grass (either from livestock edible weeds or companion crops) is allowed.

**Table Q-3. USDA AMS Alfalfa Guidelines (for domestic livestock use and not more than 10 percent grass)**

| Quality | ADF   | NDF   | *RFV    | **TDN-100 percent | **TDN-90 percent | CP    |
|---------|-------|-------|---------|-------------------|------------------|-------|
| Supreme | <27   | <34   | >185    | >62               | >55.9            | >22   |
| Premium | 27-29 | 34-36 | 170-185 | 60.5-62           | 54.5-55.9        | 20-22 |
| Good    | 29-32 | 36-40 | 150-170 | 58-60             | 52.5-54.5        | 18-20 |
| Fair    | 32-35 | 40-44 | 130-150 | 56-58             | 50.5-52.5        | 16-18 |
| Utility | >35   | >44   | <150    | <56               | <50.5            | <16   |

\*RFV calculated using the Wis/Minn formula. \*\*TDN calculated using the western formula. Quantitative factors are approximate, and many factors can affect feeding value. Values based on 100 percent dry matter (TDN showing both 100 percent & 90 percent). Guidelines are to be used with visual appearance and intent of sale (usage).

USDA's Natural Resources Conservation Service (NRCS) provides the following key to nutrient values and maturity levels for legumes, grass, and grass/legume mixtures (table Q-4).

**Table Q-4. Quality standards for legume, grass, and grass and legume mixture (USDA NRCS 2002)**

| Maturity      | ADF   | NDF   | RFV     |
|---------------|-------|-------|---------|
| Pre-bloom     | <31   | <40   | >151    |
| Early bloom   | 31-35 | 40-46 | 151-125 |
| Mid bloom     | 36-35 | 47-53 | 124-103 |
| Full bloom    | 41-42 | 54-60 | 102-87  |
| Rain damaged  | 43-45 | 61-65 | 86-75   |
| Severe damage | >45   | >65   | <75     |

The AMS maturity-to-protein-content categories do not seem to agree with the NRCS table Q-4. For example, the Fair category is described as mid to late bloom in the AMS narrative standards and has an ADF of 32-35, NDF of 40-44, and RFV of 130-150. In the NRCS table similar nutrient levels are categorized as early bloom. The one difference between the two sources is that AMS alfalfa guidelines are for legumes with less than 10 percent grass and the NRCS table is for legume, grass, and grass and legume mixtures of unspecified percentages. Because grass has lower nutrient value than legumes, legume/grass mixtures would have to be harvested earlier to achieve the same nutrient ratings as pure legumes. Therefore, for alfalfa stands with less than 10 percent grass, the AMS table may be more accurate.

Iowa State University Extension has created a tool for alfalfa farmers in Iowa that can help them predict the RFV of the first harvest of the year (Lang, 2001). The Predictive Equations for Alfalfa Quality (PEAQ) allows growers to use height of tallest stem (in inches) and the maturity of the most mature stems to predict RFV, then subtract 10 to 20 RFV units for losses during harvest. This tool is helpful because climatic differences from year to year make calendar date harvesting unreliable. The tool has been validated in the Midwest and other environments in California and New York. Lang (2001) recommends 150 RFV for milking dairy herds, and 120 to 130 for heifers, stocker cattle and lactating beef cattle. So for hay to achieve RFV of 150, late vegetative (no visible buds) corresponds with 28 inches in height, bud stage (no flowers) corresponds with 26 inches in height, and flower stage (1 or more nodes with open flowers) corresponds with 24 inches in height. So clearly maturity based on bloom is not fully predictive of nutrient content.

If the AMS narrative criteria could be taken at face value, then a crude estimate of the tonnage of hay alfalfa that goes to mid and late bloom could be estimated by examining the quantity of hay

sold in the good and fair categories. USDA Market News tracks alfalfa hay prices on a weekly basis for some regions. The alfalfa hay market for June, 2008 is summarized in table Q-5. Only data for California, Nevada, Idaho, Washington, and Oregon included information on tonnage. For other states and regions average prices were reported, but not tonnage. Factors that contribute to the inaccuracy of this crude estimate include:

Nursery crops – Annual companion crops that are interseeded with alfalfa to reduce weed growth during stand establishment (first year) typically have lower protein content than alfalfa.

Therefore the presence of companion crop in a harvest can lower the quality of the hay regardless of the maturity of the alfalfa. This factor applies mainly to the first year of stand life because established alfalfa is a good competitor and companion plants are reduced.

Weeds – The prevalence and protein content of weeds in any given batch of alfalfa is unknown and highly variable. In general weeds lower alfalfa protein quality and overall quality regardless of alfalfa maturity level at harvest.

Tonnage ≠ Acreage – Yield (tons/acre) is not consistent between the quality categories. Because the biomass of the alfalfa is lower when the plants are younger, harvesting supreme and premium hay results in lower yields. If the alfalfa is permitted to gain more biomass yield is higher, but the quality of the hay drops to good or fair. Therefore tonnage does not indicate acres. In addition yield also fluctuates due to many other factors, both environmental and farm management.

Based on June, 2008 data for the five Western states listed in table Q-4, 57 percent of the alfalfa hay sold was in the supreme and premium categories, which are harvested before flowers mature. Forty three percent of the tonnage was in the good to fair categories. Based on the category descriptions one might conclude that 43 percent of the tonnage was harvested at 10 to 75 percent bloom. Again it should be noted that tonnage does not translate to acreage because yield (tons/acre) increases the later in maturity that alfalfa is cut. Since 15 percent of the harvest was sold as fair, it could be that 15 percent of the tonnage (not acreage) was harvested no sooner than 50 percent bloom. Clearly this crude calculation is not adequate to truly estimate pollen availability. In addition, the geographic breakdown is not fine enough to be helpful, because the markets in table Q-5 are hundreds of square miles in size and pollen flow happens at the scale of feet to a few miles. However, based on this crude calculation, it may be inaccurate to make the blanket statement that alfalfa hay is harvested at less 10 percent bloom except in rare cases. However, this statement may be accurate for GT alfalfa because farmers that purchase GT alfalfa seed are required to agree to harvest at less than 10 percent bloom. Presumably farmers that prefer to harvest at later bloom stages would not adopt GT alfalfa.

**Table Q-5. Alfalfa Hay Market – Tons and Quality Rating (Month of June 2008)<sup>58</sup>**

| State                  | Market                                      | Supreme | Premium and good/<br>premium | Good  | Fair  | Utility | Total  |
|------------------------|---------------------------------------------|---------|------------------------------|-------|-------|---------|--------|
| California             | Antelope Valley                             |         | 2990                         | 100   | 1500  |         | 4590   |
|                        | Blythe                                      |         | 4800                         | 9750  | 9700  |         | 24250  |
|                        | Chino<br>Los Angeles<br>San Diego           | 800     | 6170                         | 8082  | 4650  |         | 19702  |
|                        | Escalon<br>Modesto<br>Turlock               | 23500   | 8325                         | 5925  | 5875  |         | 43625  |
|                        | Hanford<br>Corcoran<br>Tulare<br>Visalia    | 3215    | 3937                         | 3334  | 1015  |         | 11501  |
|                        | Imperial Valley                             | 1100    | 18353                        | 15550 | 3908  |         | 38911  |
|                        | Kern County                                 | 1435    | 12300                        | 9326  | 8975  |         | 32036  |
|                        | Los Banos<br>Dos Palos<br>Merced            | 19995   | 12587                        | 4515  | 3552  |         | 40649  |
|                        | Northern<br>Intermountain                   | 5800    | 1200                         | 1050  |       |         | 8050   |
|                        | Petaluma                                    | 3050    | 400                          | 2400  | 3900  |         | 9750   |
|                        | Sacramento<br>Valley                        | 2895    | 13993                        | 7618  | 12210 |         | 36716  |
|                        | South<br>Central-Coastal                    |         | 1925                         |       |       |         | 1925   |
|                        | Tracy<br>Patterson<br>Stockton              | 13894   | 3300                         | 6450  | 2000  |         | 25644  |
|                        | Tulare<br>Visalia<br>Hanford<br>Bakersfield | 17390   | 16690                        | 14180 | 7915  |         | 56175  |
|                        | Fresno<br>Madera<br>Firebaugh               | 4839    | 4779                         | 1450  | 1150  |         | 12218  |
| Subtotal CA            |                                             | 97913   | 111749                       | 89730 | 66350 |         | 365742 |
| Subtotal CA<br>percent |                                             | 26.77   | 30.55                        | 24.53 | 18.14 |         | 100.00 |
| Nevada                 | Northern                                    | 2380    |                              |       |       |         | 2380   |
|                        | Western                                     | 2200    | 5450                         |       |       |         | 7650   |
|                        | Central/East<br>Central                     | 700     | 650                          |       |       |         | 1350   |
| Subtotal NV            |                                             | 5280    | 6100                         |       |       |         | 11380  |
| Subtotal NV            |                                             | 46.40   | 53.60                        |       |       |         | 100.00 |

<sup>58</sup>Current: <http://www.ams.usda.gov/AMSV1.0/ams.fetchTemplateData.do?template=TemplateN&navID=MarketNewsAndTransportationData&leftNav=MarketNewsAndTransportationData&page=LSMarketNewsPageHay>  
Idaho, June, 2008: <http://search.ams.usda.gov/mndms/2008/06/LS20080601Mmlgr312.pdf>  
Nevada, June, 2008: <http://search.ams.usda.gov/mndms/2008/06/LS20080601Mmlgr314.pdf>  
Oregon, June, 2008: <http://search.ams.usda.gov/mndms/2008/06/LS20080601Mmlgr313.pdf>  
Washington, June, 2008: <http://search.ams.usda.gov/mndms/2008/06/LS20080601Mmlgr310.pdf>  
California, June, 2008: <http://search.ams.usda.gov/mndms/2008/06/LS20080601Mmlgr311.pdf>

| State                | Market                                   | Supreme      | Premium and good/<br>premium | Good         | Fair         | Utility     | Total         |
|----------------------|------------------------------------------|--------------|------------------------------|--------------|--------------|-------------|---------------|
| percent              |                                          |              |                              |              |              |             |               |
| Idaho                |                                          | 18275        | 19999                        | 9235         | 7975         |             | 55484         |
| Subtotal ID percent  |                                          | 32.94        | 36.04                        | 16.64        | 14.37        |             | 100.00        |
| Washington           | Columbia Basin                           | 4005         | 54282                        | 63575        | 9600         | 200         | 131662        |
| Subtotal WA percent  |                                          | 3.04         | 41.23                        | 48.29        | 7.29         | 0.15        | 100.00        |
| Oregon               | Crook<br>Deschutes<br>Jefferson<br>Wasco |              | 1200                         |              |              |             | 1200          |
|                      | Klamath Basin                            | 400          | 2840                         |              |              |             | 3240          |
|                      | Lake County                              | 500          | 120                          | 130          |              |             | 750           |
|                      | Harney County                            | 50           |                              |              |              |             | 50            |
|                      | Eastern Oregon                           |              | 650                          | 200          | 1110         |             | 1960          |
| Subtotal OR          |                                          | 950          | 4810                         | 330          | 1110         |             | 7200          |
| Subtotal OR percent  |                                          | 13.19        | 66.81                        | 4.58         | 15.42        |             | 100.00        |
| Total Tons           |                                          | 126423       | 196940                       | 162870       | 85035        | 200         | 571468        |
| <b>Total percent</b> |                                          | <b>22.12</b> | <b>34.46</b>                 | <b>28.50</b> | <b>14.88</b> | <b>0.03</b> | <b>100.00</b> |

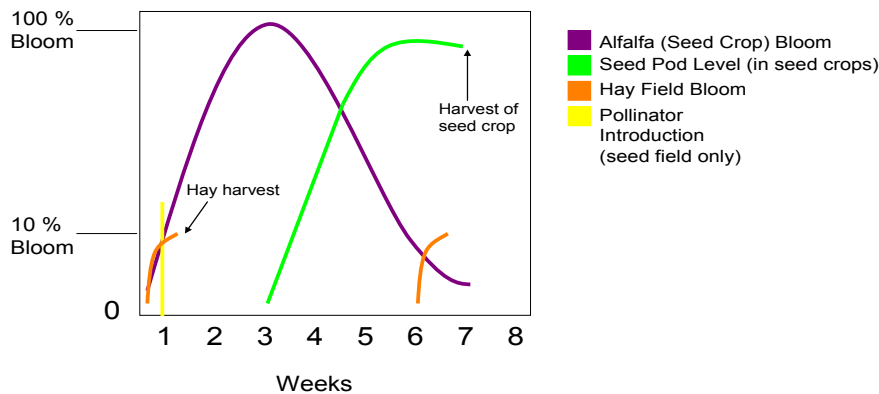
### 3.4 Flowering Time

Flowering of seed fields and hay fields may not be synchronized, depending on mowing schedules, inputs (irrigation, fertilizer), and cultivar. For cross pollination to occur, the flowers must be blooming at the same time. Within a field this is fairly simple to synchronize because the seeds are planted at the same time and varieties are bred to have low variability in germination time within varieties.

Alfalfa flowers for an amount of time that is dependent on factors such as region where it is grown, management practices and the species of pollinators used. In general, alfalfa will bloom longer and open flowers will accumulate when fewer pollinators are present, but there will be a decrease in standing crop of open flowers in the presence of many pollinators. After the alfalfa has been pollinated, it no longer devotes energy to flower production, but instead diverts energy to fruit development. This is evidenced by the fact that after pollination, nectar production ceases and wilting occurs in about 4 hours at warm temperatures, or 24 hours at cool temperatures (Strickler and Vinson, 2000). Different pollination management strategies will affect the blooming duration for alfalfa. For example, in regions where alfalfa leafcutter bees are used, they are released quickly after bloom and large numbers are released at once (up to 52,000 females per hectare). This would result in a short duration of open alfalfa flowers. In regions where honey bees are used for pollination, such as California, fewer bees are used and pollination occurs at a more moderate pace, leading to a longer bloom time for alfalfa (Strickler and Freitas, 1999)

In a study in Idaho (Strickler and Freitas, 1999), alfalfa leafcutter bees were released when the alfalfa had started blooming, and because the bees need a couple of weeks to establish their nests, stabilize themselves, and reach constant rates of foraging (Bosch and Kemp, 2005), the amount of flowers reached a peak two weeks after bee release. After this point and once the pollinators began steadily foraging, the amount of flowers decreased exponentially and moved to seed production. Twenty-five percent of the peak bloom was present four weeks after pollinator release. This pattern was also observed in fields in Oregon (Bosch and Kemp, 2005), where flowers accumulated for the first three weeks of the study, and by week four, one to two weeks after alfalfa leafcutter bee release, the standing crop of flowers decreased rapidly.

Hay fields are treated differently than seed fields, and are typically cut when the field is at one-tenth bloom. About four weeks are allowed to pass between cuttings, to allow fields to reach one-tenth bloom again. Figure Q-3 shows one possible typical pattern of alfalfa blooming for seed fields, including pollinator introduction (alfalfa leafcutter bees) and seed formation, with hay field bloom and cutting overlaid. If these two fields were geographically close enough that pollinators could visit both fields, the potential for pollen exchange would only occur when the curves overlap. In figure Q-3 the hay and seed field start synchronized. The figure illustrates the relatively short amount of time that hay and seed field bloom would overlap. Note the hay field is harvested at 10 percent bloom.



**Figure Q-3: Flowering overlap between hay and seed fields**

### 3.5 Forage and Seed Field Proximity

The Agricultural Resources and Environmental Indicators Database has a mapping tool that converts agricultural data to map form (<http://maps.ers.usda.gov/AgResources/index.asp?Describ=Alfalfa+hay+%28tons%2C+dry%29%2C+harvested+%28acres%29&TableNo=28&CatalogVal=Field+Seeds%2C+Grass+Seeds%2C+Hay%2C+Forage%2C+and+Silage&Year=D97&Type=Total&drawtype=drawmap&action=&boundaryflag=&labelflag=&drawtypesaved=drawmap&sort=&sorttype=&printflag=&yearvalue=D97&x=280&y=187>). It contains data on alfalfa hay and seed production for the United States from 1997, and shows the approximate distribution of this production. As the color gets darker, production increases. This gives a visual idea of the regions of the country with the most alfalfa, and shows that seed production is far less than hay

production and is more geographically clustered. Figure Q-4 presents alfalfa hay acreage and figure Q-5 presents alfalfa seed acreage.

presents alfalfa



**Figure Q-4: 1997 Alfalfa hay (tons, dry), harvested (acres)**



**Figure Q-5: 1997 Alfalfa seed (pounds), harvested (acres)**

Forage and seed field data for 2007 is presented in table Q-6. Alfalfa hay and seed production occurs mainly in the west and northwest United States. The biggest producers of hay (pounds) are California, South Dakota, and Idaho, while the biggest producers of seed (pounds) are California, Washington, and Idaho. When looking at acreage, however, South Dakota, Montana and Wisconsin have the largest hay production, while California, Washington and Idaho have the most acreage for seed production. Acreage might be a more important concern when looking at gene flow, as the spatial distribution of alfalfa fields is a factor in determining the potential of pollination. California, Washington and Idaho would be the states that would most likely have farmers concerned about the adventitious presence of the GT trait, as they not only have the most acreage devoted to seed production, but also produce the most seed in the country.

Roundup® is only registered for alfalfa seed production in 13 states: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oklahoma, Oregon, Texas, Utah, Washington, and Wyoming. There are several states which produce seed but would not be able to produce GT alfalfa seed because Roundup® is not approved for use on seeds: South Dakota, North Dakota, Minnesota, Kansas, and Nebraska (FGI, 2007).



**Table Q-6. Top 20 States for Alfalfa Hay and Seed Acreage and Quantity, 2007 U.S. Census of Agriculture**

| Dry Hay                                                       |                           |                 |                             |                            | Seeds         |                           |                 |                             |                                   |
|---------------------------------------------------------------|---------------------------|-----------------|-----------------------------|----------------------------|---------------|---------------------------|-----------------|-----------------------------|-----------------------------------|
| State                                                         | Number of Farms Harvested | Acres Harvested | Quantity (pounds) Harvested | Percent of Total Hay Acres | State         | Number of Farms Harvested | Acres Harvested | Quantity (pounds) Harvested | Percent of Total Pounds Harvested |
| United States                                                 | 290726                    | 20244497        | 65349074                    | 100.00%                    | United States | 806                       | 121467          | 62115239                    | 100.00%                           |
| South Dakota                                                  | 12653                     | 1996599         | 4414338                     | 9.86%                      | California    | 114                       | 36625           | 19083458                    | 30.72%                            |
| Montana                                                       | 9711                      | 1868756         | 3936445                     | 9.23%                      | Washington    | 82                        | 17127           | 10860608                    | 17.48%                            |
| Wisconsin                                                     | 30810                     | 1517522         | 3673619                     | 7.50%                      | Idaho         | 92                        | 12788           | 9346709                     | 15.05%                            |
| North Dakota                                                  | 8985                      | 1457604         | 3072682                     | 7.20%                      | Wyoming       | 62                        | 10548           | 5915816                     | 9.52%                             |
| Nebraska                                                      | 14820                     | 1085921         | 3955881                     | 5.36%                      | Nevada        | 19                        | 6498            | 4237101                     | 6.82%                             |
| Idaho                                                         | 8817                      | 1037520         | 4254543                     | 5.12%                      | Montana       | 80                        | 10338           | 3729635                     | 6.00%                             |
| California                                                    | 3587                      | 986982          | 7057014                     | 4.88%                      | Oregon        | 32                        | 4959            | 3183375                     | 5.12%                             |
| Minnesota                                                     | 20398                     | 944775          | 2671173                     | 4.67%                      | Utah          | 54                        | 3803            | 2077813                     | 3.35%                             |
| Colorado                                                      | 8648                      | 861053          | 2887865                     | 4.25%                      | Arizona       | 53                        | 5206            | 1902669                     | 3.06%                             |
| Iowa                                                          | 22040                     | 830440          | 3054729                     | 4.10%                      | South Dakota  | 47                        | 6014            | 428447                      | 0.69%                             |
| Kansas                                                        | 9643                      | 793140          | 2986134                     | 3.92%                      | Oklahoma      | 29                        | 2004            | 281121                      | 0.45%                             |
| Michigan                                                      | 16431                     | 698595          | 1707036                     | 3.45%                      | Texas         | 24                        | 546             | 79885                       | 0.13%                             |
| Wyoming                                                       | 4007                      | 674284          | 1696438                     | 3.33%                      | Minnesota     | 17                        | 611             | 63461                       | 0.10%                             |
| Utah                                                          | 7780                      | 548570          | 2172218                     | 2.71%                      | Missouri      | 19                        | 399             | 40540                       | 0.07%                             |
| Pennsylvania                                                  | 14402                     | 475873          | 1357225                     | 2.35%                      | North Dakota  | 6                         | (D)             | 34784                       | 0.06%                             |
| New York                                                      | 7707                      | 450144          | 1119421                     | 2.22%                      | New Mexico    | 15                        | 310             | 29907                       | 0.05%                             |
| Washington                                                    | 4294                      | 448588          | 2192001                     | 2.22%                      | Kansas        | 5                         | 342             | 22430                       | 0.04%                             |
| Ohio                                                          | 15354                     | 437658          | 1256174                     | 2.16%                      | Nebraska      | 29                        | 545             | 21216                       | 0.03%                             |
| Oregon                                                        | 3569                      | 428812          | 1777894                     | 2.12%                      | Michigan      | 10                        | (D)             | 15610                       | 0.03%                             |
| Oklahoma                                                      | 3781                      | 334990          | 1131938                     | 1.65%                      | New York      | 3                         | 27              | 6180                        | 0.01%                             |
| D = data withheld to protect the identity of individual farms |                           |                 |                             |                            |               |                           |                 |                             |                                   |

### 3.6 Seed Purity Standards and Requirements

Alfalfa farmers follow state mandated certification standards when cultivating seed crops. These standards vary based on the state and the level of certification desired, and outline guidelines for the management of seed crops. The Association of Official Seed Certifying Agencies (AOSCA) is an overview body that assists these state-level offices in producing, identifying, distributing and promoting various classes of seed. The AOSCA provides the alfalfa seed certification standards for each state to the public ([www.aosca.org](http://www.aosca.org)). These are based on the Federal Seed Act (7 CFR part 201) which is as follows (only standards for alfalfa and applicable footnotes are shown)( <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=b2641469d5186de8667eaef9eb58e654&rgn=div8&view=text&node=7:3.1.1.7.27.0.327.109&idno=7>):

#### Title 7: Agriculture

#### PART 201—FEDERAL SEED ACT REGULATIONS

##### Certified Seed 4.2.1.1.1

##### § 201.76 Minimum Land, Isolation, Field, and Seed Standards.

In the following table Q-7 the figures in the “Land” column indicate the number of years that must elapse between the destruction of a stand of a kind and establishment of a stand of a specified class of a variety of the same kind. A certification agency may grant a variance in the land cropping history in specific circumstances where cultural practices have been proven adequate to maintain genetic purity. The figures in “Isolation” column indicate the distance in feet from any contaminating source. The figures in the “Field” column indicate the minimum number of plants or heads in which one plant or head of another variety is permitted. The figure in the “Seed” column indicates the maximum percentage of seed of other varieties or off-types permitted in the cleaned seed.

**Table Q-7. Minimum Land, Isolation, Field and Seed Standards (7 CFR 201.76)**

| Crop           | Foundation     |                                                  |                     |      | Registered     |                                                   |       |      | Certified        |                                                   |                   |      |
|----------------|----------------|--------------------------------------------------|---------------------|------|----------------|---------------------------------------------------|-------|------|------------------|---------------------------------------------------|-------------------|------|
|                | Land           | Isolation                                        | Field               | Seed | Land           | Isolation                                         | Field | Seed | Land             | Isolation                                         | Field             | Seed |
| <b>Alfalfa</b> |                |                                                  |                     |      |                |                                                   |       |      |                  |                                                   |                   |      |
| Non hybrid     | 4 <sup>1</sup> | 600 <sup>44,48</sup><br>(182.88m <sup>59</sup> ) | 1,000               | 0.1  | 3 <sup>1</sup> | 300 <sup>3,44,48</sup><br>(91.44m <sup>59</sup> ) | 400   | 0.25 | 1 <sup>1,2</sup> | 165 <sup>44,49</sup><br>(50.29m <sup>59</sup> )   | 100               | 1.0  |
| Hybrid         | 4 <sup>1</sup> | 1,320 <sup>43</sup><br>(402.34m <sup>59</sup> )  | 1,000 <sup>42</sup> | 0.1  |                |                                                   |       |      | 1 <sup>1,2</sup> | 165 <sup>3,43,44</sup><br>(50.29m <sup>59</sup> ) | 100 <sup>42</sup> | 1.0  |

<sup>1</sup>The land must be free of volunteer plants of the crop kind during the year immediately prior to establishment and no manure or other contaminating material shall be applied the year previous to seeding or during the establishment and productive life of the stand.

<sup>2</sup>At least 2 years must elapse between destruction of indistinguishable varieties or varieties of dissimilar adaptation and establishment of the stand for the production of the Certified class of seed.

<sup>3</sup>Isolation distance for certified seed production shall be at least 500 feet (152.07m) from varieties of dissimilar adaptation.

<sup>42</sup>The ratio of male sterile (A) strains and pollen (B or C) strains shall not exceed 2:1.

<sup>43</sup>Parent lines (A and B) in a crossing block, or seed and pollen lines in a hybrid seed production field, shall be separated by at least 6 feet (1.83m) and shall be managed and harvested in a manner to prevent mixing.

<sup>44</sup>Distance between fields of certified classes of the same variety may be reduced to 10 feet (3.05m) regardless of the class or size of the fields.

<sup>48</sup>This distance applies for fields over 5 acres (2ha). For alfalfa fields of 5 acres (2ha) or less that produce the Foundation and Registered seed classes, the minimum distance from a different variety or a field of the same variety that does not meet the varietal purity requirements for certification shall be 900 feet (274.32m) and 450 feet (137.16m), respectively.

<sup>49</sup>There must be at least 10 feet (3.05m) or a distance adequate to prevent mechanical mixture between a field of another variety (or non-certified area within the same field) and the area being certified. The 165 feet (50.29m) isolation requirement is waived if the area of the “isolation zone” is less than 10 percent of the field eligible for the Certified class. The “isolation zone” is that area

calculated by multiplying the lenGRh of the common border(s) with other varieties of alfalfa by the average width of the field (being certified) falling within the 165 feet (50.29m) isolation. Areas within the isolation zone nearest the contamination source shall not be certified.

<sup>59</sup>Indicates metric equivalent in meters.

[59 FR 64516, Dec. 14, 1994, as amended at 65 FR 1710, Jan. 11, 2000]

California, the largest producer of seed alfalfa, outlines typical guidelines for field eligibility (past use and spatial isolation) and seed purity standards ([http://ccia.ucdavis.edu/seed\\_cert/alfalfa\\_seedcert\\_standards.htm](http://ccia.ucdavis.edu/seed_cert/alfalfa_seedcert_standards.htm)). For cultivating Foundation seed, seed of the highest purity, alfalfa must not have grown on the land in the previous four years, and for Certified seed, one to two years, depending on the intervening crops. All volunteer plants and noxious weeds must be eradicated and definite boundaries to the field set before field use. Foundation seed fields must be isolated from alfalfa of different varieties by 900 feet, while Certified fields must be isolated by 165 feet. However, the 10 percent rule is followed for Certified fields, where if 10 percent or less of the Certified field is in the 165 foot isolation zone, the entire field is considered Certified, but if more than 10 percent is in the isolation zone, then that part of the field must be separated and not harvested as Certified seed. These rules are followed by most states.

Seed purity standards vary slightly across states, but remain high, especially for Foundation seed stock. As apparent in table Q-8, which shows seed purity standards for California, Idaho, Wisconsin and Montana(<http://www.idahocrop.com/standards.aspx>)( <http://www.wisc.edu/wcia/2008StandardW.pdf>)( <http://ag.montana.edu/msga/Seed%20Standards/alfalfa%20standards.pdf> ), at least 99 percent of each seed harvest must contain the pure seed variety, and there are strict limits on the allowable amounts of other crops, weeds and inert matter as well. After seed crops have been evaluated by seed labs, they are tagged with seed labels in accordance with law. Seed labs perform multiple tests mandated by the AOSCA on a representative sample from each submitted crop. All types of seed crops are accurately labeled, while Foundation and Certified seeds are denoted with a special tag. Information on the tag includes variety, kind, origin, net weight, percent pure seed, percent other materials, amount of noxious seed and weeds, and the information of the company performing the analysis (figure Q-6).

FGI has validated their Best Practices for seed production and believes they can produce seed reliably with >99.5 percent purity (FGI 2007). To put this in context, one seed in 200 could be for an off-variety, such as GT alfalfa in conventional alfalfa. Assuming that the contaminating variety has the same germination and fitness as the certified variety, then one can calculate the number of plants in an acre that would be off-type.<sup>59</sup> A thriving alfalfa hay field can have 15 plants per square foot (Orloff et al., 1997), which equals 653,400 plants in an acre; 0.5 percent of 653,400 is 3267. If the contaminating variety is mixed evenly in the seed batch, then there might be an off-type plant every 13.3 square feet. In older stands where plant density may be closer to 5 plants per square foot, there might be an off-type plant every 40 square feet. FGI's 2000 to 2002 field studies (See table Q-10), which assayed 30,000 seedlings, detected 0.000 percent gene flow (99.9 percent confidence interval is 0.01 percent), 0.01 percent contamination is 1 seed in 10,000, which is 1 plant in 667 square feet at a stand density of 15 plants per square foot.

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<sup>59</sup> Only 60 percent of the seeds germinate and emerge and only 40 percent of emerged seedlings survive the first year (Orloff et al., 1997).

**Table Q-8. Seed Purity Standards by State**<sup>60 61 62 63</sup>

| State      | Type of Seed | Pure Seed (Min percent) | Other Crops (max percent) | Other Varieties (max percent) | Other Material (max percent) | Isolation Distance, < 5 acres (ft) |
|------------|--------------|-------------------------|---------------------------|-------------------------------|------------------------------|------------------------------------|
| California | Foundation   | 99.5                    | 0.1                       | 0.1                           | 0.5                          | 900                                |
|            | Certified    | 99.5                    | 0.1                       | 0.2                           | 0.5                          | 165                                |
| Idaho      | Foundation   | 99                      | 0.1                       | 0.0                           | 1.1                          | 900                                |
|            | Registered   | 99                      | 0.1                       | 0.0                           | 1.2                          | 450                                |
|            | Certified    | 99                      | 0.25                      | 1.0                           | 1.25                         | 330*                               |
| Wisconsin  | Foundation   | 99                      | 0.2                       | 0.1                           | 0.85                         | 900                                |
|            | Certified    | 99                      | 0.75                      | 0.25                          | 0.95                         | 165                                |
| Montana    | Foundation   | 99.5                    | 0.1                       | 0.1                           | 0.6                          | 1320                               |
|            | Registered   | 99.5                    | 0.1                       | 0.25                          | 0.7                          | 660                                |
|            | Certified    | 99.5                    | 0.1                       | 1.0                           | 0.8                          | 330                                |

\*GMO from non-GMO: 900 ft

12-10-10-421

Species \_\_\_\_\_ Acc. No. \_\_\_\_\_

Common Name \_\_\_\_\_ Year Grown \_\_\_\_\_

Weight \_\_\_\_\_ Origin \_\_\_\_\_

Purity \_\_\_\_\_ % Germination \_\_\_\_\_ %

Other Crop Seeds \_\_\_\_\_ % Hard Seeds \_\_\_\_\_ %

Total Germination \_\_\_\_\_

Inert Matter \_\_\_\_\_ % and Hard Seeds \_\_\_\_\_ %

Weed Seeds \_\_\_\_\_ % Date of Test \_\_\_\_\_

Noxious Weed Seed \_\_\_\_\_

This seed was produced, collected, or purchased by the  
U. S. Government for use in conservation plantings  
ABERDEEN PLANT MATERIALS CENTER - SOIL CONSERVATION SERVICE  
U. S. Dept. of Agriculture, Aberdeen, Idaho

**Figure Q-6: Example of a seed tag (Hoag et al., 2002)**

### 3.7 Pollination of Alfalfa

As mentioned, alfalfa is pollinated by various insect pollinators. Hammon et al. (2007) studied alfalfa fields in Colorado, and collected data on the insects observed visiting the alfalfa. That list is in table Q-9, in order of abundance, followed by estimated ranges collected from various sources. In general, the alfalfa leafcutter bee is the preferred pollinator for alfalfa, but it is not used widely in the warmer regions of the U.S. because it has a low heat tolerance (Rogan and Fitzpatrick, 2004). Bee habits vary based on range and climate. In general, bees will forage where they need to in order to collect pollen and nectar. If there is an abundant source of both close to the nest, then their average foraging distances will be lower than if the bees must forage further to find adequate pollen and nectar. Both honey bees and alfalfa leafcutter bees will increase their foraging distance as the distance to high-reward resources (high nectar and pollen amounts) increases, and as closer resources become scarce. Patchiness of the environment also

<sup>60</sup> <http://ag.montana.edu/msga/Seed%20Standards/alfalfa%20standards.pdf>

<sup>61</sup> <http://www.idahocrop.com/standards.aspx>

<sup>62</sup> <http://www.wisc.edu/wcia/2008StandardW.pdf>

<sup>63</sup> <http://ag.montana.edu/msga/Seed%20Standards/alfalfa%20standards.pdf>

affects this foraging distance, as bees can prefer certain flowers over others (depending on the species and season), and might need to travel through or around obstacles in the environment, so they will adapt foraging habits accordingly (Greenleaf et al., 2007).

**Table Q-9. Pollinator Foraging Distance**

| <b>Pollinator (Species)</b>                           | <b>Forage Distance from Nest</b>                                                                                                             |
|-------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| Alfalfa leafcutter bee ( <i>Megachile rotundata</i> ) | 300-600 feet (McCaslin et al., 2000)                                                                                                         |
| Honey bee ( <i>Apis mellifera</i> )                   | Measured up to 6.21 miles away, average distance depends on availability of pollen/nectar, typically 1.86 miles (Beekman and Ratnieks, 2000) |
| Alkali bee ( <i>Nomia melanderi</i> )                 | Will forage up to 4 or 5 miles away; typical pollination within 2 mile radius (USGS, 2008)                                                   |
| Long-horned bee ( <i>Melissodes</i> sp)               | Data not found                                                                                                                               |
| Mud/Digger bee ( <i>Anthophora</i> spp) (2)           | Data not found                                                                                                                               |
| Bumblebee ( <i>Bombus morrisoni</i> )                 | Data not found                                                                                                                               |
| Bumblebee ( <i>Bombus griseocollis</i> )              | Data not found                                                                                                                               |
| Sweat bee ( <i>Lasioglossum sisymbrii</i> )           | Data not found                                                                                                                               |
| Sweat bee ( <i>Halictus tripartitus</i> )             | Data not found                                                                                                                               |
| Sweat bee ( <i>Halictus confusus</i> )                | Data not found                                                                                                                               |
| Leafcutter bee ( <i>Megachile texana</i> )            | Data not found                                                                                                                               |
| Mason bee ( <i>Osmia laticulcata</i> )                | Data not found                                                                                                                               |

Cane (2002) performed a study on the primary pollinators of alfalfa and measured their pollination effectiveness. Alfalfa has a mechanical trip for pollination, where once the bee lands on the flower, the mechanical pressure releases the stamen and pistils, which then fly up and either deposit pollen on the bee's underside or picks up pollen if the bee has already visited another alfalfa flower. This is an irreversible process, so one visit is enough for pollination to occur. However, because honey bees dislike getting hit by the flower, they often cheat by approaching the flower from the side to get nectar, which does not pollinate the flower. This accounts for the varying pollination rates of different bee species. Females of the alfalfa leafcutter bee and the alkali bee are the most effective pollinators, tripping 81 and 78 percent of flowers visited, respectively. Males of these species are less effective, with efficiencies of 61 and 51 percent, respectively. Honey bees trip only 22 percent of flowers visited.

Agricultural farmers manipulate bee colonies to control pollination of their crops. Alfalfa farmers purposely stock bees only in seed farming, as they do not want pollination of hay fields, and because most regions that cultivate alfalfa seed do not have naturally occurring populations of alfalfa pollinators, farmers must produce, introduce and manage these pollinators to ensure pollination (Rogan and Fitzpatrick, 2004). Alfalfa leafcutter bees, a typical managed species, are established next to the target crop of alfalfa. The release of these bees can be controlled by directing incubation temperatures, which signal the bee developmental processes. Farmers judge when blooming of the crop will be at a peak, and will time the incubation and subsequent release of the bees accordingly. See section 3.4 for discussion of the interaction between flowering time and pollination, for both hay and seed fields. Once the released bees have completed their season and die, the larvae laid throughout the season are collected and cleaned, then stored at a temperature that keeps them in a pupating stage until the desired release time next year. Honey bee colonies, however, are moved from field to field as they are highly portable and stay with their queen. They also tend to forage at much larger distances, and this increases the chances of pollen being spread from one location to another. Table Q-10 presents factors that influence bee

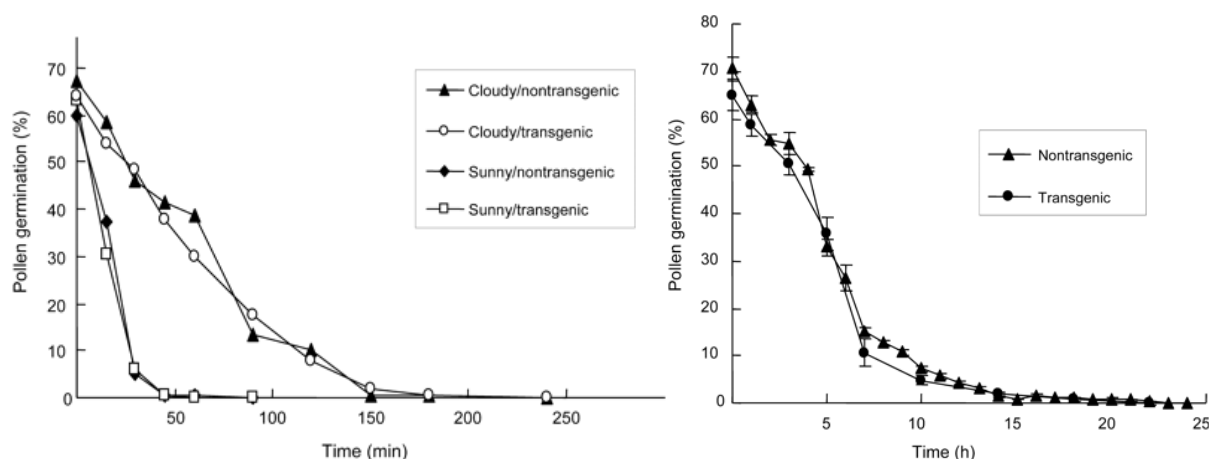
activity (adapted from Greenleaf et al., 2007; Strickler and Vinson, 2000;  
<http://www.beeepollination.com/growers.php>).

**Table Q-10. Factors That Influence Bee Activity**

| <b>Factor</b>                     | <b>Description</b>                                                                                                                                                                            |
|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Weather (rain, wind, cloud cover) | Honey bees do not fly in rain or in wind over approx. 15 mph, and have less activity on cloudy days                                                                                           |
| Temperature                       | There is a minimum temperature for bees to forage at, usually about 55°F for honey bees                                                                                                       |
| Season                            | Bees forage at specific times in the season based on species; some bees forage throughout the late spring, summer and early fall while others might only forage for a few weeks in the summer |
| Flower availability               | Bees will forage further from the nest in order to reach high reward flowers                                                                                                                  |
| Time of day                       | Bees used for alfalfa pollination typically only forage during the day                                                                                                                        |
| Hive placement                    | Hives placed at the edges of fields will pollinate the field in a different pattern than if they are placed in the middle of a field                                                          |
| Number of bees                    | If there are too many bees at a field and competition is too high, bees may leave the field to establish new colonies or nests                                                                |
| Flower biology                    | The number of days flowers are in bloom can affect pollination efficacy—the longer flowers bloom, the more chances for pollination                                                            |
| Plant competition                 | Bees will preferentially forage on more attractive flowers if given the option                                                                                                                |
| Strength of colony                | Strong colonies (higher numbers) have more flying bees and will forage in lower temperatures than weak colonies                                                                               |
| Disease and parasites             | Infected colonies and bees will forage less than uninfected colonies and bees                                                                                                                 |

### *3.7.1 Pollen Viability in the Environment*

For bees whose hives are moved between fields throughout a season, there is a question of whether viable pollen could survive in the hive and be transported. Pollen environmental viability has been tested for the wind pollinated forage grass, tall fescue (Wang et al., 2004). Pollen viability is highly sensitive to environmental conditions. This particular study examined differences between transgenic pollen and non-transgenic pollen, which were non-significant. There is an optimal temperature peak (approx 25°C or 77°F), above and below which the pollen viability decreases. Both types of pollen dropped to 5 percent viability in 30 minutes in sunny conditions, while they dropped to the same level in 150 minutes in cloudy conditions (figure Q-7a). In growth chamber conditions with controlled temperature and humidity, both types of pollen decreased to about 5 percent viability in 12 hours, with a complete loss of viability after 22 hours (figure Q-7b). This rapid decrease of pollen viability in ambient atmospheric conditions is also found in wheat (none after 65-70 min), triticale, a wheat-rye hybrid (none after 110-120 min) and maize (none after 120 min). From these data it appears that if honey bee hives are transported more than two hours away, residual pollen would be unviable in the new environment. The degree to which tall fescue and alfalfa have pollen with similar longevity is unknown. In general pollen is only viable for hours or days in the environment (Mallory-Smith and Zapiola, 2008). The FGI Best Practices do not permit hives to be moved from GT alfalfa to non-GT alfalfa within a growing season.



**Figure Q-7: Pollen longevity in tall fescue (Wang et al., 2004)**

Figure Q-7a: Longevity of pollen of tall fescue under ambient atmospheric conditions. Pollen was collected from seed-derived plants and transgenic progenies of tall fescue, and germination was evaluated under sunny (Sunny/nontransgenic, Sunny/transgenic) and cloudy (Cloudy/nontransgenic, Cloudy/transgenic) conditions.

Figure Q-7b: Longevity of pollen of tall fescue under controlled conditions (24°C, relative humidity 54 ± 5 percent) in a growth chamber as measured by percentage germination (means ± 1 SE). Pollen was collected from seed-derived plants (nontransgenic) and transgenic progenies (transgenic) of tall fescue. (Wang, 2003)

### 3.7.2 Honey Production

Alfalfa honey makes up one-third of the annual production of U.S. honey, and there is a market for organic honey. Because honey bees are known to forage over long distances, there is a chance that honey bees would bring pollen containing GT trait back to honey-producing hives if there was a GT alfalfa field nearby (Hubbard 2008).

## 3.8 Gene Flow Between Alfalfa Populations

Gene flow is a measure of exchange of genes between populations. The concern is how much gene flow is occurring between populations of GT alfalfa and non-GT alfalfa. Some farmers may want very low (<0.5 percent) or zero presence of the GT trait in their crops in order to meet the needs of their customers. This section discusses each of the nine possible combinations of gene flow between the three classes of alfalfa populations (table Q-11).

There are several factors that influence the probability of gene flow between fields (adapted from Putnam 2006):

- Probability of synchronous flowering (e.g., the percentage of days where synchronous flowering occurs).
- Availability of pollen (e.g., the percentage of bloom during each day of synchronous flowering).
- Pollinator activity on days of synchronous flowering and placement of bee hives (e.g., influenced by timed bee release and weather).
- Distance between fields (alfalfa populations).
- Probability of seed maturation.
- Probability of seed germination.



In the following sections, each of the above factors is discussed within the context of each of the nine gene flow scenarios. A summary of the research on gene flow in alfalfa is presented in table Q-11.

**Table Q-11. U.S. Research on Gene Flow in Alfalfa**

| Location                                                                         | Researcher Affiliation                | Dates            | Alfalfa Populations            | Pollinators                                                                         | Publications                                                                    |
|----------------------------------------------------------------------------------|---------------------------------------|------------------|--------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Prosser, Washington                                                              | USDA/ARS and Kansas State University  | 1994             | Seed to seed (within a field)  | Leafcutter ( <i>Megachile</i> spp.)                                                 | Amand et al., 2000                                                              |
| Prosser, Washington and Manhattan, Kansas*                                       | USDA/ARS and Kansas State University  | 1995             | Hay to seed and Seed to seed   | Not indicated                                                                       | Amand et al., 2000                                                              |
| Prosser, Washington                                                              | USDA/ARS and Kansas State University  | Not indicated    | Feral to feral                 | Not indicated                                                                       | Amand et al., 2000                                                              |
| Canyon County, Idaho                                                             | Forage Genetics International (FGI)   | 2000, 2001, 2002 | Seed to seed                   | Leafcutter bees ( <i>Megachile rotundata</i> ) (some honey bees observed)           | Fitzpatrick et al., 2002; Fitzpatrick et al., 2003 ; Rogan and Fitzpatrick 2004 |
| Touchet, Washington                                                              | University of CA Davis, FGI           | 2002             | Hay (50 percent bloom) to seed | Leafcutter bees ( <i>Megachile rotundata</i> )                                      | Rogan and Fitzpatrick 2004; Teuber and Fitzpatrick 2007                         |
| Kings County, California (San Joaquin Valley)                                    | University of CA Davis, FGI, Monsanto | 2003             | Seed to seed                   | Honey bee ( <i>Apis mellifera</i> )                                                 | Teuber et al., 2004; Teuber et al., 2005; Teuber et al., 2007                   |
| San Joaquin Valley California                                                    | University of CA Davis, FGI           | 2006             | Hay (20 percent bloom) to seed | Honey bee ( <i>Apis mellifera</i> )                                                 | Teuber and Fitzpatrick 2007; Teuber et al., 2007                                |
| San Joaquin Valley California                                                    | University of CA Davis, FGI, USDA/ARS | 2006, 2007       | Seed to seed                   | Honey bees and leafcutter bees                                                      | Teuber et al., 2007; Van Deynze et al 2008                                      |
| Fruita, Colorado                                                                 | Colorado State University             | 2006             | Seed to feral                  | Honey bees and leafcutter bees plus 9 other bee species                             | Hammon et al., 2006                                                             |
| California, Colorado, Idaho, Montana, Nevada, Oregon, Texas, Washington, Wyoming | FGI                                   | 2006             | Seed to seed                   | Leafcutter bees, alkali bees, and honey bees (used according to FGI Best Practices) | FGI 2007                                                                        |

\* both locations had both seed and hay fields as pollen sources

### 3.8.1 Seed to Seed Gene Flow

As discussed in section 3.6, there are standards in place that ensure >99 percent (Certified) and >99.9 percent (Foundation) purity for seed varieties. The mean seed yield in Nebraska and Kansas were 72 and 100 lbs per acre (1988-1992) versus greater than 500 lbs per acre for states

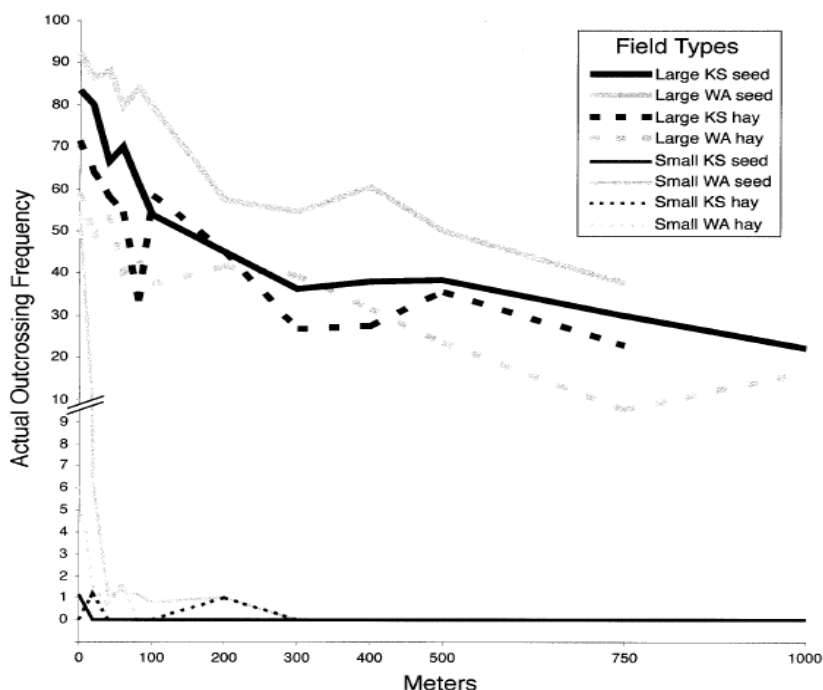
in prime seed growing states (Hower et al., 1999). In the 2006 growing season FGI commercial seed fields averaged 500 to 1100 pounds per acre (FGI, 2007). The factors that influence seed to seed gene flow are as follows:

- Probability of synchronous flowering – Seed fields flower for about 5-6 weeks (Bosch and Kemp, 2005). The FGI Best Practices for seed production does not mention whether flowering is intentionally offset between seed fields. Because of the length of time alfalfa can flower, there will likely be some overlap between flowering time among seed fields.
- Availability of pollen – Seed fields are allowed to go to 100 percent bloom, so pollen is available.
- Pollinator activity on days of synchronous flowering and placement of bee hives – Bee activity is managed in seed fields. Wild bees are present, but at much lower levels than the bees that are brought in for pollination.
- Distance between fields (alfalfa populations) – Refer to section B.6 for the distances between fields that are recommended for seed fields to reduce pollen flow. FGI Best Practices requires 900 feet when leafcutter bees are used, 1 mile when alkali bees are used, and 3 miles when honeybees are the predominant pollinator species (FGI 2007).
- Probability of seed maturation – Although 100 percent of the flowers that are pollinated do not mature, in seed fields most of the pollinated flowers produce mature seed. This is in contrast to hay fields, which are mowed before seed is allowed to mature.
- Probability of seed germination. – Orloff et al. (1997) state that about 60 percent of seeds germinate when planted under good conditions (correct depth and soil conditions). When a hay farmer plants commercially produced seed the germination rate is indicated on the label. This assumes that the field has been properly prepared and the soil is free of herbicides and alfalfa autotoxic compounds.

#### 3.8.1.1 Summary of Research – Seed to Seed

Armand et al. (2000) examined gene flow from both alfalfa hay and seed fields to outside populations (trap plots), and the differences between small and large source populations. Their results indicate that pollen does not travel far within a field, with dispersal distances of 4 meters or less. This could indicate that the bees are being cleansed of marker pollen by visiting non-marker plants close by, as opposed to depositing marker pollen far away. At 1,000 meters (3,281 feet), up to 22.2 percent of the trap population seed was from outcrossing (possibly more as the 1,000 meter populations were the farthest examined). Also, a higher amount of gene flow was found when the source population was a large field as opposed to a small study population, and the marker was exchanged between escaped alfalfa populations. A summary of Armand et al (2002) data is reproduced in figure Q-8. It should be noted that the trap populations Armand et al. (2000) used were clonal and therefore likely to have a high degree of self-incompatibility. Self-incompatibility within the clonal trap population would lead to seeds being formed more frequently from outcrossing from the source field. The clonal traps may not represent how feral alfalfa would receive pollen, since feral populations would pollinate among themselves and thus be less receptive to distant pollen sources (Rogan and Fitzpatrick, 2004). The clonal nature of the trap plots was because the researchers identified a unique marker gene in a single plant and

bred several generations to develop homozygous plants for the marker band. GT alfalfa varieties and conventional varieties do not have as high degree of genetic similarity as the research line created by Armand et al. (2000).



• **Figure Q-8: Summary data from Armand et al. (2000)**

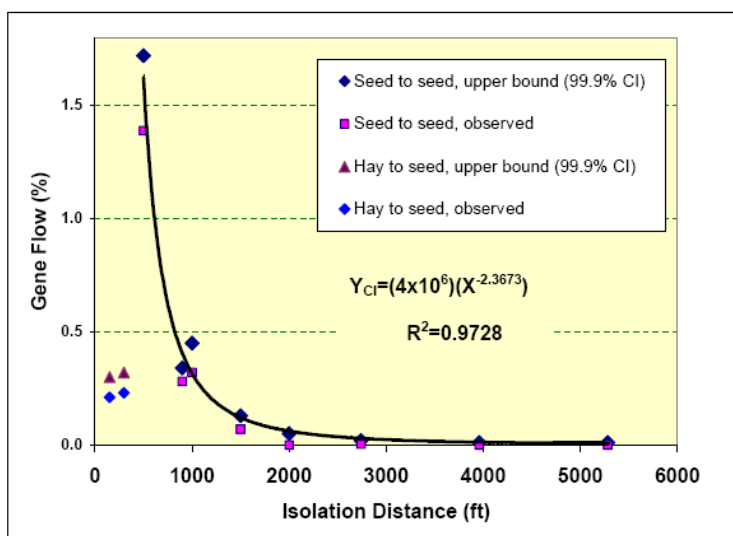
Gene movement away from commercial-scale (large) seed and hay production fields and research-scale (small) seed and hay plots in Kansas and Washington State. Progeny from trap plots of cloned alfalfa were examined for a specific marker-gene and for apparent non-self events using RAPDs. Outcrossing from small plots was not detected beyond 200 m (note axis scale change)

FGI's 2000 to 2002 field studies using leafcutter bees, in Idaho, showed a range of 1.39 percent (1.72 percent is the 99.9 percent confidence level upper limit) at 500 feet and 0.0000 percent (0.01 percent CI) at  $\frac{3}{4}$  of a mile (Fitzpatrick et al., 2002). Table Q-12 and figure Q-9 present a summary of these field studies.

**Table Q-12. Summary of FGI Idaho Gene Flow Studies (Fitzpatrick et al., 2002)**

| Isolation distance                     | Year 2000                         | Year 2001 <sup>a</sup>                 | Year 2002 <sup>a, b</sup>            | 2000-2002 Overall Mean Observed gene flow (99.9% C.I. upper bound) |
|----------------------------------------|-----------------------------------|----------------------------------------|--------------------------------------|--------------------------------------------------------------------|
| 0 ft (Source Plot)                     | Source (1.0 A)                    | Source (1.6 A)                         | Source (1 A)                         |                                                                    |
| 500 ft                                 | Reps 1-4: 0.03 A, N. <sup>c</sup> | -                                      | -                                    | 1.39% (1.72%)                                                      |
| 900 ft                                 | -                                 | Rep 1: 0.7 A, N.<br>Rep 2: 1.6 A, N.E. | -                                    | 0.28% (0.34%)                                                      |
| 1000 ft                                | Reps 1-4: 0.03 A, N. <sup>c</sup> | -                                      | -                                    | 0.32% (0.45%)                                                      |
| 1500 ft                                | Reps 1-4: 0.03 A, N. <sup>c</sup> | Rep 1: 1.6 A, W.<br>Rep 2: 1.6 A, N.W. | Rep 1: 1 A, S.W.<br>Rep 2: 1 A, S.E. | 0.08% (0.13%)                                                      |
| 2000 ft                                | Rep 1: 2.0 A, N.W. <sup>a</sup>   | -                                      | -                                    | 0.00% (0.05%)                                                      |
| 2640 ft (1/2 mi)                       | -                                 | -                                      | Rep 1: 1 A, S.W.<br>Rep 2: 1 A, S.E. | 0.003% (0.02%)                                                     |
| 3960 ft (3/4 mi)                       | -                                 | -                                      | Rep 1: 1 A, S.W.<br>Rep 2: 1 A, S.E. | 0.0000% (0.01%)                                                    |
| 5280 ft (1 mi)                         | -                                 | -                                      | Rep 1: 1 A, N.W.<br>Rep 2: 1 A, S.E. | 0.0000% (0.01%)                                                    |
| Mean no. seed tested per trap distance | 14,750                            | 41,250                                 | 60,000                               |                                                                    |

Table Q-12. Isolation distance between trap and source, number of replicates per distance, replicate plot size (acres), trap plot cardinal direction from source and, interplot land cover <sup>a,b,c</sup>, the mean observed gene flow and the upper bound of true gene flow (i.e., the 99.9% confidence interval upper limit) are given.  
Interplot land cover: <sup>a</sup> Various crop species typical for the area (e.g., onions, corn, wheat, etc.); <sup>b</sup> roadways, or <sup>c</sup> fallow. “-” indicates distance not tested.



**Figure Q-9: Summary of GFI 2000-2002 gene flow studies (Rogan and Fitzpatrick 2004)**

Three-year summary of alfalfa gene flow for seed production using leafcutter bees with 150 ft to 1 mile isolation distance from gene source plot. Values given are the observed and upper bound of true gene flow (99.9% confidence) based on all data collected during 2000, 2001, and 2002 field studies. The equation for,  $Y_{Ci} = (4 \times 10^6)(X^{-2.3673})$  was calculated using seed production source plots only. USDA Notification Numbers: 00-053-07n (2000); 01-009-08n (2001); 02-020-09n (2002).

University of California—Davis, FGI and Monsanto studied seed to seed gene flow using honey bees (2003 growing season). At 900 feet gene flow was 1.49 percent, near 5,000 feet it was 0.2 percent, and at 2.53 miles it was  $\leq 0.06$  percent (Teuber et al., 2004). Gene flow was estimated by growing seeds from the trap plots and testing the seedlings for glyphosate tolerance (75,000 to 90,000 seedlings were tested per trap plot). Seed samples from the 2003 field study were also

tested using the transgene protein detection strip test. The strip test results were in agreement with the large scale seedling growout assays (Teuber et al., 2007).

In 2006 and 2007, in the San Joaquin Valley of California, a mixed honey bee and leafcutter bee gene flow study was done (Teuber et al., 2007; Van Deynze et al., 2008). A summary data from those studies is presented in table Q-13.

**Table Q-13. Seed to Seed Gene Flow (Teuber et al., 2007)**

| <b>Distance</b> | <b>Gene Flow (percent adventitious presence)</b> |
|-----------------|--------------------------------------------------|
| 165 feet        | 2.3                                              |
| 900 feet        | 0.9                                              |
| 4,000 feet      | 0.6                                              |
| 1 mile          | 0.2                                              |
| 3 miles         | 0.03                                             |
| 5 miles         | Not detected                                     |

During the 2006 growing season, FGI conducted a study to validate their FGI Best Practices (FGI 2007). They tested 122 of their conventional commercially-grown seed lots. Of the 122 lots, 115 of the lots were grown in a region containing at least one GT alfalfa seed field at a know isolation distance and 32 of the lots had detectable gene flow. In the lots where gene flow was detected, it was at the low level of 0.004 to 0.180 percent. Experimental plots were also set up to capture gene flow that occurs at distances less than recommended by FGI Best Practices. The data from this study are presented in table Q-14.

**Table Q-14. Summary of FGI Commercial-scale Seed Production Gene Flow Study (FGI 2007)**

| Distance from source field (feet, x) | Small conventional fields with worse-case setting for gene flow |                                                            |                                                        | Large conventional fields grown under commercial-practice settings |
|--------------------------------------|-----------------------------------------------------------------|------------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------------------------|
|                                      | Predicted gene flow (%) at < 1 mile isolation <sup>c</sup>      | Predicted gene flow (%) at > 1 mile isolation <sup>d</sup> | Observed gene flow in test plots (%) <sup>a or b</sup> | Observed gene flow (%) in FGI commercial fields                    |
| 50                                   | 1.84                                                            |                                                            |                                                        |                                                                    |
| 165                                  | 1.80                                                            |                                                            | 1.96 <sup>b</sup>                                      |                                                                    |
| 600                                  | 1.67                                                            |                                                            |                                                        |                                                                    |
| 900                                  | 1.58                                                            |                                                            | 1.49 <sup>a</sup>                                      |                                                                    |
| 1320                                 | 1.46                                                            |                                                            | 1.06 <sup>b</sup>                                      |                                                                    |
| 1500                                 | 1.40                                                            |                                                            |                                                        |                                                                    |
| 2000                                 | 1.25                                                            |                                                            |                                                        |                                                                    |
| 2640                                 | 1.06                                                            |                                                            | 0.99 <sup>b</sup>                                      |                                                                    |
| 2796                                 | 1.01                                                            |                                                            | 0.99 <sup>a</sup>                                      |                                                                    |
| 3000                                 | 0.95                                                            |                                                            |                                                        |                                                                    |
| 3960                                 | 0.66                                                            |                                                            | 0.39 <sup>b</sup>                                      |                                                                    |
| 4000                                 | 0.65                                                            |                                                            |                                                        |                                                                    |
| 4692                                 | 0.44                                                            |                                                            | 0.19 <sup>a</sup>                                      |                                                                    |
| 5000                                 | 0.35                                                            |                                                            |                                                        |                                                                    |
| 5280 (1 mile)                        | 0.27                                                            | 0.58                                                       |                                                        | 0.09 <sup>b</sup>                                                  |
| 6588                                 | 0.00                                                            | 0.42                                                       | 0.15 <sup>a</sup>                                      |                                                                    |
| 6,600-7,920                          |                                                                 | 0.34                                                       |                                                        | 0.01 <sup>b</sup>                                                  |
| 8484                                 |                                                                 | 0.20                                                       | 0.05 <sup>a</sup>                                      |                                                                    |
| 10,119                               |                                                                 | 0.00                                                       |                                                        |                                                                    |
| 10,380                               |                                                                 | 0.00                                                       | 0.02 <sup>a</sup>                                      |                                                                    |
| 12,276                               |                                                                 | 0.00                                                       | 0.07 <sup>a</sup>                                      |                                                                    |
| 14,520-15,840                        |                                                                 | 0.00                                                       |                                                        | 0.01 <sup>e</sup>                                                  |
| 26,400                               |                                                                 | 0.00                                                       |                                                        | 0.00 <sup>e</sup>                                                  |
| 42,240-52,800                        |                                                                 | 0.00                                                       |                                                        | 0.00 <sup>e</sup>                                                  |
| > 52,800                             |                                                                 | 0.00                                                       |                                                        | 0.00 <sup>e</sup>                                                  |

Analysis of honeybee-mediated gene-flow (%) between adjacent alfalfa seed fields predicted using two linear models developed from research trial data presented by Teuber et al. (2005) and data observed in 2003<sup>a</sup> and in 2006<sup>b</sup> experiments. "Small" (≤2.2 acre) or "large" conventional seed fields were separated from Roundup Ready alfalfa seed fields at a range of isolation distances (165 feet to more than 10 miles). In 2003 and 2006 experiments, each individual conventional trap plot was 11 or 150 times smaller than the Roundup Ready pollen source plot, respectively. Also in the experimental plots, isolation was compromised ("bridged") for all but shortest distance by other alfalfa trap seed plots stocked with honeybee hives at commercial density. Combined, these biases favored maximum Roundup Ready gene flow and allowed for measurement and modeling of pollen-mediated gene flow under "worse-case situations". In contrast, in the 2006 commercial-practice "large" seed fields true isolation was used and the conventional and Roundup Ready seed fields were approximately equal in size (non worse-case). Gene flow potential using cultured honeybee pollination, commercial seed grower practices and 1 mile true isolation resulted in approximately three to five times less gene flow than predicted using worse-case models.

<sup>a</sup> 2003 Data published previously in Teuber et al., 2004 and 2005, % observed in bioassay test. These data values were used by Teuber et al. (2005) to calculate the linear regression models for honeybees, given below.

<sup>b</sup> 2006 Data developed by Teuber et al., unpublished, preliminary data; % estimated from laboratory test; these fields did not conform to Best Practices isolation by experimental design.

<sup>c</sup> Predicted values for <1 mile were calculated per Teuber et al. 2005 linear regression model:  $y = -0.00030x + 1.8529$ ,  $x^2 = 0.98$ , where y is % gene flow and x is distance (ft.)

<sup>d</sup> Predicted values for >1 mile were calculated per linear regression model calculated using the data published by Teuber et al. 2005 data for distances >1 mile:  $y = -0.00012x + 1.2143$ ,  $r^2 = 0.72$ ,  $p = 0.02$  (significant fit).

<sup>e</sup> 2006 Data developed by FGI from commercial seed fields; these FGI-owned conventional seed fields were grown to conform to FGI Best Practices

In summary, the largest data set collected under actual seed production conditions, using FGI Best Practices, found a range of gene flow from 0.00 to 0.18 percent. This is well below the FGI company goal of less than 0.5 percent adventitious presence.

### 3.8.2 Hay to Seed Gene Flow

Hay to seed gene flow is another possible source of presence of the GT trait in non-GT alfalfa seeds. The factors that influence hay to seed gene flow are as follows:

Probability of synchronous flowering – Seed fields flower for about 5-6 weeks (Bosch and Kemp, 2005). Hay fields that are harvested at 10 percent bloom only have flowers for about a week (Shroyer et al., 1984) and for most of that time the field is at far below 10 percent bloom.<sup>64</sup> There may be some overlap between flowering time among hay fields and seed fields, but it is likely to be limited to a few days (figure Q-3).

Availability of pollen from hay fields – Hay fields may be harvested any time between pre-bud and 100 percent bloom; however the majority of fields are harvested at or below 10 percent bloom.

Pollinator activity on days of synchronous flowering and placement of bee hives – Bees are brought in for seed fields, but not for hay fields. Wild bees are present at relatively low levels compared to bees brought in for seed field pollination. There will likely be some bee activity in hay fields with bloom, especially if bee hobbyists have hives nearby.

Distance between fields (alfalfa populations) – There are no required distances between hay fields, but seed fields are still required to be separated from hay fields (section 3.6).

Probability of seed maturation – Although 100 percent of the flowers that are pollinated do not mature, in well cared for seed fields most of the pollinated flowers produce mature seed. This is in contrast to hay fields, which are mowed before seed is allowed to mature.

Probability of seed germination. – Orloff et al. (1997) state that about 60 percent of seeds germinate when planted under good conditions (correct depth and soil conditions). When a hay farmer plants commercially produced seed the germination rate is indicated on the label. This assumes that the field has been properly prepared and the soil is free of herbicides and alfalfa autotoxic compounds.

#### 3.8.2.1 Summary of Research – Hay to Seed

Table Q-6 (Armand et al., 2000) presents hay to seed data. Refer to section 3.8.1 for discussion of Armand et al (2000).

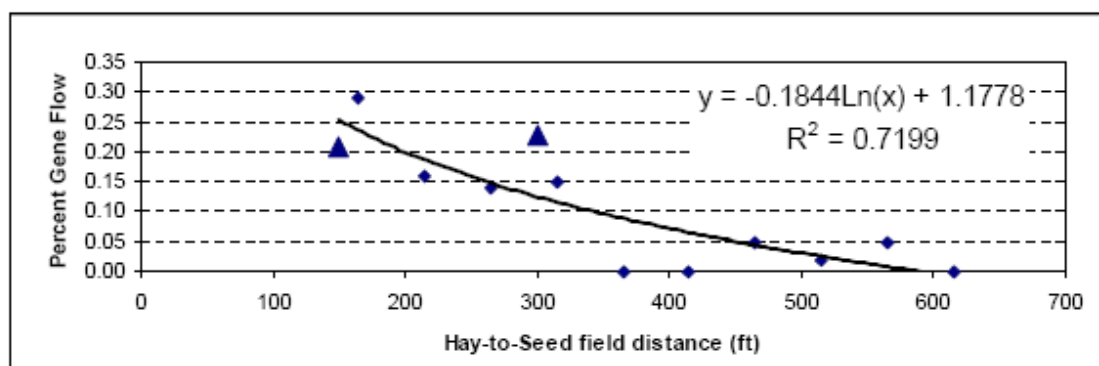
In field studies in 2002, in Washington, FGI detected 0.21 percent gene flow at 150 feet and 0.23 percent gene flow at 300 feet. The hay fields which were the source of pollen were mowed at 50 percent bloom (Teuber and Fitzpatrick, 2007; Rogan and Fitzpatrick, 2004). Figure Q-10 presents this hay to seed in the same graph as the seed to seed data that FGI collected in the same time period in Idaho. A larger scale hay to seed gene flow study by the same researchers, but performed in the San Joaquin Valley of California, in 2006, yielded the data presented in table Q-15. Hay was harvested at 20 percent bloom and seed fields had been stocked with honey bees.

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<sup>64</sup> Maturity timeline varies based on environmental conditions. However, Shroyer et al. (1984) present a figure with alfalfa progressing from bud to 1/10 bloom in one week.

**Table Q-15. Hay to Seed Gene Flow (Teuber and Fitzpatrick, 2007)**

| Distance between hay and seed field (feet) | Percentage gene flow |
|--------------------------------------------|----------------------|
| 165                                        | 0.29                 |
| 215                                        | 0.16                 |
| 265                                        | 0.14                 |
| 315                                        | 0.15                 |
| 365                                        | 0.00                 |
| 415                                        | 0.00                 |
| 465                                        | 0.05                 |
| 515                                        | 0.02                 |
| 565                                        | 0.05                 |
| 615                                        | 0.00                 |



**Figure Q-10: Hay to seed gene flow (Teuber and Fitzpatrick 2007)**

Observed gene flow (Y %) from hay field plots growing near replicated alfalfa seed field plots in 2000 (▲) and 2006. These trials simulated delayed harvest of hay fields growing near and beyond the AOSCA certified seed field isolation standard (i.e., 165 ft). In 2000, replicated hay plots in Washington were allowed to mature to 50% flower (5X the optimum hay cut stage), seed field plots were stocked with leafcutter bees and separated by 150 or 300 ft from the Roundup Ready® hay field plot<sup>2</sup>. In 2006, replicated seed field plots at the University of California were allowed to mature to 20% flower (2X the optimum hay cut stage), seed field plots were stocked with honeybees and separated by 165 to 615 ft from the Roundup Ready hay field plot.

In summary, hay to seed gene flow is less likely than seed to seed gene flow because hay fields do not usually have more than 10 percent bloom, and that is only for a few days. In addition, certified and foundation seed fields are required to have specific distances between them and other alfalfa fields. There are some farmers that grow uncertified seed which could be immediately adjacent to GT alfalfa hay fields thus GT alfalfa could cross pollinate with conventional alfalfa.

### 3.8.3 Feral to Seed Gene Flow

Many seed farmers control feral alfalfa that may be growing near their seed fields. The factors that influence feral to seed gene flow are as follows:

- Probability of synchronous flowering – Seed fields flower for about 5-6 weeks (Bosch and Kemp, 2005). Feral alfalfa blooms as environmental growth conditions permit. There may be some overlap between flowering time among feral alfalfa and seed fields.



- Availability of pollen from feral alfalfa – Feral alfalfa, if not managed (mowed), and if environmental conditions permit, will flower. Environmental stresses such as drought and insects may greatly reduce flower formation compared to cultivated alfalfa.
- Pollinator activity on days of synchronous flowering and placement of bee hives – Bees are brought in for seed fields and may also visit feral alfalfa if the hives are close enough to the feral populations. Bees may prefer other flowering wild species growing with feral alfalfa, which could reduce bee visits to feral alfalfa. Wild bees are present at relatively low levels compared to bees brought in for seed field pollination. There will likely be some bee activity in feral alfalfa populations and those bees may also visit alfalfa seed fields.
- Distance between seed fields and feral alfalfa – If seed farmers properly manage feral populations, then there should be a sufficient distance between feral populations and seed fields to achieve the current goals of seed purity. Seed farmers will need to be aware of seeding practices in neighboring rangelands because falcata (yellow-flowered alfalfa) may become increasingly adopted for rangeland forage improvement. Falcata seed is available commercially (<http://www.windriverseed.com/Website%20catalog.pdf>).
- Probability of seed maturation – Although 100 percent of the flowers that are pollinated do not mature, in well cared for seed fields most of the pollinated flowers produce mature seed.
- Probability of seed germination – Orloff et al. (1997) state that about 60 percent of seeds germinate when planted under good conditions (correct depth and soil conditions). When a hay farmer plants commercially produced seed the germination rate is indicated on the label. This assumes that the field has been properly prepared and the soil is free of herbicides and alfalfa autotoxic compounds.

No studies that specifically addresses feral to seed gene flow were identified.

#### 3.8.4 *Seed to Feral Gene Flow*

The factors that influence seed to feral gene flow are as follows:

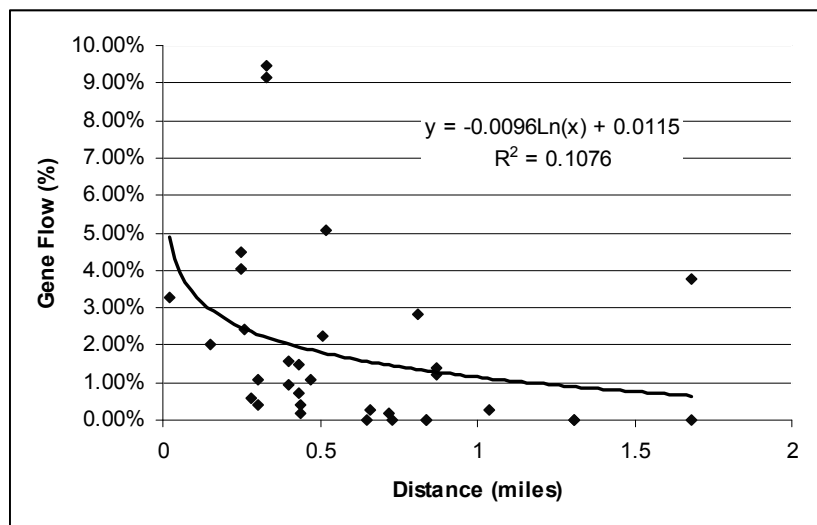
- Probability of synchronous flowering – Seed fields flower for about 5-6 weeks (Bosch and Kemp, 2005). Feral alfalfa blooms as environmental growth conditions permit. There may be some overlap between flowering time among feral alfalfa and seed fields.
- Availability of pollen from seed fields – Seed fields have the highest amount of available pollen compared to the other two populations of alfalfa (hay and feral). Farmers manage field conditions (water and insect control) to maximize flower formation.
- Pollinator activity on days of synchronous flowering and placement of bee hives – Bees are brought in for seed fields. Wild bees are present at relatively low levels compared to bees brought in for seed field pollination. There will likely be some bee activity in the feral populations, especially if bee hobbyists have hives nearby.
- Distance between seed fields and feral alfalfa – If seed farmers properly manage feral alfalfa, there should be very little feral alfalfa to receive pollen. Seed farmers will need to be aware of seeding practices in neighboring rangelands because falcata (yellow-flowered alfalfa) may become increasingly adopted for rangeland forage improvement. Most rangeland farmers will not be sensitive to the presence of GT alfalfa growing on their

rangeland, however there may be organic beef and dairy farmers who will want their rangeland to be free of the presence of the GT trait.

- Probability of seed maturation – If genetic compatibility and the health of the plant are sufficient then feral seeds will mature. Because feral alfalfa is under environmental stresses, such as insect predation and drought that are managed in seed fields, feral alfalfa is likely to have a much lower seed yield than plants in seed fields. If feral alfalfa is mowed, then it will have a much reduced likelihood of maturing.
- Probability of seed germination. – If seed is not set, germination is irrelevant. Germination near parent plants is limited by the autotoxicity of alfalfa. Seeds of many plant species, including alfalfa, are spread through the feces of wildlife and other grazing animals (personal communication Gerald Schuman, retired USDA ARS, July 30, 2008).

#### 3.8.4.1 Summary of Research – Seed to Feral

Hammon et al. (2007) harvested feral alfalfa plants from 23 sites within two miles of GT alfalfa seed fields near Fruita, Colorado. The GT transgene was found at 83 percent of the collection sites out to a distance of 1.7 miles. Figure Q-11 shows the gene flow recorded by Hammon et al. (2007).



**Figure Q-11: Seed to feral gene flow (Hammon et al., 2006)**

#### 3.8.5 Feral to Feral Gene Flow

The factors that influence feral to feral gene flow are as follows:

- Probability of synchronous flowering – Feral alfalfa blooms as environmental growth conditions permit. There is evidence of naturalized alfalfa populations that are over 80 years old (Smith, 1997), so it is clear that feral populations have some level of

synchronous blooming even under rangeland grazing conditions. Very small feral populations may have less synchronous blooming, unless the environment (including soil conditions) promotes synchronous blooming.

- Availability of pollen – Feral alfalfa, if not managed (mowed), and if environmental conditions permit, will flower. Environmental stresses such as drought and insects may greatly reduce flower formation compared to cultivated alfalfa.
- Pollinator activity on days of synchronous flowering and placement of bee hives – Pollination within and between feral populations depends on wild pollinators, unless hobbyists' honey bee hives are nearby. There may also be some bee activity from hives brought in for seed fields. The presence of bees for pollinating remote feral populations is much lower than for feral populations that are near seed fields and other farming operations that utilize managed bee hives.
- Distance between feral populations – Feral populations may be so remote that they do not interbreed. Kendrick et al. (2005) surveyed feral alfalfa at 940 sites in six states. Feral alfalfa populations along roadsides were one to greater than 12 miles apart.<sup>65</sup>
- Probability of seed maturation – If genetic compatibility and the health of the plant are sufficient then feral seeds will mature. Because feral alfalfa is under environmental stresses, such as insect predation and drought that are managed in seed fields, feral alfalfa is likely to have a much lower seed yield than plants in seed fields. If feral alfalfa is mowed, then it will have a much reduced likelihood of maturing.
- Probability of seed germination. – If seed is not set, germination is irrelevant. Germination near parent plants is limited by the autotoxicity of alfalfa. Seeds of many plant species, including alfalfa, are spread through the feces of wildlife and other grazing animals (personal communication Gerald Schuman, retired USDA ARS, July 30, 2008).

### 3.8.5.1 Summary of Research – Feral to Feral

Armand et al. (2000) placed feral trap plants along roadsides and in urban areas at least 800 meters from known alfalfa fields. Feral to feral gene flow was detected at 230 meters, but not in any of the urban sites. Table Q-16 summarizes Armand et al. (2000) feral to feral gene flow data.

**Table Q-16. Feral to Feral Gene Flow (Armand et al., 2000)**

| Sample                                                                  | Isolation Distance (meters) <sup>a</sup> | Total Seeds Tested | Outcrossing Frequency Percent |
|-------------------------------------------------------------------------|------------------------------------------|--------------------|-------------------------------|
| Escape #1                                                               | 70                                       | 22                 | 90.9                          |
| Escape #2                                                               | 79                                       | 20                 | 80.0                          |
| Escape #3                                                               | 145                                      | 15                 | 46.7                          |
| Escape #4                                                               | 230                                      | 51                 | 92.2                          |
| Urban #1                                                                | >800                                     | 0 <sup>b</sup>     | NA                            |
| Urban #2                                                                | >800                                     | 0 <sup>b</sup>     | NA                            |
| Urban #3                                                                | >800                                     | 0 <sup>b</sup>     | NA                            |
| <sup>a</sup> Distance to the nearest individual alfalfa plant or field. |                                          |                    |                               |
| <sup>b</sup> No seed set in urban areas.                                |                                          |                    |                               |

If a gene is introduced to a population at a low frequency, then it will begin to move towards an equilibrium frequency in the population. In general, genes at low frequencies in populations

<sup>65</sup> For a review of Kendrick et al. (2005) see the Technical Report Effects of Glyphosate-Tolerant Weeds in Non-Agricultural Ecosystems

undergoing random mating experience genetic drift, which can push an allele out of a population. (Genetic drift is the change in gene frequencies due to random chance. For example, if one plant out of 100 has the GT gene, then gene flow is at one percent, but if that plant happens to be eaten by a deer, then the frequency of the gene in the population randomly changed to 0 percent). However, if the gene imparts a selective advantage, then natural selection will act to maintain the gene in the population. The GT trait is not expected to impart increased fitness in feral alfalfa. If there is high gene flow between populations, then even if a gene is pushed out of a population by a force such as drift, then it could be reintroduced again at a later time (Scott, 2007). The GT trait has not been shown to have a fitness cost and herbicide resistance transgenes have been shown to persist in *Brassica napus* and *Brassica rapa* hybrids under field conditions, even though the hybrids themselves had a fitness penalty (Mallory-Smith and Zapiola, 2008). The frequency of the GT trait in feral alfalfa populations after introduction would be based on a balance between these factors.

### 3.8.6 Hay to Feral Gene Flow

The factors that influence hay to feral gene flow are as follows:

- Probability of synchronous flowering – Hay fields that are harvested at 10 percent bloom only have flowers for about a week (Shroyer et al., 1984) and for most of that time the field is at far below 10 percent bloom. Feral alfalfa blooms as environmental growth conditions permit. There may be some overlap between flowering time among feral alfalfa and hay fields.
- Availability of pollen – Hay fields may be harvested any time between pre-bud and 100 percent bloom; however the majority of fields are harvested at or below 10 percent bloom.
- Pollinator activity on days of synchronous flowering and placement of bee hives – Wild bees and hobbyist bee hives are the sources of pollinators between hay and feral populations.
- Distance between fields (alfalfa populations) – Out of all the alfalfa populations, feral and hay populations are likely to be the closest the most often. Hay farmers do not typically control feral alfalfa, and much of the feral alfalfa near hay fields is escaped hay seed, which may not persist as a breeding population. Kendrick et al. (2005) surveyed feral alfalfa populations in six states at 940 sites. In Idaho, feral and cultivated populations occurred within 2000 meters of each other in approximately three sites per county. In approximately half of those sites, the average distance was less than 20 meters. In Wisconsin, three-fourths of the sites where feral and cultivated populations occurred together had an average distance of less than 20 meters. In California, feral and cultivated populations occurred within 2000 meters of each other in approximately six sites per county. In approximately half of those sites, the average distance was less than 20 meters.
- Probability of seed maturation – If the health of the plant is sufficient then feral seeds will mature. Because feral alfalfa is under environmental stresses, such as insect predation and drought that are managed in seed fields, feral alfalfa is likely to have a much lower

seed yield than plants in seed fields. If feral alfalfa is mowed, then it will have a much reduced likelihood of maturing.

- Probability of seed germination – If seed is not set, germination is irrelevant. Germination near parent plants is limited by the autotoxicity of alfalfa. Seeds of many plant species, including alfalfa, are spread through the feces of wildlife and other grazing animals (personal communication Gerald Schuman, retired USDA ARS, July 30, 2008).

No studies that specifically address hay to feral gene flow were identified.

### *3.8.7 Seed to Hay Gene Flow*

Hay fields have the lowest probability of producing seed compared to feral plants and seed fields. Regardless of the any cross-pollination that happens, hay fields are unlikely to produce seed, therefore they are the lowest risk of propagating gene flow. The factors that influence seed to hay gene flow are as follows:

- Probability of synchronous flowering – Seed fields flower for about 5-6 weeks (Bosch and Kemp, 2005). Hay fields that are harvested at 10 percent bloom only have flowers for about a week (Shroyer et al., 1984) and for most of that time the field is at far below 10 percent bloom. There may be some overlap between flowering time among hay fields and seed fields, but it is likely to be limited to a few days (figure Q-3).
- Availability of pollen – Seed fields have the highest amount of available pollen compared to the other two populations of alfalfa (hay and feral). Farmers manage field conditions (water and insect control) to maximize flower formation.
- Pollinator activity on days of synchronous flowering and placement of bee hives – Bees are brought in for seed fields, but not for hay fields. Wild bees are present at relatively low levels compared to bees brought in for seed field pollination. Seed farmers maximize pollinator activity within seed fields. Bees brought into seed fields do visit nearby hay fields.
- Distance between fields (alfalfa populations) – There are no required distances between hay fields, but seed fields are still required to be separated from hay fields (section 3.6).
- Probability of seed maturation – Mowing during early bloom basically eliminates the chances of seed set. If there are marginal areas of the field that escape mowing, those plants can be considered part of the escaped feral population. Hay fields that are intentionally left to set seed are considered seed fields. Sometimes farmers harvest a few crops of hay, then a crop of seed from the same field. Farmers growing GT alfalfa are prohibited from this practice, unless they have a seed grower contract with FGI and follow FGI Best Practices.
- Probability of seed germination – If seed is not set, germination is irrelevant. In the case that some small amount of seed does set in a hay field, then germination is limited by the autotoxicity of alfalfa.

No studies that specifically address seed to hay gene flow were identified. This is because any study that potentially addressed seed to hay gene flow did not mow the hay. Studies where trap plants were allowed to mature and set seed are not accurate representations of hay fields.

### 3.8.8 *Feral to Hay Gene Flow*

The factors that influence hay to seed gene flow are as follows:

- Probability of synchronous flowering – Feral alfalfa blooms as environmental growth conditions permit. Hay fields that are harvested at 10 percent bloom only have flowers for about a week (Shroyer et al., 1984) and for most of that time the field is at far below 10 percent bloom. There may be some overlap between flowering time among hay fields and feral populations, but it is likely to be limited to a few days.
- Availability of pollen – Feral alfalfa, if not managed (mowed), and if environmental conditions permit, will flower. Environmental stresses such as drought and insects may greatly reduce flower formation compared to cultivated alfalfa.
- Pollinator activity on days of synchronous flowering and placement of bee hives – Wild bees and hobbyist bee hives are the sources of pollinators between hay and feral populations.
- Distance between feral populations and hay fields – Out of all the alfalfa populations, feral and hay populations are likely to be the closest the most often. Hay farmers do not typically control feral alfalfa, and much of the feral alfalfa near hay fields is escaped hay seed, which may not persist as a breeding population. (See section 3.8.6 for description of Kendrick et al., 2005)
- Probability of seed maturation – Mowing during early bloom basically eliminates the chances of seed set. If there are marginal areas of the field that escape mowing, those plants can be considered part of the escaped feral population. Hay fields that are intentionally left to set seed are considered seed fields. Feral populations should be managed near seed fields and hay fields that are occasionally harvested as seed fields.
- Probability of seed germination. – If seed is not set, germination is irrelevant. In the case that some small amount of seed does set in a hay field, then germination is limited by the autotoxicity of alfalfa.

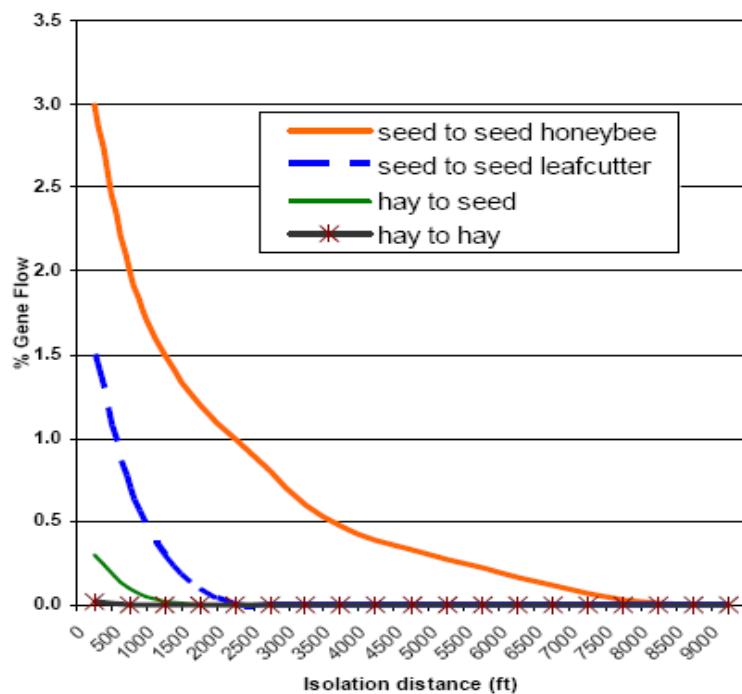
### 3.8.9 *Hay to Hay Gene Flow*

The factors that influence hay to hay gene flow are as follows:

- Probability of synchronous flowering – Adjacent hay fields will bloom at the same time if the variety of alfalfa is similar, planting schedules are similar and the growing conditions are similar. Irrigation inputs, fertilization inputs, and pest management (weeds, insects, small mammals, and diseases) can influence the maturity of alfalfa hay.
- Availability of pollen – Hay fields may be harvested any time between pre-bud and 100 percent bloom; however the majority of fields are harvested at or below 10 percent bloom.
- Pollinator activity on days of synchronous flowering and placement of bee hives – Bees are brought in for seed fields, but not for hay fields. Wild bees are present at relatively low levels compared to bees brought in for seed field pollination. There will likely be some bee activity in hay fields with bloom, especially if bee hobbyists have hive nearby.

- Distance between hay fields (alfalfa populations) – There are no required distances between hay fields.
- Probability of seed maturation – Mowing during early bloom basically eliminates the chances of seed set. If there are marginal areas of the field that escape mowing, those plants can be considered part of the escaped feral population. Hay fields that are intentionally left to set seed are considered seed fields. Sometimes farmers harvest a few crops of hay, then a crop of seed from the same field. Farmers growing GT alfalfa are prohibited from this practice, unless they have a seed grower contract with FGI and follow FGI Best Practices.
- Probability of seed germination. – If seed is not set, germination is irrelevant. In the case that some small amount of seed does set in a hay field, then germination is limited by the autotoxicity of alfalfa.

No studies that specifically address hay to hay gene flow were identified. However Putnam (2006) provided an estimate based on probabilities which are included in figure Q-12. Gene flow between seed and hay fields is summarized in figure Q-12 from Van Deynze et al. (2008).



**Figure Q-12: Gene flow likelihood (Van Deynze et al., 2008)**

#### *Conditions Increasing Probability of Gene Flow*

As the above sections indicate, there are multiple factors involved in studying the impact of GT alfalfa. Factors have the potential to increase gene flow between crops include, but not limited to, the following:

- Feral alfalfa creates gene flow corridors — If feral alfalfa grows between fields of GT alfalfa and non-GT alfalfa, then it could provide a corridor for gene flow between these fields. It could act as a stepping stone for pollinators that would be more likely to travel between flowers that are closer together than between distant fields.
- A pest management strategy currently in practice is that of leaving a strip of uncut alfalfa during hay harvest, which can act as a reserve for both insect pests and beneficial pollinators. If these alfalfa strips are GT alfalfa, and are not ever cut, they would have the chance to flower and seed. This would result in a the risk of pollinator-mediated spreading of the GT trait to nearby established feral populations, and could mean that the chance of gene flow from hay fields to other fields can be just as great as the chance of gene flow from seed fields to other fields. (Mueller 2005).
- Seed field proximity can increase gene flow between the fields. The seed fields are generally found in a compact geographic area, and with pollinators that have the potential to forage over miles (honey bees; for instance), this creates a potential for cross fertilization in non-GT alfalfa seed fields. (Hubbard 2008)
- As with any agricultural crop, there is the possibility of volunteer alfalfa growing in the field during other crop rotations. If these volunteer plants were GT, then normal glyphosate-based herbicide routines would not eradicate them, creating a possibility that the volunteer plants would flower, set seed, and be a source of pollen for gene flow (Altieri, 2001). Also, alfalfa produces “hard seeds”, seeds whose hard coating prevents moisture from germinating the seed. It is possible that these seeds can remain dormant from one season to the next, and then germinate at a later time, creating the possibility of the presence of GT alfalfa even after alfalfa is no longer produced in a field (Hubbard, 2008).
- Movement of honey bees from crop to crop could increase the chance of transferring pollen from one field to another.
- Release of too many bees to pollinate one field by farmers can lead to far dispersal of the bees. Bees will respond to the competition at that one field, and then will forage further to find nectar and pollen or to establish nests at alternate sites. This might happen before they visit any flowers of the target field, or they might visit the target field before traveling, increasing the risk of gene flow from the target field (which may be GT alfalfa) to other fields (possibly non-GT alfalfa) (Bosch and Kemp, 2005).

### *3.8.13 Conditions Decreasing Probability of Gene Flow*

FGI and Monsanto have developed stewardship programs to address concerns regarding gene flow (FGI 2007).<sup>66</sup> Seed growers undergo training and have to be licensed to grow GT alfalfa seed. Any farmer who purchases GT alfalfa seed for producing hay is required to sign a Monsanto Technology/Stewardship Agreement (MTA). The FGI Best Practices for seed growers is the primary mechanism for limiting gene flow. Features of the MTA and FGI Best Practices are as follows:

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<sup>66</sup> The stewardship programs also address other concerns such as weediness potential and glyphosate resistant weed formation.



- GT alfalfa seed producers may not sell seed to any party other than FGI and growers may not save seed for any purpose.
- Bee hives cannot be moved out of GT alfalfa until pollination is finished for the year. This prevents pollen being carried via hive between GT and non-GT alfalfa. Grower must indicate main pollinator species on the FGI Seed Grower Contract.
- Isolation through distance from other alfalfa fields is required. For pollination with leafcutter bees the distance must be greater than or equal to 900 feet, for Alkali bees greater than or equal to one mile, for honey bees greater than or equal to three miles.
- FGI reports seed field location and planting date to local seed certifying organizations, which GMO-sensitive farmers can refer to in order to certify isolation distances.
- Stand removal and volunteer management must be sufficient to allow seed certification inspectors to validate stand removal. Stand removal date and method must be reported to FGI and verified.
- Cleaning requirements for equipment are included in the FGI Best Practices.
- The Monsanto MTA requires hay growers to harvest at or before 10 percent bloom.
- The Monsanto MTA states that GT alfalfa hay growers are not allowed to produce seed off of hay fields.

Additional factors that could decrease the potential for gene flow include:

- Barriers between fields – Types of barriers can include bodies of water, or other, more attractive plants for bee foraging in between fields. A border of plants at field edges has the benefit of being a buffer zone, as pollen would be deposited in the border population before leaving a GT alfalfa field. If the border were also alfalfa, this would ensure that pollinators would not preferentially avoid the border area. However, the border would need to be treated as GT alfalfa, and if it starts out as non-GT alfalfa, then the spread of genes from that population to the GT alfalfa could adversely affect the cultivation of GT alfalfa seeds by reducing seed purity. If the border were not alfalfa, but a different plant, this would prevent bees from traveling far from the field, and fewer GT genes would be spread. However, this could be difficult if the border plant has different growing and management requirements from the alfalfa, or if it is an attractive plant to pollinators, which would discourage the alfalfa pollinators from pollinating the alfalfa, and could encourage distant bees to forage there, increasing long-distance pollen flow. Seeds produced by a non-alfalfa plant could also contaminate the purity of the alfalfa seed crop. (Amand, et al., 2000; Rogan and Fitzpatrick, 2004)
- Competition with existing plants is difficult for volunteer alfalfa plants that must establish themselves and compete for nutrients against adult plants.

#### *3.8.14 Modeling Gene Flow*

GENESYS is a modeling program that allows the simulation of gene flow between crops, based on cropping systems and other parameters (Colbach et al., 2001a, 2001b). Given the available data and variables for entire cropping systems in a region, cropping systems that would minimize the potential of gene transmission and dispersal can be identified (along with those of high dispersal potential). This program has previously been used to evaluate the potential of transmission of herbicide-tolerant genes from rapeseed crops to rapeseed volunteers, and can be

adapted and applied to other crops. It can also analyze the effect of cropping systems on the genetic evolution of the crop.

- Parameters that are used in the model include (Dzeroski et al., 2006):
- The field plan of the region, comprising cultivated fields and field-edges or borders consisting of spontaneous vegetation;
- The crop rotation of each field;
- The cultivation techniques applied to each crop (intercrop cultivation, soil tillage, sowing date and density, herbicide applications, cutting dates and seed loss at harvest);
- The type of the transgene, either a dominant allele *A* or recessive *a*, as well as the genotype of the crop varieties.

The more accurate and complete the parameters entered into the model are, the more accurate the results of the model will be. The model output is the level of GE seed present in conventional crops. The model can also identify key variables that are most influential on gene dispersal. This model could be adapted to predict alfalfa gene flow; however it may not be necessary because FGI has obtained actual gene flow data from commercial scale seed production (FGI 2007).

A Gene Flow Index (GFI) ranking scheme has been developed for sugar beet, oilseed rape, potato, perennial ryegrass, maize, wheat, and barley (Mullins 2005). This index could be used to put alfalfa in perspective to other GE crops.

### 3.9 Summary of Findings

Alfalfa is a perennial crop, pollinated by alfalfa leafcutter bees (*Megachile rotundata*), honey bees (*Apis mellifera*), and alkali bees (*Nomia melanderi*), and it is cultivated primarily for hay (forage) or seed. Because it is pollinated by insects, pollen and gene flow between different alfalfa fields is possible. This is an issue when a proportion of cultivated alfalfa is GT alfalfa, and growers of non-GT alfalfa wish to prevent the entry of GT traits in their seed stocks and crops.

For hay farmers, the quality of the hay is dependent on nutrient content, which is linked to the maturity of the plants at harvest, both of which are predicted by the amount of bloom present at harvest. The nutrient content of hay is tested before sale price is determined. The earlier the harvest, the better quality the hay is. It is often recommended to harvest hay when it is at one-tenth bloom. It is important to know the level of bloom present in alfalfa hay fields in order to gauge the possibility of pollen flow between the fields or from hay fields to seed fields. Alfalfa hay production occurs mainly in the West and Northwest United States, and while California produces the most hay in the country in pounds, South Dakota has the most hay acreage.

Seed farmers are concerned with the purity of their seed stock, and follow state and Federal-mandated standards in order to produce seed of certified purity. Isolation distances between fields and threshold amounts of allowable off-types of seed vary by state, but in general, seed stock must be 99 percent of the variety or varieties stated on the label. Alfalfa seed production

also occurs mainly in the West and Northwest United States, and California produces the most seed in the country, in both pounds and acreage.

Pollination of alfalfa is highly dependent on the species of pollinator used. Honey bees have been known to forage over 6 miles from their nests, while alfalfa leafcutter bees only forage 300-600 feet from their nests. Female alfalfa leafcutter and alkali bees are the most effective alfalfa pollinators, pollinating 81 and 78 percent of visited flowers, respectively. Honey bees only pollinate 22 percent of visited flowers. Alfalfa seed farmers manipulate bee colonies in order to ensure pollination of their fields, and release of pollinators influences the duration of flowering in alfalfa fields. The more bees released at one time, the quicker the flowers stop blooming, and flower availability and number of bees can impact pollen transport. Other factors that affect bee activity and therefore affect pollination include weather, season, time of day, hive placement, plant competition, strength of the colony and disease.

Given proper adherence to FGI Best Practices and Monsanto's MTA the risk of cross-fertilization is well below FGI's goal of less than 0.5 percent presence. Gene flow between and into seed fields is of higher concern than gene flow into hay fields. This is primarily because hay fields are mowed before seed is set, so even if pollen with GT trait arrives at a non-GT hay field, propagation of seed is unlikely. Feral alfalfa is a concern if it is not managed near seed fields. Feral alfalfa near GT alfalfa hay fields may receive GT trait, but the trait's survival in the feral population depends on whether there is selection pressure to maintain the trait and chance. The GT trait is not expected to enhance feral alfalfa fitness. Rangeland alfalfa (*falcata*) populations may be growing as ranchers intentionally seed *falcata* into rangeland to increase forage quality and soil nitrogen. The impact of GT alfalfa on rangeland *falcata* is unstudied.

## 4.0 Glyphosate-Tolerant Alfalfa Presence in Food or Animal feed

Human food uses of alfalfa are minor, with majority of alfalfa consumed by humans as freshly sprouted seedlings (sprouts) or as compressed leaf material in dietary supplements or herbal teas. In efforts to assess the human health and livestock risks of exposure to the GT alfalfa gene, gene product, transgene, and glyphosate will be evaluated in this report.

Monsanto Company and Forage Genetics International, jointly developed GT alfalfa, designated as events J101 and J163 that were genetically engineered for tolerance to the herbicide glyphosate (Roundup®). The possibility of these GE varieties being present in food and feed supplies and the importance of the alfalfa crop, warrant a thorough assessment of the impacts, if any, of introducing the GT alfalfa crop for commercialization.

Limited data on the effects of GT alfalfa presence in human food and animal feed is available at present. However, the CP4 EPSPS gene that confers glyphosate resistance in alfalfa has been used in previous GT crops, such as soybeans, corn, canola, and wheat. Previous data on CP4 EPSPS can therefore be considered in evaluating the presence of GT alfalfa in human food and animal feed.

### 4.1 Probability of Presence

Monsanto the manufacturer of GT alfalfa does not allow GT alfalfa to be planted for sprouts (Hubbard, 2008); therefore, human exposure to GT alfalfa appears to be minimal.

### 4.2 Health Effects of CP4 EPSPS Transgene or Protein

The CP4 EPSPS transgene may pose a food safety risk for two reasons: 1) the transgene product could be toxic to humans or livestock due to direct toxicity, anti-nutritive effects or allergenic effects or 2) the transgene could cause a change in the metabolic pathways of the crop altering levels of pre-existing metabolites or introducing new metabolite(s). The U.S. Food and Drug Administration (FDA), the lead U.S. regulatory agency for review of the food and feed safety of GE crops, completed a voluntary consultation with FGI and Monsanto in 2004 regarding the GT alfalfa (US FDA, 2004b). The FDA's safety assessment of the gene product, CP4 EPSPS protein, concluded that Roundup Ready® alfalfa is safe for consumption by humans and animals (US FDA, 2004b).

#### *4.2.1 Health Effects of cp4 epsps Transgene on Humans*

The CP4 EPSPS was found to be readily degraded by digestive juices and based on amino acid sequence homology searches, shown to be structurally or functionally unrelated to any known protein allergens or toxins. Transgene products associated with GT crops have been shown to have no allergenic properties. Sten et al. (2004), in a study with soybean-sensitized patients, found that the allergenicity of ten glyphosate-tolerant and eight non-transgenic soybean cultivars were not different. Chang et al. (2003) found no significant allergenicity to rats of the CP4 EPSPS gene product conferring glyphosate resistance.

#### *4.2.2 Health Effects of cp4 epsps Transgene on Livestock*

The persistence of plant-derived recombinant DNA in sheep and pigs fed genetically engineered (GT) canola was assessed by Sharma et al. (2006) utilizing Polymerase Chain Reaction (PCR) and Southern hybridization analysis of DNA extracted from digesta, gastrointestinal (GI) tract tissues, and visceral organs. This study confirmed that feed-ingested DNA fragments (endogenous and transgenic) do survive to the terminal GI tract and that uptake into gut epithelial tissues does occur. A very low frequency of transmittance to visceral tissue was confirmed in pigs, but not in sheep. There was no evidence to suggest that recombinant DNA would be processed in the gut in any manner different from endogenous feed-ingested genetic material.

The nutritional safety of a similar GT maize line GA21 was evaluated by Sidhu et al. (2000) in a poultry feeding study. Results from this study showed that there were no significant differences in growth, feed efficiency, adjusted feed efficiency, and fat pad weights between chickens fed with GA21 grain or with parental control grain.

#### *4.2.3 Health Effects of cp4 epsps Transgene on Forage Bees*

The CP4 EPSPS transgene is similar to the gene that is normally present in alfalfa and is not known to have any toxic property. Field observations of events J101 and J163 revealed no negative effects on non-target organisms. The lack of known toxicity for this enzyme suggests no potential for deleterious effects on beneficial organisms such as bees and earthworms.

#### *4.2.4 Health Effects of cp4 epsps Transgene on Non-livestock Animals (Wildlife)*

No specific data or scientific literature was found relating to the health effects of the CP4 EPSPS Transgene on non-livestock animals. The *cp4 epsps* gene contained in GT crops is similar to other members of the EPSPS family of genes that are common in the environment. Therefore, there is no evidence the *cp4 epsps* gene will exhibit adverse biological activity towards wildlife.

#### *4.2.5 Health Effects of CP4 EPSPS Protein on Humans*

The novel CP4 EPSPS protein present in glyphosate-tolerant alfalfa J101 and J163 has been assessed previously for safety in approved lines of canola, cotton, soybean, and corn. Previous assessments have shown that CP4 EPSPS administered directly to animals at a high dose is not toxic, and the evidence indicates no potential for this protein to be allergenic in humans (FSANZ, 2006).

#### *4.2.6 Health Effects of CP4 EPSPS Protein on Livestock*

Coombs and Hartnell (2007) fed dairy cows GT alfalfa grown in southeastern Washington State harvested at the late vegetative state, or other conventional alfalfa harvested from the same geographic region. Milk production, milk composition, feed intake, and feed efficiency were not affected by feeding diets that contained nearly 40 percent glyphosate-tolerant alfalfa hay to

lactating dairy cows (Coombs and Hartnell, 2007). Detection of the gene or protein in milk, feces, or flesh of these cows was not performed.

In another dairy cow study, GT corn or non-GE corn was consumed (Ipharraguerre et al., 2003). The production of milk, quality of milk, and udder health were unaffected by GT gene or protein consumption in dairy cattle.

Steer were fed GT corn or a control near isogenic parental hybrid non-GE corn diet for 144 days. Weight, feed:gain ratio, marbling, and fat composition were no different between feeding groups (Pol et al., 2003).

Glyphosate-tolerant soybean meal was fed for 3 months (172 g/kg) to post-smolt salmon (Bakke-McKellep et al., 2007). Other post-smolt salmon were fed a non-modified soy; however, this soy was non-parental soy with several differences in the levels of anti-nutritional factors. Thus the qualitative and quantitative differences in the inflammatory response observed in the distal intestine as well in the head kidney of the genetically modified soy fed salmon were due to difference in soybean variety. Further study is needed with the control group needing to be near-isogenic parental line soybeans (Bakke-McKellep et al., 2007). In addition to this, no specific data or scientific literature was found relating to the health effects of the CP4 EPSPS protein on livestock animals.

#### *4.2.7 Health Effects of CP4 EPSPS Protein on Forage Bees*

A number of researchers have conducted laboratory investigations with different types of arthropods exposed to GE crops containing the CP4 EPSPS protein (Goldstein, 2003; Boongird et al., 2003; Jamornman et al., 2003; Harvey et al., 2003). Representative pollinators, soil organisms, beneficial arthropods and pest species were exposed to tissues (pollen, seed, and foliage) from GE crops that contain the CP4 EPSPS protein. These studies, although varying in design, all reported a lack of toxicity observed in various species exposed to these crops (Dunfield and Germida, 2003, Siciliano and Germida 1999).

No effects were observed on pollen harvest behavior of workers bees, or on survival and development of honey bee egg, larvae or pupa when exposed to GT corn pollen during and after pollination (Boongird et al., 2003).

#### *4.2.8 Health Effects of Protein on Non-livestock Animals (Wildlife)*

No specific data or scientific literature was found relating to the health effects of the CP4 EPSPS protein on non-livestock animals. The CP4 EPSPS protein contained in GT crops is similar to other members of the EPSPS family of proteins that are common in the environment; thus there no evidence that the CP4 EPSPS protein will exhibit adverse biological activity towards wildlife.

### 4.3 Health Effects of Herbicide Glyphosate Residue on GT Alfalfa to Humans

Glyphosate has a complete regulatory data base (toxicity, environmental fate, and ecological toxicity) that has been evaluated by EPA to support all currently approved uses including GT alfalfa. EPA and USDA have stated that they have a high level of confidence in the quality of the existing studies and the reliability of the toxicity endpoints that are the basis for risk assessment (US EPA, 1993, 2006a, 2006b, USDA, 2003). In general, the herbicidal activity of glyphosate is due primarily to a metabolic pathway that does not occur in humans or other animals, and, thus, this mechanism of action is not directly relevant to the human health risk assessment. EPA considers glyphosate to be of low acute and chronic toxicity by the dermal route of exposure. Glyphosate is considered a Category IV dermal toxicant and is expected to cause only slight skin irritation.

Comprehensive toxicological studies in animals have demonstrated that glyphosate does not cause cancer, birth defects, mutagenic effects, nervous system effects or reproductive problems (US EPA, 1993, 2006a, 2006b, USDA, 2003; WHO/FAO, 2004). In fact, after a thorough review of all available toxicology data, the US EPA concluded that glyphosate should be classified in Group E - Evidence of Non-carcinogenicity in Humans (US EPA, 1993).

In establishing food and feed tolerances to support the use of glyphosate on animal feed and forage crops (the group tolerance that supports the use of glyphosate in conventional and GT alfalfa), EPA noted that it had conducted “a complete and thorough review of the available data for glyphosate,” and determined that “glyphosate will not pose unreasonable risks or adverse effects to humans or the environment” (US EPA, 2002<sup>67</sup>). The risk assessment process as mandated by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) requires that any pesticide prior to the sale or distribution must be evaluated for its potential risks to humans and the environment. The process of registering a pesticide is a scientific, legal, and administrative procedure through which EPA examines the ingredients of the pesticide; the particular site or crop on which it is to be used; the amount, frequency, method and timing of application, and other conditions of its use; and storage and disposal practices. In evaluating a pesticide registration application, EPA assesses a wide variety of potential human health and environmental effects associated with use of the product.

The data required by EPA are used to evaluate whether a pesticide has the potential to cause adverse effects on humans, wildlife, fish, and plants (including endangered species and “non-target” organisms – organisms that the pesticide is not intended to act against). The registration applicant must also supply data addressing the pesticide’s potential impact on surface water or ground water (which might result from leaching or runoff, for example). Potential human health and safety risks range from short-term toxicity to long-term effects such as cancer and reproductive system disorders.

Where pesticides may be used on food or feed crops, EPA also sets tolerances (maximum pesticide residue levels) for the amount of the pesticide that can legally remain in or on foods. EPA undertakes this analysis under the authority of the Federal Food, Drug, and Cosmetic Act (FFDCA). Under the FFDCA, EPA must find that such tolerances will be safe, meaning that there is a reasonable certainty that no harm will result from aggregate exposure to the pesticide

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<sup>67</sup> Prior to 2002, separate alfalfa forage and alfalfa hay tolerances were established for glyphosate.

chemical residue. This finding must be made and the appropriate tolerance established before a pesticide can be registered for use on the particular food or feed crop in question. Several factors must be addressed before a tolerance can be established, including:

the aggregate, non-occupational exposure from the pesticide (exposure through diet, from using pesticides in and around the home, and from drinking water);

the cumulative effects from exposure to different pesticides that produce similar effects in the human body;

whether there is increased susceptibility to infants and children, or other sensitive subpopulations, from exposure to the pesticide; and

whether the pesticide produces an effect in humans similar to an effect produced by a naturally-occurring estrogen or produces other endocrine-disruption effects.

**Table Q-17. Established Glyphosate Tolerances Prior to GT Crops (1993)**

| <b>Crop</b>       | <b>Established Food/Feed Tolerances</b>                   | <b>Publication</b> | <b>Percent of Reference Dose (RfD)</b>                                            |
|-------------------|-----------------------------------------------------------|--------------------|-----------------------------------------------------------------------------------|
| <b>Soybean</b>    | Seed – 20 ppm<br>forage & hay – 15 ppm<br>hulls – 100 ppm | US EPA, 1993       | General Population - 1.2 percent<br>Non-nursing infants <1 year old - 2.9 percent |
| <b>Alfalfa</b>    | 200 ppm                                                   |                    |                                                                                   |
| <b>Cotton</b>     | forage, hay, & seed – 15 ppm                              |                    |                                                                                   |
| <b>Sugar beet</b> | Roots – 0.2 ppm                                           |                    |                                                                                   |



**Table Q-18. Summary of EPA Approvals for Glyphosate Use in GT Crops**

| <b>Product</b>                   | <b>Commercial Introduction Year</b> | <b>Required Changes in Food/Feed Tolerances</b>                                                                                                                        | <b>Federal Register Publication Establishing New or Modified Tolerance</b> | <b>Percent of Reference Dose (RfD) Dietary Exposure Only (Food + Water)</b>                                                                        |
|----------------------------------|-------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Roundup Ready soybean</b>     | 1996                                | Increase soybean forage to 100 ppm.<br>Increase soybean hay to 200 ppm.<br>Establish new tolerance for aspirated grain fractions at 50 ppm.                            | 61 FR 15192<br>Petition No. 4F4369<br>US EPA, 1996b                        | General Population – 1<br>Non-nursing infants- 2.5                                                                                                 |
| <b>Roundup Ready cotton</b>      | 1997                                | Establish new tolerance for gin byproduct at 100 ppm.                                                                                                                  | 61 FR 7729<br>Petition No. 5F4493<br>US EPA, 1996a                         | General Population - 1<br>Non-nursing infants - 2.4                                                                                                |
| <b>Roundup Ready corn</b>        | 1998                                | Establish new tolerance for corn forage at 1 ppm.                                                                                                                      | 62 FR 17723<br>Petition No. 5F4555<br>US EPA, 1997                         | General Population - 1<br>Non-nursing infants < 1 year old - 3                                                                                     |
| <b>Roundup Ready canola</b>      | 1999                                | Establish new tolerances for canola seed at 10 ppm<br>meal at 15 ppm                                                                                                   | 64 FR 18360<br>Petition No. 2E4118<br>US EPA, 1999                         | General Population - 1.5<br>Non-nursing infants <1 year old - 3.3                                                                                  |
| <b>Roundup Ready sugar beet</b>  | 2008                                | Establish new tolerances for sugar beet roots at 10 ppm<br>tops at 10 ppm<br>pulp (dried) at 25 ppm                                                                    |                                                                            |                                                                                                                                                    |
| <b>Roundup Ready corn 2</b>      | 2004                                | Increased tolerance for corn forage to 6 ppm.                                                                                                                          | 68 FR 36472<br>US EPA, 2003                                                | Change in forage tolerance did not affect estimated dietary exposure from animal products; therefore no dietary risk assessment was conducted.     |
| <b>Roundup Ready Flex cotton</b> | 2006                                | Increase tolerance for gin byproduct to 175 ppm.<br>Increase tolerance for cottonseed to 35 ppm.                                                                       | 69 FR 65081<br>Petition No. 3F6570<br>US EPA, 2004d                        | General Population - 2.2<br>All infants < 1 year old - 3.9                                                                                         |
| <b>Roundup Ready alfalfa</b>     | 2006                                | Establish new tolerances for alfalfa seed at 0.5 ppm.<br>Existing tolerances for alfalfa forage (400 ppm) and hay (200 ppm) were sufficient to cover new in-crop uses. | 70 FR 7861<br>Petition No. 2F6487<br>US EPA, 2005                          | Dietary exposure insignificant, did not conduct new risk assessment. Deferred to assessment conducted for flex cotton as published in 69 FR 65081. |

Residue tolerances currently established for glyphosate in or on alfalfa raw agricultural commodities are, for the most part, the same as they were prior to the approval of GT alfalfa. The use of glyphosate in GT alfalfa did not require an increase in the tolerances in either alfalfa forage or hay (US EPA, 2000), therefore no increase in animal commodity tolerances were required. In 2002, EPA included alfalfa in the animal feed, nongrass group tolerance (US EPA, 2002), so individual tolerances for alfalfa forage and hay were no longer needed. However, the postemergence use of glyphosate for the production of GT alfalfa seed did require the establishment of a new tolerance for alfalfa seed at 0.5 ppm (US EPA, 2005) to account for the

potential human exposure to glyphosate residues resulting from the inadvertent use of GT alfalfa seed in the production of alfalfa sprouts.

**Table Q-19. Aggregate Exposure Assessment for Glyphosate**

| Population Subgroup                     | Acute Aggregate <sup>2</sup> | RfD (mg/kg/day) <sup>2</sup> | Chronic Aggregate <sup>1,2</sup> |             | Short/Intermediate Term Aggregate <sup>2</sup> |             |
|-----------------------------------------|------------------------------|------------------------------|----------------------------------|-------------|------------------------------------------------|-------------|
|                                         |                              |                              | Exposure (mg/kg/day)             | Percent RfD | Exposure (mg/kg/day)                           | Percent RfD |
| General U.S. population                 | Not applicable               | 1.75                         | 0.041                            | 2           | -                                              | -           |
| All infants (<1 year)                   |                              |                              | 0.127                            | 7           | 0.157                                          | 9           |
| <b>Non-nursing infants (&lt;1 year)</b> |                              |                              | <b>0.158</b>                     | <b>9</b>    | <b>0.188</b>                                   | <b>11</b>   |
| Children 1-2 years                      |                              |                              | 0.095                            | 5           | 0.125                                          | 7           |
| Children 3-5 years                      |                              |                              | 0.088                            | 5           | 0.118                                          | 7           |
| Children 6-12 years                     |                              |                              | 0.059                            | 3           | 0.089                                          | 5           |
| Youth 13-19 years                       |                              |                              | 0.037                            | 2           | -                                              | -           |
| Adults 20-49 years                      |                              |                              | 0.033                            | 2           | 0.063                                          | 4           |
| Adults 50+ years                        |                              |                              | 0.028                            | 2           | -                                              | -           |
| Females 13-49 years                     |                              |                              | 0.031                            | 2           | -                                              | -           |

<sup>1</sup> Chronic aggregate exposure is the same as chronic dietary exposure because chronic non-dietary exposure is not expected based upon the current registered non-crop uses of glyphosate.

<sup>2</sup> U.S. EPA OPPTS. Glyphosate Human Health Risk Assessment for Proposed Uses on Safflower and Sunflower. Petition No. 4E6878. Sept. 5, 2006.

#### 4.4 Health Effects of Herbicide Glyphosate Residue on GT Alfalfa to Livestock

The US EPA's toxicological and ecotoxicology and fate databases on glyphosate are considered adequate and complete (US EPA, 2006a; 1993), and based on this data, glyphosate is considered to be a toxicologically and ecologically low-risk herbicide (Cerdeira and Duke, 2006). For an in depth look at the effects of glyphosate to the environment please refer to technical report *Potential Impacts To Wildlife, Amphibians, Plants, And Ecosystems From Increased Glyphosate And Other Chemical Usage* (appendix N).

#### 4.5 Health Effects of Herbicide Glyphosate Residue on GT Alfalfa to Forage Bees

Technical grade glyphosate and Roundup are slightly toxic to bees when applied orally or topically with 2-day LD<sub>50</sub> values of  $\geq 100 \mu\text{g}$  (a.i. or product) per bee. Scientific literature shows that pollen from GT canola has no adverse effects on honeybees (Huang et al. 2004).

#### 4.6 Health Effects of Herbicide Glyphosate Residue on GT Alfalfa to Non-Livestock Animals (Wildlife)

Glyphosate has not been reported to have insecticidal or other activities against terrestrial arthropods. Studies on the effects of glyphosate on spiders have shown that it is harmless to non-target arthropods (Haughton et al. 2001). No effects of glyphosate on microarthropods in soil at double the recommended application rates have been reported (Gomez and Sagardoy, 1985). No adverse effects of glyphosate on the fecundity and fertility of green lacewings have been reported and the glyphosate formulation - Sting SE, has been documented to have no adverse impact on the food uptake and mortality of the beetle *Poecilus* (IPCS-INCHEM, 1994).

No adverse effects on earthworms have been reported with the use of glyphosate. With an LC<sub>50</sub> value of > 5,000 parts per million (ppm) (Ahrens 1994), glyphosate has been ranked zero on a scale of zero (nontoxic) to four (extremely toxic) for its toxicity to earthworms (Edwards and Bohlen 1996). Glyphosate formulations on the other hand (Roundup and Roundup D-pak) are slightly toxic to earthworms with 14-day NOEC values of 500 and 158 mg product per kg dry weight, respectively.

For an in depth look at the effects of glyphosate to the environment please refer to technical report *Potential Impacts To Wildlife, Amphibians, Plants, And Ecosystems From Increased Glyphosate And Other Chemical Usage* (appendix N).

#### 4.7 Summary of Findings

The use of glyphosate herbicide does not appear to result in adverse effects on development, reproduction, or endocrine systems in humans and other mammals. Under present and expected conditions of use, glyphosate herbicide does not pose a health risk to humans. There is little evidence of any direct effect of glyphosate on arthropods in the field or in natural environments. The higher toxicity of glyphosate to aquatic invertebrates can mainly be attributed to the presence of surfactants.

Current weight-of-evidence from similar GE crops (Peterson, 2005) suggests that the transgenic CP4 EPSPS protein present in GT alfalfa poses negligible risk to humans, livestock, and wildlife. Most studies available in scientific literature support the view that food from GT crops is substantially equivalent to non-transgenic crops.

## Appendix Q-1.      References

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## Appendix Q-2. Literature Search

### 5.0 Literature Search Strategy

#### 5.1 Purpose

The purpose of this literature search is to locate references about the presence of human and animal feed due to GT alfalfa as well as health and safety implications.

We propose that the following DIALOG databases be included in the search:

The following DIALOG databases will be included in the search:

|                                    |                                                 |
|------------------------------------|-------------------------------------------------|
| File 5: BIOSIS                     | File 117: Water Resources Abstracts             |
| File 6: NTIS                       | File 144: PASCAL                                |
| File 10: AGRICOLA                  |                                                 |
| File 34: SciSearch                 | File 154: MEDLINE                               |
| File 41: Pollution Abstracts       | File 156:ToxFile                                |
| File 40: Enviroline                | File 245: WATERNET™                             |
| File 72: EMBASE                    | File 250: CAB Abstracts                         |
| File 76: Environmental Sciences    | File 266: Federal Research In Progress (FEDRIP) |
| File 79: Aqualine                  | File 399: CA SEARCH®: Chemical Abstracts®       |
| File 98: General Science Abstracts |                                                 |

Descriptions of these files are available at <http://library.dialog.com/bluesheets/>.

#### 5.2 Scope of Search

The search will focus any published references after 1990. A reference list with abstracts will be screened for relevance to fermentation processes. English language only publications will be retrieved.

The following list will be retrieved and expanded upon.

#### 5.3 Strategy Overview

A list of search parameters is listed below.

#### 5.4 Synonyms

|                                 |                                     |
|---------------------------------|-------------------------------------|
| Glyphosate                      | <i>N</i> -(phosphonomethyl) glycine |
| Glyphosate, isopropylamine salt | Roundup®                            |
| Glyphosate, sodium salt         | Rodeo®                              |
|                                 | Honcho®                             |

Glyphosate, potassium  
Glyphosate, ammonium  
Glyphosate, sulfosate

## 5.5 Keywords

|                        |                     |
|------------------------|---------------------|
| Acute                  | Health effect(s)    |
| Alfalfa                | Ingest*             |
| Allowable daily intake | Leach*              |
| Chronic                | Metabo*Occupational |
| Contaminat*            | Persistence         |
| Crop                   | Residue             |
| Degradation            | Risk                |
| Detect*                | Tolerance           |
| Dietary risk           | Toxic*              |
| Emission               | Usage patterns      |
| Environmental impacts  |                     |
| Exposure(s)            |                     |

## 5.6 Submission of Citations for Approval

Using reference management software, pooled information obtained from the various bibliographic databases will be screened to remove duplicates. Additionally, ICF will review the list prior to submission and eliminate any irrelevant citations. Information will include the following (when available):

Author(s). Publication Year. Title. Source Document Name, Volume, Page Numbers.  
Abstract  
Descriptors/Identifiers (*i.e.*, keywords and subject headings)

Search Terms for Gene Flow Appendix

Google

Alfalfa biology  
Alfalfa hard seed  
Alfalfa pollination  
Alfalfa pollinator use  
Alkali bee forage distance  
Alkali bee range  
Apis mellifera forage distance  
Apis mellifera range

Bee dispersal  
Bee agriculture use  
Crop pollination  
Honey bee agriculture  
Honey bee alfalfa  
Alkali bee agriculture  
Alkali bee alfalfa  
Medicago sativa  
Alfalfa gene flow  
Pollen gene flow  
Alfalfa bloom time  
Pollen viability

## 5.7 Literature Search Results:

File 10:AGRICOLA 70-2008/Apr  
(c) format only 2008 Dialog  
File 154:MEDLINE(R) 1990-2008/Jun 03  
(c) format only 2008 Dialog  
File 156:ToxFile 1965-2008/May W4  
(c) format only 2008 Dialog  
File 266:FEDRIP 2008/Feb  
Comp & dist by NTIS, Intl Copyright All Rights Res  
File 245:WATERNET(TM) 1971-2008Apr  
(c) 2008 American Water Works Association  
File 55:Biosis Previews(R) 1993-2008/Jun W1  
(c) 2008 The Thomson Corporation  
File 6:NTIS 1964-2008/Jun W2  
(c) 2008 NTIS, Intl Cpyrght All Rights Res  
File 41:Pollution Abstracts 1966-2008/May  
(c) 2008 CSA.  
File 40:Enviroline(R) 1975-2008/Apr  
(c) 2008 Congressional Information Service  
File 76:Environmental Sciences 1966-2008/Jun  
(c) 2008 CSA.  
File 24:CSA Life Sciences Abstracts 1966-2008/Mar  
(c) 2008 CSA.  
File 117:Water Resources Abstracts 1966-2008/Mar  
(c) 2008 CSA.  
File 144:Pascal 1973-2008/May W4  
(c) 2008 INIST/CNRS  
File 50:CAB Abstracts 1972-2008/Apr  
(c) 2008 CAB International  
File 44:Aquatic Science & Fisheries Abstracts 1966-2008/Mar  
(c) 2008 CSA.  
File 71:ELSEVIER BIOBASE 1994-2008/May W3

(c) 2008 Elsevier B.V.  
File 143:Biol. & Agric. Index 1983-2008/Apr  
(c) 2008 The HW Wilson Co

**S1 31158 GLYPHOSATE OR PHOSPHONOMETHYL()GLYCINE OR ROUNDUP  
OR GLYPHOSPHATE**

**S2 13844 RN=1071-83-6 OR PHOSPHONOMETHYLMINOACETIC()ACID OR  
SILGLIF**

**S3 12713 (S1 OR S2)/2000:2008**

**S4 6842306 ACUTE OR SUBACUTE OR CHRONIC OR SUBCHRONIC OR  
INGEST? OR I-**

**NHAL? OR DOSE OR DOSAGE OR DIETARY**

**S5 4866541 TOXIC? OR (HEALTH OR ADVERSE)(3N)(EFFECT OR EFFECTS OR  
RISK**

**OR RISKS OR IMPACT OR IMPACTS) OR NEUROTOXIC? OR  
GENOTOXIC? -**

**OR IMMUNOTOXIC?**

**S6 4789703 CANCER? OR CARCINO? OR TUMOR? OR NEOPLAS?**

**S7 4311730 DERMA? OR SKIN OR REPRODUCTI? OR TERATOL? OR  
TERATOGEN? OR**

**IRRITAT? OR IRRITANT OR NEUROLOG?**

**S8 9723660 MUTAGEN? OR MUTAT? OR SENSITIZ? OR EXPOS? OR  
METABOLI?**

**S9 3685201 USAGE()PATTERN? ? OR SPRAY()DRIFT? OR TOLERANCE OR  
PERSIST-**

**ENCE OR INHIBITION OR DEGRADATION OR ALFALFA OR LEACH?**

**S22 11698 S3 NOT (S20 OR S21) (eliminate most foreign languages)**

**S23 2887 S22 AND S19**

**S24 1505 RD S23 (unique items)**

**S25 535 S24 AND (S4 OR S5 OR S6)**

**S26 698 S24 AND (S7 OR S8 OR S9)**

**S27 776 S24 AND (S10 OR S11)**

**S28 1184 S25 OR S26 OR S27 (all 3 sets of terms)**

**S29 162 S25 AND S26 AND S27 (multiple terms in cite)**

4823622/7

DIALOG(R)File 10:AGRICOLA

(c) format only 2008 Dialog. All rts. reserv.

4823622 44034750 Holding Library: AGL

Herbicides, glyphosate resistance and acute mammalian toxicity:  
simulating an environmental effect of GT weeds in the USA

Gardner, Justin G. Nelson, Gerald C.

John Wiley & Sons, Ltd.

Pest management science. 2008 Apr., v. 64, no. 4 p. 470-478.

ISSN: 1526-498X

DNAL CALL NO: SB951 .P47

Language: English

Includes references

4575453/7

DIALOG(R)File 10:AGRICOLA

(c) format only 2008 Dialog. All rts. reserv.

4575453 43878403 Holding Library: AGL

Histological, digestive, metabolic, hormonal and some immune factor responses in Atlantic salmon, *Salmo salar* L., fed genetically modified soybeans

Bakke-McKellep, A.M. Koppang, E.O.; Gunnes, G.; Sanden, M.; Hemre, G-I.; Landsverk, T.; Krogdahl, Df.

Oxford, UK : Blackwell Publishing Ltd

Journal of fish diseases. 2007 Feb., v. 30, no. 2 p. 65-79.

ISSN: 0140-7775

DNAL CALL NO: SH171.A1J68

Language: English

Includes references

<http://dx.doi.org/10.1111/j.1365-2761.2007.00782.x>

0009010362/7

DIALOG(R)File 50:CAB Abstracts

(c) 2008 CAB International. All rts. reserv.

0009010362 CAB Accession Number: 20063078964

Detection of transgenic and endogenous plant DNA in digesta and tissues of sheep and pigs fed Roundup Ready canola meal.

Ranjana Sharma; Damgaard, D.; Alexander, T. W.; Dugan, M. E. R.; Aalhus, J. L.; Stanford, K.; McAllister, T. A.

Author email address: [mcallister@agr.gc.ca](mailto:mcallister@agr.gc.ca)

Agriculture and Agri-Food Canada Research Centres, Lethbridge, Alberta T1J 4B1, Canada. Journal of Agricultural and Food Chemistry vol. 54 (5): p.1699-1709

Publication Year: 2006

ISSN: 0021-8561

Publisher: American Chemical Society Washington, USA

Language: English

0008536913/7

DIALOG(R)File 50:CAB Abstracts

(c) 2008 CAB International. All rts. reserv.

0008536913 CAB Accession Number: 20033205456

The effects of refining consumer exposure assessments of glyphosate.

Harris, C. A.; Gaston, C. P.

Author email address: [charris@uk.exponent.com](mailto:charris@uk.exponent.com)

Exponent International Ltd, 2D Hornbeam Park Oval, Harrogate, HG2 8RB, UK.

Book Title: The BCPC International Congress: Crop Science and Technology, Volumes 1 and 2. Proceedings of an international congress held at the SECC, Glasgow, Scotland, UK, 10-12 November 2003

Conference Title: The BCPC International Congress: Crop Science and Technology, Volumes 1 and 2. Proceedings of an international congress held at the SECC, Glasgow, Scotland, UK, 10-12 November 2003.

p.575-582

Publication Year: 2003

Publisher: British Crop Protection Council Alton, UK

ISBN: 1-901396-63-0

Language: English

Document Type: Book chapter; Conference paper

0009249000/7

DIALOG(R)File 50:CAB Abstracts

(c) 2008 CAB International. All rts. reserv.

0009249000 CAB Accession Number: 20073056777

Evaluating glyphosate treatments on roundup ready alfalfa for crop injury and feed quality.

Steckel, L. E.; Hayes, R. M.; Montgomery, R. F.; Mueller, T. C.

Author email address: tmueller@utk.edu

Department of Plant Sciences, University of Tennessee, Jackson, TN 38301, USA.

Forage and Grazinglands (February): p.1-6

Publication Year: 2007

ISSN: 1547-4631

Publisher: Plant Management Network St. Paul, USA

Language: English

0009443255/7

DIALOG(R)File 50:CAB Abstracts

(c) 2008 CAB International. All rts. reserv.

0009443255 CAB Accession Number: 20073293296

Herbicidal effects on nontarget vegetation: investigating the limitations of current pesticide registration guidelines.

White, A. L.; Boutin, C.

Author email address: celine.boutin@ec.gc.ca

National Wildlife Research Centre, Environment Canada, Carleton University, 1125 Colonel By Drive (Raven Road), Ottawa, Ontario K1A 0H3, Canada.

Environmental Toxicology and Chemistry vol. 26 (12): p.2634-2643

Publication Year: 2007

ISSN: 0730-7268

Digital Object Identifier: 10.1897/06-553.1

Publisher: Society of Environmental Toxicology and Chemistry (SETAC)Pensacola, USA

Language: English



0009021925/7

DIALOG(R)File 50:CAB Abstracts

(c) 2008 CAB International. All rts. reserv.

0009021925 CAB Accession Number: 20063092172

Hormesis: is it an important factor in herbicide use and allelopathy?

Duke, S. O.; Cedergreen, N.; Velini, E. D.; Belz, R. G.

Natural Products Utilization Research Unit, USDA, ARS, P.O. Box 8048,  
University, MS 38677, USA.

Outlooks on Pest Management vol. 17 (1): p.29-33

Publication Year: 2006

ISSN: 1743-1026

Publisher: Research Information Ltd Burnham, UK

Language: English

0008704096/7

DIALOG(R)File 50:CAB Abstracts

(c) 2008 CAB International. All rts. reserv.

0008704096 CAB Accession Number: 20043187113

Responses of farmland wildlife to genetically modified  
herbicide-tolerant crops.

Strandberg, B.

National Environmental Research Institute (NERI), Department of  
Terrestrial Ecology, Vejlsvej 25, DK-8600 Silkeborg, Denmark.

AgBiotechNet vol. 6 (ABN 122): p.7

Publication Year: 2004

Publisher: CAB International Wallingford, UK

Language: English

0009435833/7

DIALOG(R)File 50:CAB Abstracts

(c) 2008 CAB International. All rts. reserv.

0009435833 CAB Accession Number: 20083016215

Glyphosate translocation from plants to soil - does this constitute a  
significant proportion of residues in soil?

Laitinen, P.; Ramo, S.; Siimes, K.

Author email address: sari.ramo@mtt.fi

MTT Agrifood Research Finland, 31600 Jokioinen, Finland.

Plant and Soil vol. 300 (1/2): p.51-60

Publication Year: 2007

ISSN: 0032-079X

Publisher: Springer Science + Business Media Dordrecht, Netherlands

Language: English

18370247/7

DIALOG(R)File 55:Biosis Previews(R)

(c) 2008 The Thomson Corporation. All rts. reserv.  
18370247 BIOSIS NO.: 200510064747  
Effect of glyphosate contaminated feed on rumen fermentation parameters and  
in sacco degradation of grass hay and corn grain  
AUTHOR: Huether Liane (Reprint); Drebes Svenja; Lebzien Peter  
AUTHOR ADDRESS: Fed Agr Res Ctr Braunschweig FAL, Inst Anim Nutr,  
Bundesallee 50, D-38116 Braunschweig, Germany\*\*Germany  
AUTHOR E-MAIL ADDRESS: liane.huether@fal.de  
JOURNAL: ARCHIVES OF ANIMAL NUTRITION 59 (1): p73-79 FEB 05 2005  
ISSN: 1745-039X\_(print) 1477-2817\_(electronic)  
LANGUAGE: English

18166086/7  
DIALOG(R)File 55:Biosis Previews(R)  
(c) 2008 The Thomson Corporation. All rts. reserv.  
18166086 BIOSIS NO.: 200500073151  
Effects of refining predicted chronic dietary intakes of pesticide  
residues: a case study using glyphosate  
AUTHOR: Harris C A (Reprint); Gaston C P  
AUTHOR ADDRESS: Exponent Int Ltd, 2D Hornbeam Pk Oval, Harrogate, HG2 8RB,  
AUTHOR E-MAIL ADDRESS: charris@uk.exponent.com  
JOURNAL: Food Additives and Contaminants 21 (9): p857-864 September 2004  
ISSN: 0265-203X\_(ISSN print)  
LANGUAGE: English

0020116582/7  
DIALOG(R)File 55:Biosis Previews(R)  
(c) 2008 The Thomson Corporation. All rts. reserv.  
0020116582 BIOSIS NO.: 200800163521  
Alfalfa containing the glyphosate-tolerant trait has no effect on feed  
intake, milk composition, or milk production of dairy cattle  
AUTHOR: Combs D K (Reprint); Hartnell G F  
AUTHOR ADDRESS: Univ Wisconsin, Dept Dairy Sci, St Louis, MO 63167 USA\*\*USA  
AUTHOR E-MAIL ADDRESS: dkcombs@wisc.edu  
JOURNAL: Journal of Dairy Science 91 (2): p673-678 FEB 2008 2008  
ITEM IDENTIFIER: doi:10.3168/jds.2007-0611  
ISSN: 0022-0302  
LANGUAGE: English

0019528226/7  
DIALOG(R)File 55:Biosis Previews(R)  
(c) 2008 The Thomson Corporation. All rts. reserv.  
0019528226 BIOSIS NO.: 200700187967  
Development and characterization of alfalfa populations tolerant to glyphosate.

AUTHOR: Rogan Glen (Reprint); Fitzpatrick Sharie; Pester Todd; Kendrick Daniel; Horak Michael; McCann Melinda; Karunanandaa Karu; Temple Stephen; McCaslin Mark  
AUTHOR ADDRESS: Monsanto Co, St Louis, MO 63167 USA  
AUTHOR E-MAIL ADDRESS: glennon.j.rogan@monsanto.com  
JOURNAL: In Vitro Cellular & Developmental Biology Animal 42 (Suppl. S): p16A SPR 2006  
CONFERENCE/MEETING: Meeting of the Society-for-In-Vitro-Biology  
Minneapolis, MN, USA June 03 -07, 2006; 20060603  
SPONSOR: Soc In Vitro Biol  
ISSN: 1071-2690  
DOCUMENT TYPE: Meeting; Meeting Abstract  
RECORD TYPE: Citation  
LANGUAGE: English

18047665/7

DIALOG(R)File 55:Biosis Previews(R)

(c) 2008 The Thomson Corporation. All rts. reserv.

18047665 BIOSIS NO.: 200400418454

Use of quantitative real-time and conventional PCR to assess the stability  
of the cp4 epsps transgene from Roundup Ready(R) canola in the  
intestinal, ruminal, and fecal contents of sheep

AUTHOR: Alexander Trevor W; Sharma Ranjana; Deng Ming Y; Whetsell Amy J;  
Jennings James C; Wang Yuxi; Okine Erasmus; Damgaard Dana; McAllister Tim A (Reprint)

AUTHOR ADDRESS: Res Ctr, Agr and Agri Food Canada, POB 3000, Lethbridge, AB, T1J  
4B1, AUTHOR E-MAIL ADDRESS: mcallister@agr.gc.ca

JOURNAL: Journal of Biotechnology 112 (3): p255-266 October 20, 2004

ISSN: 0168-1656 (ISSN print)

LANGUAGE: English

34/6/52 (Item 52 from file: 55)

19403590 BIOSIS NO.: 200700063331

Effects of feeding \*Roundup\* Ready (R) \*alfalfa\* on intake and milk production of dairy cows.  
\*2006\*

Jamornman, S., S. Sopa, S. Kumsri, T. Anantachaiyong, and S. Rattithumkul. 2003. effect of  
Roundup Ready corn NK603 on green lacewing - *Mallada basalis* (Walker) under laboratory  
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Boongird, S., T. Suavansri, T. Anantachaiyong, and S. Rattithumkul. 2003. Effect of Roundup  
Ready Corn NK603 on foraging behavior and colony development of *Apis mellifera* L. under  
greenhouse condition. Proc. Sixth Nat. Plant Protect. Conf. Thailand 24th - 27th Nov 2003,  
p26-27, Abstract

Jasinski, J.R., J.B. Eisley, C.E. Young, J. Kovach, and H. Wilson. 2003. Select nontarget  
arthropod abundance in transgenic and nontransgenic field crops in Ohio. Environ. Ent. 32:407-  
413.

Mojan, W.E. and L.P. Pedigo. 2002. Suitability of transgenic GT soybeans to green cloverworm (*Lepidoptera: Noctuidae*). J. Econ. Ent. 95:1275-1280

Jackson, R.E. and H.N. Pitre. 2004. Influence of Roundup Ready soybean production systems and glyphosate application on pest and beneficial insects in narrow-row soybeans. J. Ent. Sci. 39:62-70.

Buckelew, L.D., L.P. Pedig, H.M. Mero, M.D.K. Owen, and G.L. Tylka. 2000. Effects of weed management system on canopy insects in herbicide-tolerant soybeans. J. Econ. Ent. 93:1437-1443.

Bitzer, R.J., L.D. Buckelew, and L.P. Pedigo. 2002. Effects of transgenic herbicide-resistant soybean varieties and systems on surface-active springtails (*Entognatha: Collembola*). Environ. Entomology. 31:449-461

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Siciliano, S.D., and Germida, J.J. 1999. Taxonomic diversity of bacteria associated with the roots of field-grown transgenic *Brassica napus* cv. Quest, compared to the non-transgenic *B. napus* cv. Excel and *B. rapa* cv. Parkland. FEMS Microbiol. Ecol. 29: 273-272.

Kim, Y.T., B.K. Park, E.I. Hwang, N.H. Yim, N.R. Kim, T.H. Kang, S.H. Lee, and S.U. Kim. 2004. Investigation of possible gene transfer to soil microorganisms for environmental risk assessment of genetically modified organisms. J. Micro. Biotech. 14:498-502.

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Tiedje, J.M., R.K. Colwell, Y.L. Grossman, R.E. Hodson, R.E. Lenski, R.N. Mack and P.J. Regal. 1989. The Planned Introduction of Genetically Engineered Organisms: Ecological Considerations and Recommendations, Ecology, 70, 298-315.

Buckley, D.H. and T.M. Schmidt. 2001. The structure of microbial communities in soil and the lasting impact of cultivation. Microbial Ecology, 42: 11-21.

Lesins, K.A., and I. Lesins. 1979. Genus *Medicago* (Leguminosae): A Taxogenetic Study. Dr. W. Junk Publishers, Kluwer, Dordrecht, The Netherlands

**Appendix R:       Impacts to United States Trade of  
Deregulation of Glyphosate-Tolerant  
Alfalfa**

# **Impacts to United States Trade of Deregulation of Glyphosate-Tolerant Alfalfa**

## **Executive Summary**

U.S. exports of alfalfa hay and processed alfalfa are considerably concentrated in Japan, and U.S. exports of alfalfa seeds have increasingly gone to Saudi Arabia. Japan and South Korea are the world's largest importers of forage and Saudi Arabia is the largest importer of alfalfa seed, after the United States.

Saudi Arabia will not import glyphosate-tolerant (GT) alfalfa seeds. There is no evidence, however, that Saudi Arabia will not continue to import non-GT U.S. alfalfa seed as long as exporters are able to guarantee seed purity standards.

There is evidence that Japan may decrease its imports of non-GT alfalfa hay from the United States with GT alfalfa deregulation. This seems to be motivated mainly by businesses concerned with negative reactions from consumers, even in the absence of labeling requirements in downstream dairy and meat products.

U.S. imports of alfalfa hay and seed come mostly from Canada. To the extent that GT alfalfa deregulation reduces foreign demand for U.S. exports, alfalfa hay and seed production previously destined to foreign markets may be channeled to the domestic market. As the domestic market for non-GT alfalfa hay and seed is expected to decrease with GT alfalfa deregulation, U.S. production is likely to substitute imports.

## 1.0 Introduction

### 1.1 Scope of Report

This report analyzes impacts to United States trade of deregulation of glyphosate-tolerant (GT) alfalfa.

### 1.2 Methodology

Analysis of the potential impact of deregulation of GT alfalfa on U.S. trade was divided into its impact on U.S exports and its impacts on U.S. imports. Exports and imports of alfalfa seed, alfalfa hay and processed alfalfa are examined. We also look at exports of downstream products such as dairy and meat.

On several occasions the analysis in the present Technical Report makes use of conclusions drawn from our previous Technical Reports *Economic and Social Impacts to Conventional and Organic Farmers of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix S), and *Downstream Effects to Organic Production and Marketing of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix T).

Section 2 of this report analyzes exports and section 3 looks at imports. As in previous Technical Reports, we explain our bibliographic search methods in appendix R-2 of this technical report. In appendix R-3 of this technical report, we make a few considerations on how foreign trade impacts on the county level analysis that was done in previous reports.

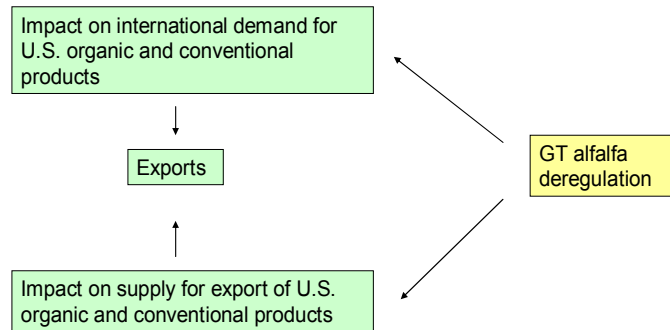
#### 1.2.1 Assumptions

The impact of GT alfalfa deregulation on international demand for U.S. exports stems from the availability of GT alfalfa in the U.S. market, potentially generating perceptions by foreign clients that U.S. exports of non-GT alfalfa and animal products produced from non-GT alfalfa fed livestock may contain GT alfalfa. How this would affect demand depends on a) whether there is any GT sensitivity among foreign clients for U.S. alfalfa; and b) how clients react to potential unintended presence. There may be no impact on demand at all, or markets may distinguish between GT alfalfa and non-GT alfalfa, as well as between products made from animals fed with GT alfalfa and non-GT alfalfa, with different conditions for acceptance in each of these markets (market segmentation).

On the side of the U.S. supply for exports, the impact of GT alfalfa deregulation will depend on the capacity of U.S. producers to meet their clients' demands and whether this capacity comes at a higher cost than before.

The figure below illustrates the cause-effect links to be analyzed.

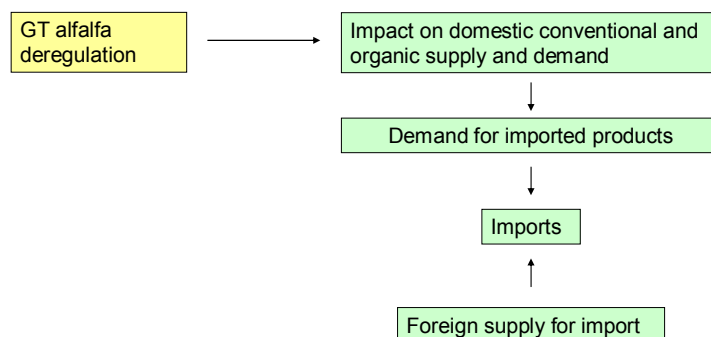
For:  
 1) Alfalfa seed  
 2) Alfalfa hay and processed alfalfa  
 3) Dairy, beef, livestock and pet care products



**Figure R-1: Deregulation impact on exports**

Impacts on imports may occur if GT alfalfa deregulation increases or decreases the need of domestic markets for imports or the costs of domestic products competing with imports. This would affect U.S. demand for imported alfalfa and derived products. We illustrate with the figure below.

For:  
 1) Alfalfa seed  
 2) Alfalfa hay and processed alfalfa  
 3) Dairy, beef, livestock and pet care products



**Figure R-2: Deregulation impact on imports**



### *1.2.2 Data and Information Sources*

Most U.S. trade data was obtained from USDA's Foreign Agriculture Service that reports exports and imports since 1989 as classified under the U.S. 10 digit Harmonized System and compatible with the World Customs Organization's 6 digit Harmonized System. Trade data was typically report up to 2007, to be consistent with the domestic information from the 2007 Census of Agriculture. Trade data as reported by the US Harmonized System does not discriminate for organic products.

For trade data for other countries we made use of foreign government data sources or the United Nations' Commodity Trade Statistics Database (Comtrade).

Data was complemented with information obtained from articles, typically of an academic nature and peer-reviewed whenever possible, under the assumption that these documents are subject to standards that should help reduce if not eliminate any intentional bias.

## 2.0 Impacts on Exports

### 2.1 Trends

#### 2.1.1 Alfalfa Seed

Data on alfalfa seed exports is provided by USDA Foreign Agricultural Service (FAS) through its U.S. Trade Internet System (FASonline). Saudi Arabia has been the largest export market of U.S. alfalfa seed after passing Argentina, having increased its purchases significantly in 2006 and doubling in size in 2007. Other important markets in Mexico, Canada, and Argentina have fluctuated but remain at similar levels over the five year period. Data for the first six months of 2008 suggests Saudi Arabia's major purchases continue (\$14,801,000 in January – June of 2008). Table R-1 shows the size of the major export markets over a six-year period.

**Table R-1. U.S. Exports of Alfalfa Seed, \$1000**

|              | 2002   | 2003   | 2004   | 2005   | 2006   | 2007   |
|--------------|--------|--------|--------|--------|--------|--------|
| Saudi Arabia | 7,533  | 13,523 | 11,659 | 12,233 | 17,172 | 38,075 |
| Mexico       | 6,600  | 8,636  | 9,652  | 9,955  | 10,018 | 9,578  |
| Argentina    | 2,837  | 3,300  | 7,682  | 6,793  | 5,521  | 5,062  |
| Canada       | 2,081  | 2,867  | 4,294  | 5,573  | 5,042  | 2,960  |
| Other*       | 6,912  | 10,674 | 10,685 | 10,404 | 7,389  | 10,379 |
| Total        | 25,963 | 39,000 | 43,972 | 44,958 | 45,142 | 66,054 |

Source: USDA, FAS (FASonline). Code 120921 of the US Harmonized Tariff System; \*Includes Japan, China, and Peru, among others.

FASonline does not provide price data for the different export markets. However, by comparing quantities imported to the value of the export market, table R-2 shows value per metric ton of exported U.S. alfalfa seed. Saudi Arabia not only purchases the most U.S. alfalfa seeds, it also pays the highest price.

**Table R-2. U.S. Exported Alfalfa Seed, \$ value per Metric Ton**

|              | 2002   | 2003  | 2004  | 2005  | 2006  | 2007  |
|--------------|--------|-------|-------|-------|-------|-------|
| Saudi Arabia | 1,655  | 3,714 | 3,202 | 3,393 | 3,919 | 4,852 |
| Mexico       | 2,550  | 2,435 | 2,721 | 3,018 | 3,346 | 3,438 |
| Argentina    | 2,635  | 1,070 | 2,490 | 3,080 | 3,573 | 3,769 |
| Canada       | 1,863  | 2,081 | 3,117 | 2,874 | 3,829 | 3,970 |
| Other        | 11,570 | 2,515 | 2,518 | 3,105 | 3,570 | 4,087 |
| Total        | 2,614  | 2,454 | 2,767 | 3,122 | 3,668 | 4,328 |

Source: USDA FAS (FASonline). Code 120921, value of export / quantity of export.

#### 2.1.2 Alfalfa Hay and Processed Alfalfa

Total U.S. exports of alfalfa hay grew considerably between 1998 and 2002 but then stabilized somewhat in export value, while likely declining in quantities<sup>68</sup>. Japan is by far the main destiny of U.S. alfalfa hay exports, followed by South Korea and Taiwan. Japan's share of U.S. exports

<sup>68</sup> FASonline, reports quantities traded of the "greatest number of like units of measure for grouped commodities." To the extent that this reflects total quantities of alfalfa hay exported, there has been a decline in exports in recent years.

has fallen in recent years (but still at 68% of total) with an important growth of exports to South Korea. Table R-3 shows the growing value of U.S. alfalfa hay exports.

**Table R-3. U.S. Alfalfa Hay Exports, \$1000**

|         | 1998   | 1999    | 2000    | 2001   | 2002    | 2003    | 2004    | 2005    | 2006    | 2007    |
|---------|--------|---------|---------|--------|---------|---------|---------|---------|---------|---------|
| Japan   | 77,882 | 84,405  | 77,527  | 66,705 | 114,749 | 120,994 | 136,193 | 125,663 | 120,791 | 115,888 |
| S.Korea | 3,560  | 6,499   | 17,915  | 18,437 | 22,590  | 21,888  | 19,974  | 19,979  | 25,318  | 31,778  |
| Taiwan  | 4,182  | 5,223   | 3,668   | 5,010  | 10,237  | 7,866   | 7,891   | 9,646   | 10,647  | 11,563  |
| Other*  | 5,344  | 4,978   | 4,770   | 5,675  | 5,993   | 7,600   | 7,476   | 9,801   | 8,436   | 12,020  |
| Total   | 90,965 | 101,104 | 103,879 | 95,827 | 153,569 | 158,348 | 171,533 | 165,087 | 165,192 | 171,249 |

Source: USDA FAS (FASonline). Code 1214900010 of the U.S. Harmonized Tariff System; \*Includes Mexico and Canada, among others.

Woodward (2006) notes that demand for imported alfalfa hay from Japan and South Korea, the two major export markets for U.S. alfalfa hay, has steadily increased. Milk production has remained stable in both countries and livestock production has declined but this has been offset by declines in forage production in these countries. Japan has seen a decrease in forage production of 17 percent, and South Korea has faced a decline of 53 percent, maintaining the demand for imported alfalfa hay steady.

The above numbers do not include processed hay into meal and pellets. U.S. exports of meal and pellets, dehydrated or sun cured, in cubes or other form, were in 2007 approximately \$30 million. In the last 10 years, exports of processed alfalfa decreased about 30 percent (1998 to 2007). However, during that time total processed alfalfa exports experienced fluctuations between -34 percent (between 2000 and 2001) and 27 percent (between 2002 and 2003), as illustrated in table R-4. These fluctuations can be attributed primarily to Japan, the largest importer of U.S. processed alfalfa, with on average 87 percent of the U.S. export market over the past decade. In the years described above, Japan experienced fluctuations as high as 25 percent (2002-2003) and as low as -24 percent (2000-2001).

**Table R-4. U.S. Processed Alfalfa Exports, \$1000**

|         | 1998   | 1999   | 2000   | 2001   | 2002   | 2003   | 2004   | 2005   | 2006   | 2007   |
|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Japan   | 41,189 | 33,672 | 26,684 | 20,328 | 25,667 | 32,086 | 26,233 | 24,736 | 20,734 | 23,169 |
| S.Korea | 182    | 1,106  | 4,756  | 1,249  | 517    | 854    | 164    | 112    | 109    | 3,568  |
| Taiwan  | 142    | 290    | 838    | 338    | 635    | 1,138  | 2,210  | 2,510  | 2,730  | 2,374  |
| Other*  | 1,278  | 1,224  | 1,500  | 431    | 530    | 567    | 2,232  | 1,346  | 776    | 1,281  |
| Total   | 42,792 | 36,291 | 33,776 | 22,343 | 27,348 | 34,646 | 30,839 | 28,702 | 24,349 | 30,392 |

Source: USDA, FAS (FASonline). Code 121410 of the U.S. Harmonized Tariff System; \*Includes Mexico and the United Arab Emirates, among others.

United States seems to be steadily losing market share in its exports of alfalfa hay and in cubes to its main buyer, Japan. In the ten years in which Japan's total forage imports increased by 18.5 percent, exports of U.S. forage only increased by 7.5 percent. Although Canada's share of this market has remained stable, Australia's share grew 800 percent from 1995 to 2004 (Woodward, 2006). Table R-5 shows how Australia's exports grew significantly from accounting for less than 3 percent of imported alfalfa hay and cubes in Japan to be the second largest supplier of that country. During the same period, U.S. market share fell from over 81% to just over 70%.

**Table R-5. Share of Japan Export Market for Alfalfa Hay and Cubes (% by tonnage)**

|           | 1995  | 1996  | 1997  | 1998  | 1999  | 2000  | 2001  | 2002  | 2003  | 2004  |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| USA       | 81.64 | 80.90 | 80.68 | 77.74 | 78.22 | 77.83 | 77.21 | 74.86 | 77.16 | 70.01 |
| Australia | 2.29  | 4.17  | 5.11  | 5.62  | 7.01  | 7.96  | 8.67  | 12.39 | 13.54 | 16.50 |
| Canada    | 13.18 | 11.73 | 10.62 | 13.17 | 11.73 | 12.83 | 13.41 | 12.12 | 8.66  | 12.97 |
| China     | 2.43  | 2.79  | 2.88  | 2.85  | 2.49  | 0.66  | 0.02  | 0.03  | 0.19  | 0.19  |

Source: Woodward, 2006

Most of the U.S. loss in market share is accounted for by hay. The U.S. share of Japan's alfalfa cube imports actually increased over the same period from 74 percent in 1995 to 87 percent in 2004. This gain in market share for alfalfa cubes is largely accounted for by a significant decline in Canadian alfalfa cube exports to Japan while Australian exports fluctuated without steadily increasing (Woodward, 2006).

### *2.1.3 Dairy, Beef, Livestock and Pet Care Products*

Exports of dairy, beef, livestock, and pet care products are downstream markets of alfalfa production. Particularly relevant is the dairy market, that consumes a major share of alfalfa hay produced in the United States and that has seen foreign markets become increasingly important for U.S. dairy producers, with 9.5 percent of all U.S. dairy production in 2007 exported (USDEC, 2007). The export value of dairy products grew by 357 percent from 1998 to 2007. A large part of this increase in exports went to Mexico, which remains the largest importer of U.S. dairy products. The U.S. Dairy Export Council (USDEC) predicts these increases to continue as further tariffs are lifted under the North American Free Trade Agreement (NAFTA). Table R-6 shows U.S. dairy product exports to the top importing nations.

**Table R-6. U.S. Dairy Product Exports, \$1000**

|          | 1998    | 1999    | 2000    | 2001    | 2002    | 2003    | 2004      | 2005      | 2006      | 2007      |
|----------|---------|---------|---------|---------|---------|---------|-----------|-----------|-----------|-----------|
| Mexico   | 176,828 | 157,960 | 149,400 | 218,487 | 179,126 | 226,784 | 313,282   | 392,470   | 379,470   | 731,372   |
| Canada   | 98,920  | 94,911  | 109,923 | 109,036 | 99,641  | 101,450 | 148,461   | 138,185   | 133,806   | 203,342   |
| Philipp. | 15,404  | 20,164  | 24,240  | 29,611  | 23,914  | 31,019  | 59,152    | 56,741    | 86,431    | 135,507   |
| Japan    | 79,589  | 88,664  | 151,079 | 116,867 | 75,138  | 64,952  | 79,873    | 105,572   | 103,163   | 125,346   |
| Other*   | 323,523 | 307,743 | 312,537 | 330,512 | 287,688 | 307,764 | 557,781   | 600,717   | 788,233   | 1,279,623 |
| Total    | 694,266 | 669,449 | 747,178 | 804,514 | 665,512 | 731,967 | 1,158,550 | 1,293,689 | 1,491,104 | 2,475,193 |

Source: USDA FAS (FASonline). Code 04 of the U.S. Harmonized Tariff System; \*Includes China and Indonesia, among others.

Unlike foreign dairy markets, U.S. exports of meat and edible offal remained relatively stable since 2000, with an increase, however, in 2007 (table R-7).

**Table R-7. U.S. Meat and Edible Offal Exports, \$1000**

|        | 2000      | 2001      | 2002      | 2003      | 2004      | 2005      | 2006      | 2007      |
|--------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Mexico | 1,048,014 | 1,144,759 | 1,065,423 | 1,190,968 | 1,215,429 | 1,520,551 | 1,772,591 | 1,707,454 |
| Japan  | 2,600,434 | 2,477,652 | 1,851,960 | 2,129,149 | 997,052   | 1,116,641 | 1,120,258 | 1,409,774 |
| Canada | 507,911   | 530,588   | 547,196   | 589,440   | 528,098   | 659,988   | 902,873   | 1,169,748 |
| Other* | 2,367,283 | 2,542,204 | 2,368,000 | 2,779,774 | 1,966,940 | 2,725,647 | 2,749,940 | 4,045,215 |
| Total  | 6,523,647 | 6,695,199 | 5,832,578 | 6,689,331 | 4,707,523 | 6,022,825 | 6,545,663 | 8,332,194 |

Source: USDA FAS (FASonline). Code 02 of the U.S. Harmonized Tariff System; \*Includes China and the Russian Federation, among others.

Exports of U.S. live animals have fluctuated. Exports of U.S. live animals reached its highest point in 2001. In 2007 exports were at nearly the same level as ten years before. Table R-8 shows U.S. exports of live animals over a ten-year period.

**Table R-8. U.S. Live Animal Exports, \$1000**

|        | 1998    | 1999    | 2000    | 2001    | 2002    | 2003    | 2004    | 2005    | 2006    | 2007    |
|--------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Canada | 132,426 | 177,280 | 250,247 | 223,359 | 118,416 | 92,665  | 70,633  | 76,317  | 98,056  | 116,072 |
| UK     | 73,450  | 42,952  | 76,935  | 97,607  | 70,132  | 70,845  | 60,902  | 150,776 | 147,983 | 109,406 |
| Mexico | 137,224 | 101,843 | 121,561 | 144,996 | 140,992 | 69,365  | 65,853  | 67,924  | 64,367  | 91,645  |
| Japan  | 72,011  | 74,296  | 87,528  | 88,082  | 54,862  | 73,604  | 66,567  | 71,277  | 89,767  | 79,963  |
| Other* | 259,814 | 255,955 | 323,043 | 335,261 | 251,871 | 279,306 | 240,223 | 278,419 | 344,952 | 322,714 |
| Total  | 674,928 | 652,327 | 859,310 | 889,301 | 636,276 | 585,788 | 504,177 | 644,715 | 745,121 | 719,802 |

Source: USDA FAS (FASonline). Code 01 of the U.S. Harmonized Tariff System; \*Includes China and United Arab Emirates, among others.

## 2.2 Impacts of GT Alfalfa Deregulation

There is considerable heterogeneity among countries on regulation pertaining to genetically engineered (GE) food and feed (Gruère G. P., 2006). While most countries lack any regulations at all, the main U.S. markets for alfalfa and downstream products do have regulations. These regulations involve food safety approval processes, labeling, or both.

Of all regions, the European Union has arguably the most stringent regulations. GE food and feed must be approved for safety. Once approved, labeling is required even if there are no detectable GE traits in the final product, as long as GE products were intentionally used in the production process. For foods and feed where no GE products were intended, a traceability process must be implemented throughout the chain whenever potential GE content exists and labeling is required for any presence of GE material above 0.9% of total content. Both

traceability and labeling imply considerable costs to producers (Gruère G. P., 2006; Gruère G. P. and Rao S. R., 2007). Animal products such as meat, dairy and eggs, however, are exempt of such labelling and traceability requirements.

Japan, Saudi Arabia and South Korea, main alfalfa export markets, all have approval processes for GE products and labeling requirements.

### *2.2.1 Standards in Main Export Markets*

The approval of GE foods in Japan is the responsibility of the Ministry of Health, Labor and Welfare (MHLW). MHLW has zero tolerance for unapproved GE foods and conducts inspection and testing of cargoes arriving in Japan, inspecting up to 50% of all cargoes (Gruere, 2006). Monsanto's J101 and J163 have completed MHLW's approval process (MHLW, 2008).

Approval of GE feed is the responsibility of the Ministry of Agriculture, Fisheries and Forestry (MAFF). A one per cent threshold for presence of GE content in feed is allowed as long as the GE product has been approved by the exporting country and the exporting country is considered to have safety assessments equivalent to Japan's (Gruere G. P., 2006).

Labeling is mandatory for all GE foods as long as GE content can be detected, the GE ingredient is one of the first three ingredients of a product, and accounts for more than five percent of the total weight (Gruere G. P., 2006). Unlike the labeling requirements of the European Union, labeling requirements are based only on product content and not process (Gruère G. P. and Rao S. R., 2007).

South Korea has similar approval processes and labeling requirements as Japan: the Ministry for Food, Agriculture, Forestry and Fisheries (MFAFF) regulates labeling for unprocessed GE products while the South Korea Food and Drug Administration (KFDA) regulates food safety and labeling of processed foods. As of July 2008, South Korea had approved 54 biotech products, including Monsanto's J101 x J163 Alfalfa (USDA FAS, 2008a).

Labeling in South Korea is mandatory for unprocessed GE food and for unprocessed non-GE food containing more than three percent presence of GE material. In the case of processed foods, labeling is required if the GE ingredient is among the top five and is detectable in the final product. GE animal feed must also be labeled (USDA FAS, 2008a). Processed food with non detectable levels of GE material, such as dairy, meat and vegetable oils do not require labeling.

Taiwan requires labeling for products containing more than 5% GE content of (USTR, undated).

For alfalfa seed, the most important export market is Saudi Arabia. Although the country allows imports of labeled GE variety grains and plant/vegetable processed foodstuffs, imports of GE variety seeds have been banned since 2004 (FAS, 2007a).

Mexico, the main downstream export market for dairy, seems to have no significant trade barriers to foods derived from biotechnology. GT alfalfa has been approved for food and feed

and Mexico imports and consumes regularly GE corn, soybeans and cotton from the United States (FAS, 2008b). Mexico's existing labeling requirements for GMOs have not been implemented, according to Gruère G. P. (2006).

In the case of Canada, another important market for alfalfa downstream products from the United States, GT alfalfa has also been approved and there is no mandatory labeling for GE products (Gruère G. P., 2006).

### *2.2.2 Beyond Standards in Main Export Markets*

As in the case of Europe, mandatory labeling requirements for food in Japan have resulted in an incentive for producers to substitute non-GE ingredients for GE ingredients (Gruère G. P. and Rao S. R., 2007). Because of the higher threshold of GE content and exemptions of highly processed foods, there are still many products with GE ingredients that are sold in Japan without GE labeling, such as cheese, soya sauce and soy oil (Gruère G. P. and Rao S. R., 2007). Corn used for feed is typically GE corn, since meat fed with GE corn does not need to be labeled. Corn used for food consumption and soybeans used for Tofu, on the other hand, are typically GE free (Gruere G. P., 2006).

Because alfalfa hay is predominantly used as feed, the impacts of deregulation associated with the export market in Japan may be similar to those of soybean and corn. Japanese regulations do not seem to have had a significant impact on these crops and labeling is not required for products from GE fed animals, at least not for meat (Gruere, 2006).

However, for retail products where labeling is not required, there may still be a share of consumers that would prefer not to consume products with GM ingredients. Several consumer surveys suggest Japanese consumers would prefer not to consume foods with GE ingredients and would be willing to pay an extra amount for GE-free products (Chern et al., 2002; Bertolini et al., 2003). In these cases, it is up to producers to decide whether using GE ingredients – or GE feed in animal products – poses a risk to businesses.

There is evidence that businesses have often chosen to protect themselves against market risks associated with commercializing GE products, in face of consumer negative perceptions, even in the absence of labeling, at least in countries other than the United States. A USDA (2005) document notes how business associations have sometimes adopted lower required levels of unintended presence for acceptance of products than those required by legislation (United Kingdom). The same document notes that some insurance companies have added exclusions to insurance contracts to protect themselves from potential losses triggered by the presence of GE material.

There is some indication that Japanese alfalfa importers are concerned with importing GE alfalfa. Putnam (2005) states that foreign importers have asked for GE-free alfalfa and that this has lead U.S. exporters to require signed contracts from producers asserting the GE-free status of alfalfa sold to them. Similar anecdotal evidence is provided by Woodward (2004) and recognized in NAFA (2008b).

The attitude of businesses in the absence of required labeling in retail products can be explained by the perception of market risks associated with GE products, given consumer negative perceptions. The extent to which this attitude of businesses changes with time may depend on consumer information as well as on perceived and real liabilities in cases of losses due to the presence of GE material.

In the case of South Korea, Non-Government Organizations (NGOs) have increasingly pressured for expansion of labeling requirements to products using GE ingredients, independently of whether these can or cannot be detected in the final product (USDA FAS, 2008a). USDA FAS (2008a) notes that labeling of feed does not seem to have an impact in the market because most feed is GE, but that an expansion of food labeling requirements to include use of GE ingredients even when not detectable could turn South Korea into a non-GE market. As in the case of Japan, there is evidence of consumer negative views of GE products (Cho, Undated; USDA FAS, 2008a). South Korean businesses, however, have been opposing expansion of GE labeling given the potential increase in their costs from buying non-GE products.

### *2.2.3 U.S. Alfalfa Supply for Export Markets*

Something between 1.1% and 1.5% of U.S. alfalfa hay production was exported in 2007 (in metric tons, calculated comparing USDA FAS export data with production data as reported by USDA ERS, 2007). An exact number is not easy to achieve because exports are reported in hay, meal and pellets and weights must be compared to production alfalfa hay production. In 2007, exports of alfalfa seed represented approximately 54% of the quantity produced (in metric tons, calculated comparing USDA FAS export data with 2007 Census of Agriculture data).

We found no detailed information on the origin of alfalfa for exports within the United States. Various documents suggest a concentration of alfalfa hay and seed for exports in Western states. Woodward (2004) suggests 99% of hay exports come from Western states. Putnam (2005) suggests about 4.5% of alfalfa from six Western states (California, Washington, Oregon, Idaho, Nevada, Utah) is exported. Woodward (2004) notes some 20% of Washington alfalfa may be exported reaching 35%-50% in the Columbia Basin where the counties of Grant, Adams, Benton and Franklin produce almost 70% of the state's alfalfa hay. Putnam (2005) also suggests California's Imperial Valley production is highly aimed at export markets. Mueller (2005) estimates that about 80 percent of California alfalfa seed production goes for export. In all of these export-heavy regions, growers do not necessarily export their entire crop but possibly only a few cuttings (Putnam, 2005). This means that export markets may have a greater influence on production decisions than their share of the market.

### *2.2.4 Discussion*

The main U.S. client for alfalfa seed, Saudi Arabia, would currently not purchase GT alfalfa seeds. Whether Saudi Arabia would continue purchasing non-GT alfalfa seeds from the United States would likely depend on the extent to which non-GT alfalfa seed producers are able to avoid unintended presence of GT alfalfa traits.



United States sales of alfalfa for forage to Japan may decrease with GT alfalfa deregulation. There is evidence of precautionary resistance from Japanese importers for GT alfalfa and the United States has already been losing market share to competitors (Australia). Exporters may have to show that any unintended presence of GT traits would fall well below Japan's one percent threshold level for presence of GM feed.

Beyond the above, there is much uncertainty surrounding the future of trade of GM products. In our Technical Report *Downstream Effects to Organic Production and Marketing of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix T), we presented evidence that there is little information in Europe, Japan, United States, as well as in other countries, regarding GE products. To the extent that familiarity is related to acceptance (or rejection) of GE products, there is space for consumer receptivity to change or consolidate over time. Many countries do not have or must still implement their own regulatory systems for GE products (Gruère and Rao, 2007) and the analysis above is focused solely on U.S. current trading partners. Other potential future clients are not considered, although by far the main world importers are Japan and South Korea in the case of alfalfa hay and Saudi Arabia (after the United States) in the case of alfalfa seeds.

## 2.3 Summary of Findings

U.S. exports of alfalfa hay and processed alfalfa are considerably concentrated in Japan, and U.S. exports of alfalfa seeds have increasingly gone to Saudi Arabia. Japan and South Korea are the world's largest importers of forage and Saudi Arabia is the largest importer of alfalfa seed, after the United States.

Saudi Arabia will not import GT alfalfa seeds. There is no evidence, however, that Saudi Arabia will not continue to import non-GT U.S. alfalfa seed as long as exporters are able to guarantee seed purity standards.

There is evidence that Japan may decrease its imports of non-GT alfalfa hay from the United States with GT alfalfa deregulation. This seems to be motivated mainly by businesses concerned with negative reactions from consumers, even in the absence of labeling requirements in downstream dairy and meat products.

## 3.0 Impacts on Imports

### 3.1 Trends

#### 3.1.1 Alfalfa Seed

Imports of alfalfa seed by the United States were, in 2007, approximately \$36.5 million. As with exports, alfalfa seed imports by the United States have been growing since 2002.

**Table R-9. U.S. Alfalfa Seed Imports, \$ millions**

| 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|------|------|------|------|------|------|------|------|------|------|------|
| 14.5 | 20.4 | 16.3 | 11.8 | 12.7 | 10.9 | 13.4 | 15.9 | 18.0 | 24.9 | 36.5 |

Source: USDA FAS (FASonline). Code 120921 of the US Harmonized Tariff System. Includes certified and uncertified seeds.

Re-exports (exports that are subsequently resold to foreign markets) are not particularly significant: about \$954,000 in 2007, \$419,000 in 2006 (FASonline).

Alfalfa seed imports are mostly from Canada and some are from Australia. About a third of alfalfa seed imports are non-certified seeds.

**Table R-10. U.S. Alfalfa Seed Imports by Main Suppliers, \$ millions**

|           | 2003   | 2004   | 2005   | 2006   | 2007   |
|-----------|--------|--------|--------|--------|--------|
| Canada    | 11,403 | 13,219 | 10,489 | 17,794 | 29,669 |
| Australia | 1,489  | 2,677  | 7,228  | 6,915  | 6,080  |
| Others*   | 531    | 46     | 252    | 227    | 739    |
| Total     | 13,423 | 15,941 | 17,968 | 24,936 | 36,489 |

Source: USDA FAS (FASonline). Code 120921 of the US Harmonized Tariff System. Includes certified and uncertified seeds.

\*Includes Argentina, Italy, and France, among others.

According to Revision 2 of the 2008 US Harmonized Tariff Schedule, alfalfa seed imports from Canada, Australia and several other countries are free from the 1.5 cents/ Kg normal import tariff.

#### 3.1.2 Alfalfa Hay and Processed Alfalfa

Imports of alfalfa hay were approximately \$7 million in 2007. In recent years alfalfa hay imports have increased steadily and 2007 imports were nearly three times those of 2003. The United States receives the vast majority of its alfalfa hay imports from Canada and most of the remaining imports from Mexico.

**Table R-11. U.S. Alfalfa Imports (Hay Bales), \$1,000**

|         | 2003  | 2004  | 2005  | 2006  | 2007  |
|---------|-------|-------|-------|-------|-------|
| Canada  | 1,873 | 2,366 | 2,376 | 3,471 | 5,493 |
| Mexico  | 20    | 57    | 5     | 75    | 1,298 |
| Others* | 454   | 11    | 49    | 68    | 8     |
| Total   | 2,348 | 2,435 | 2,430 | 3,613 | 6,800 |

Source: USDA FAS (FASonline). Code 1214900010 of the U.S. Harmonized Tariff System. \*Includes New Zealand and Argentina, among others.

Imports of processed alfalfa were approximately \$16 million in 2007. Processed alfalfa imports have also risen steadily in recent years and have almost doubled since 2003. Almost all of the U.S. processed alfalfa imports come from Canada.

**Table R-12. U.S. Processed Alfalfa Imports, \$1,000**

|         | 2003  | 2004  | 2005  | 2006   | 2007   |
|---------|-------|-------|-------|--------|--------|
| Canada  | 8,212 | 7,238 | 9,163 | 8,474  | 14,627 |
| Mexico  | 0     | 1,315 | 0     | 1,257  | 1,379  |
| Others* | 105   | 181   | 208   | 2401   | 396    |
| Total   | 8,317 | 8,735 | 9,373 | 12,131 | 16,403 |

Source: USDA FAS (FASonline). Code 121410 of the U.S. Harmonized Tariff System. \*Includes France and Hungary, among others.

## 3.2 Impacts of GT Alfalfa Deregulation

### 3.2.1 The Demand for Alfalfa Imports

In our Technical Report *Economic and Social Impacts to Conventional and Organic Farmers of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix S), we argued that deregulation of GT alfalfa will likely generate a downward pressure on prices of conventional alfalfa hay (both GT alfalfa and non-GT alfalfa). This would likely lead to increased domestic consumption of both alfalfa hay and alfalfa seed. This increase in consumption would be accompanied by market segmentation, where the consumption of non-GT alfalfa hay and seed would cede space to the consumption of GT alfalfa hay and seed.

If the United States loses export markets due to GT alfalfa deregulation (as we argued in section 2 may happen), this would generate additional domestic supply of conventional non-GT alfalfa hay and seed, likely further decreasing its price. If exported hay and seed is now channeled to domestic markets the result may be a decrease in demand for imports. The United States is highly competitive in forage and alfalfa seed, as revealed by its position as one of the largest net exporters (tables R-13 and R-14) and domestic production should be able to compete with imports.

**Table R-13. Largest Net Exporters of Forage, 2007, US\$**

|               | Exports     | Imports    | Net Exports |
|---------------|-------------|------------|-------------|
| United States | 622,144,650 | 48,386,339 | 573,758,311 |
| Australia     | 202,892,772 | 87,401     | 202,805,371 |
| Canada        | 185,121,059 | 5,359,957  | 179,761,102 |

Source: UN Comtrade, 2007. Code 1214 of the Harmonized System. Includes swedes, mangolds, fodder roots, hay, lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether or not in the form of pellets

**Table R-14. Largest Net Exporters of Alfalfa Seed Used for Sowing, 2007, US\$**

|               | Exports    | Imports    | Net Exports |
|---------------|------------|------------|-------------|
| Canada        | 40,107,509 | 3,700,730  | 36,406,779  |
| United States | 67,008,403 | 36,884,441 | 30,123,962  |
| Australia     | 25,399,677 | 22,430     | 25,377,247  |

Source: UN Comtrade, 2007. Code 120921 of the Harmonized System.

If, however, imported alfalfa hay and seed are qualitatively different from local produced hay and seed, imports may not be affected and may actually grow in some segments. One segment in

which imports could grow is that of non-GT alfalfa seed, if U.S. stewardship programs are seen as insufficient to guarantee seed purity levels. We have no reliable information on variety details of exports and imports of alfalfa hay and seed.

In our Technical Report *Downstream Effects to Organic Production and Marketing of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix T), we found no evidence that GT alfalfa deregulation will have a negative impact on main domestic downstream markets. We thus do not foresee impacts on imports in downstream markets.

### 3.2.2 The Supply of Alfalfa Imports

The main world providers (exporters) of alfalfa seed other than the United States (largest exporter) are Canada and Australia. These are also the main providers of alfalfa seed to the United States and Canada's exports are already heavily focused on the U.S. market (table R-15). Australia's exports are more diversified (table R-16)<sup>69</sup>.

**Table R-15. Canada Alfalfa Seed Exports, \$1,000**

|               | 2003   | 2004   | 2005   | 2006   | 2007   |
|---------------|--------|--------|--------|--------|--------|
| United States | 11,780 | 13,371 | 10,425 | 17,929 | 30,484 |
| Other         | 7,162  | 9,953  | 4,544  | 9,078  | 9,517  |
| Total         | 18,942 | 23,324 | 14,969 | 27,007 | 40,001 |

Source: Statistics Canada, as reported by Industry Canada, [www.ic.gc.ca](http://www.ic.gc.ca). Code 120921 of the Harmonized System.

**Table R-16. Australia Alfalfa Seed Exports, \$1,000**

|               | 2007   |
|---------------|--------|
| Saudi Arabia  | 10,555 |
| United States | 6,233  |
| Argentina     | 2,477  |
| Morocco       | 1,572  |
| Other         | 4,563  |
| Total         | 25,400 |

Source: UN Comtrade, 2007. Code 120921 of the Harmonized System.

In the case of forage, United States is again the World's largest provider followed by Australia and Canada. United States' main provider (Canada) exports considerably larger sums to Japan of forage in general (table R-17) and alfalfa meal and pellets in particular (table R-18) than to the United States

**Table R-17. Canada Forage Exports, \$1,000**

|               | 2003   | 2004    | 2005    | 2006    | 2007    |
|---------------|--------|---------|---------|---------|---------|
| Japan         | 71,059 | 99,272  | 94,631  | 106,583 | 124,027 |
| United States | 18,222 | 20,352  | 23,976  | 28,660  | 43,126  |
| Other         | 8,033  | 12,183  | 15,778  | 17,173  | 17,479  |
| Total         | 97,314 | 131,807 | 134,385 | 152,416 | 184,632 |

Source: Statistics Canada, as reported by Industry Canada, [www.ic.gc.ca](http://www.ic.gc.ca). Code 1214 of the Harmonized System.

<sup>69</sup> Data on Canada and Australia exports to the United States of a particular product may not match U.S. data on imports of the same product from those countries, depending on export and import controls and reporting of each country.

**Table R-17. Canada Alfalfa Meal and Pellets Exports, \$1,000**

|               | <b>2003</b> | <b>2004</b> | <b>2005</b> | <b>2006</b> | <b>2007</b> |
|---------------|-------------|-------------|-------------|-------------|-------------|
| Japan         | 15,117      | 25,406      | 25,223      | 22,679      | 22,470      |
| United States | 3,097       | 1,293       | 2,933       | 3,983       | 6,813       |
| Other         | 2,036       | 5,439       | 2,534       | 2,699       | 3,974       |
| Total         | 20,250      | 32,138      | 30,690      | 29,361      | 33,257      |

Source: Statistics Canada, as reported by Industry Canada, [www.ic.gc.ca](http://www.ic.gc.ca). Code 121410 of the Harmonized System: subset of 1214 reported above.

If GT alfalfa deregulation reduces U.S. exports to Japan, it is likely that Canada and Australia would try to fulfill the existing gap left by the United States. This would possibly reduce the supply of foreign non-GT alfalfa available for import to the U.S. This would impact U.S. trade only to the extent that particular varieties are imported rather than domestically produced, assuming the domestic market would already be facing an excess supply of non-GT alfalfa hay and seed.

### 3.3 Summary of Findings

U.S. imports of alfalfa hay and seed come mostly from Canada. To the extent that GT alfalfa deregulation reduces foreign demand for U.S. exports, alfalfa hay and seed production previously destined to foreign markets may be channeled to the domestic market. As the domestic market for non-GT alfalfa hay and seed is expected to decrease with GT alfalfa deregulation, U.S. production is likely to substitute imports.

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## Appendix R-2. Literature Search

### 1.0 Literature Search Strategy

Most U.S. trade data was obtained from USDA's Foreign Agriculture Service. For other countries we made use of foreign government data sources or the United Nations' Commodity Trade Statistics Database (Comtrade).

Much of the literature researched was on the market receptivity to GMOs. As in our Technical Report *Downstream Effects to Organic Production and Marketing of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix T), the search started with general internet searches and then snowballed from references found in various papers.

We found particularly useful reports elaborated by the Global Agriculture Information Network of USDA's Foreign Agriculture Service.

## Appendix R-3. County Level Analysis

In the Technical Reports *Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa* (appendix K) and *Economic and Social Impacts to Conventional and Organic Farmers of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix S) we included appendices analyzing county level implications of the information raised in each of those reports. The analysis done was limited to the scope of the reports they were a part of. In the present appendix R-3, we make a few considerations on the county level analysis done in those two reports, given the information on foreign trade that we have now gathered.

In the first of the two reports mentioned above, a ranking of counties that would most likely benefit from deregulation of GT alfalfa was done, based on the likelihood that a randomly picked acre from that county harvested forage alfalfa treated with herbicide. This ranking ignored any considerations regarding sensibilities in the end markets. In the present report we observed that foreign markets are often sensitive to the presence of GE material in food and feed. Counties producing for such markets may find it in their best interest to not plant GT alfalfa, even if ranked highly in the first of the above Technical Reports.

Unfortunately, there is no information available on alfalfa hay exports by county of origin. However, a few considerations can be made regarding our previous ranking. First, the highest ranked county in the Technical Report (appendix K) was Brown County, Wisconsin, and the hay produced in that county is unlikely for export and may adopt GT alfalfa. However, the second ranked county, Imperial County, California is unlikely to adopt GT alfalfa (telephone and email exchanges with two alfalfa experts, Dan Putnam and Shannon Mueller, between July 24 and August 06). Among the various reasons, the production of seed for foreign markets may be one of them. Second, as Imperial County, other counties may be particularly interested in export markets and thus not be willing to adopt GT alfalfa even if they were previously ranked as likely to benefit. Third, a few counties have already banned GM crops. Marin, Mendocino, Santa Cruz and Trinity have all passed legislation banning production of GE crops. Of these counties, only Mendocino had some alfalfa production in the 2007 Agricultural Census and was ranked among the 220 counties least to benefit from GT alfalfa deregulation (from 2305 counties with alfalfa production) in the first Technical Report (appendix K) mentioned above.

In the second of the two reports mentioned above, we ranked counties according to their revealed economic interest in producing alfalfa seed, while relatively little in producing alfalfa for forage with herbicide. Imperial County appears in first place, potentially explaining its resistance to GT alfalfa deregulation by the importance of alfalfa seed in that county.

Additional considerations would be possible if data were available for the source by county and country of destiny of U.S. alfalfa seed and forage exports.

**Appendix S: Economic and Social Impacts to  
Conventional and Organic Farmers of  
Deregulation of Glyphosate-Tolerant  
Alfalfa**

# **Economic and Social Impacts to Conventional and Organic Farmers of Deregulation of Glyphosate-Tolerant Alfalfa**

## **Executive Summary**

This report analyses the potential social and economic impacts to conventional and organic farmers regarding the deregulation of glyphosate-tolerant (GT) alfalfa, due to changes in demand and supply in the domestic market.

As farmers switch to producing GT alfalfa and as the demand for non-GT alfalfa falls, the impact of GT alfalfa deregulation on non-GT conventional alfalfa farmers will likely be a reduction in the market for non-GT alfalfa. The resulting final price for non-GT alfalfa is not clear, but it will likely be lower than it otherwise would be, decreased by the higher returns of its substitute: GT alfalfa. During a period of adjustment to the new market segmentation between GT alfalfa and non-GT alfalfa, prices will tend to fall if demand shifts faster to GT alfalfa than farmers, or will tend to rise if farmers shift faster than demand.

The impact of GT alfalfa deregulation on organic alfalfa farmers depends on whether there is a share of the domestic organic alfalfa market that is sensitive to products with genetic engineering (GE). With no GE sensitivity of demand, the only possible impact on organic markets is the downward shift in demand that follows the reduction in prices of conventional alfalfa, leading to a reduction in prices and quantities sold domestically of organic alfalfa. In the case of GE sensitivity of demand in organic alfalfa markets, the result of GT alfalfa deregulation depends on the extent of this GE sensitivity: the larger the GE sensitive market is, the more likely quantities sold will fall, although with unclear effect on prices. The larger the non-GE sensitive market is, the more likely prices will fall but with unclear effect on quantities.

GT alfalfa adoption by farmers, presence of GT alfalfa in non-GT alfalfa fields, and the demand response to GT alfalfa deregulation will have several distributional and social impacts: the loss and gain of businesses, changes in market structure, distribution of the costs of loss of production and avoidance in GE sensitive markets, and potential negative impacts on the preferred environment of organic farmers (one free of GE organisms).

## 1.0 Introduction

### 1.1 Scope of Report

This report analyzes the potential social and economic impacts to conventional and organic farmers due to the deregulation of glyphosate-tolerant (GT) alfalfa. We expand on our Technical Report *Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa* (appendix K), moving beyond changes in costs and yields within alfalfa farms, to discuss aggregate impacts on the supply of conventional and organic alfalfa.

We also incorporate domestic demand to our analysis leaving, however, foreign demand for our Technical Report *Impacts to United States Trade of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix R).

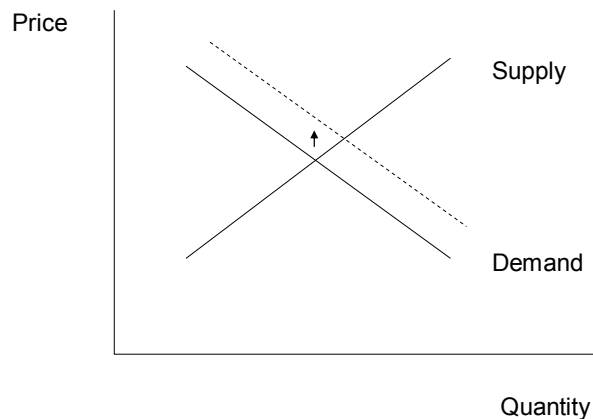
Below we explain the methodology – assumptions, scenarios and limitations – upon which this analysis is based.

### 1.2 Methodology

Analysis of the potential impact of deregulation of GT alfalfa on US organic farming was divided in its impact on the demand for organic alfalfa and its impacts on the supply of organic alfalfa in the U.S. market. When analyzing the potential impact on demand of organic alfalfa, we ignore any impacts on supply. Similarly, when analyzing the potential impact on the supply of the organic alfalfa, we ignore any impacts on demand. We then proceed to look at both demand and supply jointly.

This procedure is meant to facilitate the analysis and to improve our understanding of the sources and mechanisms of the impact of GT alfalfa deregulation. It is a conventional approach in economics, and under this approach prices and quantities are determined jointly by supply and demand. This means that in analyzing shifts in demand and supply, we will not consider how demand and supply change *in response to prices* – because prices are determined by demand and supply themselves. Rather, we look at how demand and supply change in response to other factors and draw conclusions about the resulting changes in prices and quantities. It is important to keep this in mind to understand the analysis done in this report.

We will often refer to impacts on supply and demand as “shifts,” that move the “demand curve” or the “supply curve” upwards or downwards. This language is best understood in reference to the conventional graph of supply and demand below. In this graph, an upwards shift in demand is illustrated.



**Figure S-1: Upward shift in demand**

The economic analysis of shifts in demand and supply in the alfalfa market is complex because the market is segmented in various ways: domestic and international, conventional and organic, high quality and low quality, and for the purposes of this study: markets sensitive to genetically engineered (GE) products and non-GE sensitive markets. To the extent that alfalfa of various qualities and destined to various markets are substitutes, shifts in supply in one market segment may result in shifts in both supply and demand in another. We often simplify our analysis and try to be explicit about the simplifications made.

In this report we generally do not refer to forage in general but rather hay because there is more data available on hay than other types of forage (haylage). This has no significant impact on our analysis and we do make reference to haylage when deemed appropriate. When no distinction between seed and hay is relevant, we often refer simply to alfalfa, alfalfa stands or alfalfa fields.

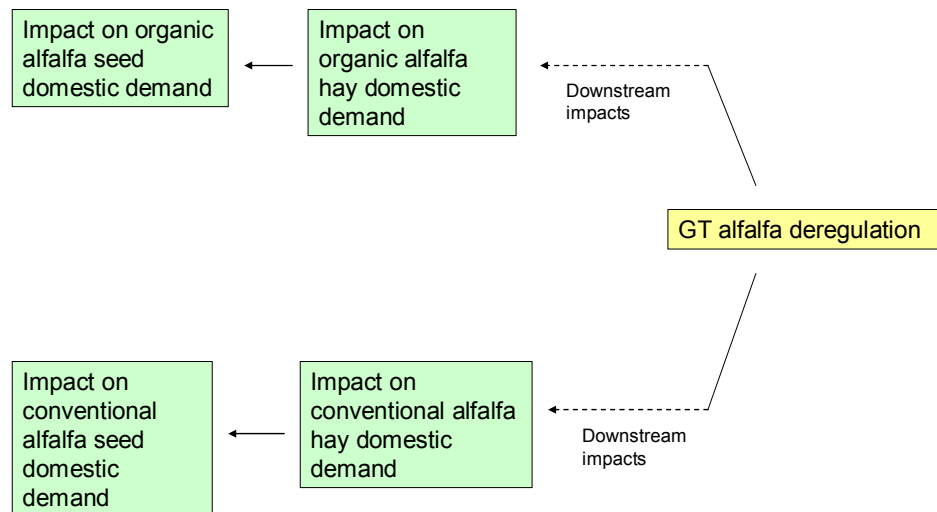
Section 2 of this report analyzes potential shifts in the demand of conventional and organic alfalfa induced by the deregulation of GT alfalfa. Section 3 does the same for the supply of conventional and organic alfalfa. In both sections we start by looking at current data and expected trends and then turn to discuss potential impacts of deregulation. In section 4 we combine our analysis of each side of the market and discuss potential impact scenarios

No quantitative estimates of the impacts of GT alfalfa deregulation are offered in this report. We feel there is not sufficient information for such estimates. However, we describe in section 4 what lacking evidence would allow such estimates for specific impact scenarios.

In appendix S-2 of this technical report we describe our bibliographic and data search. Appendix S-3 of this technical report is a county level analysis that expands on the similar analysis done in our Technical Report *Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa* (appendix K). It ranks alfalfa seed producing counties by acreage and the likelihood of not finding alfalfa hay with herbicides, where the latter variable is taken as an indicator of reduced losses in not producing GT alfalfa hay.

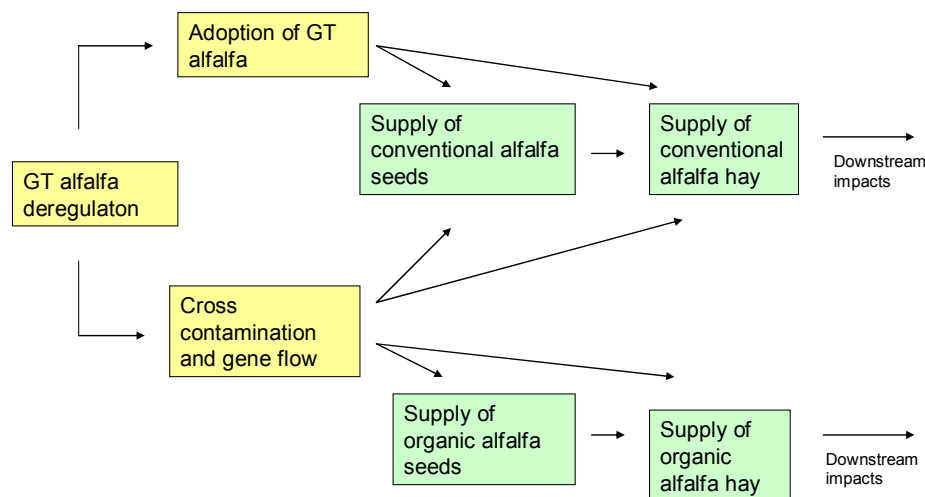
### 1.2.1 Assumptions

GT alfalfa deregulation is assumed to potentially affect organic and conventional alfalfa demand to the extent that it affects dairy, livestock, pet care and human domestic demand through perception of the presence of GT alfalfa material in these products. Changes in demand for alfalfa hay and alfalfa fields for human consumption reflect on changes in demand for alfalfa seed. The figure below illustrates the cause-effect links to be analyzed.



**Figure S-2: Deregulation impact on demand**

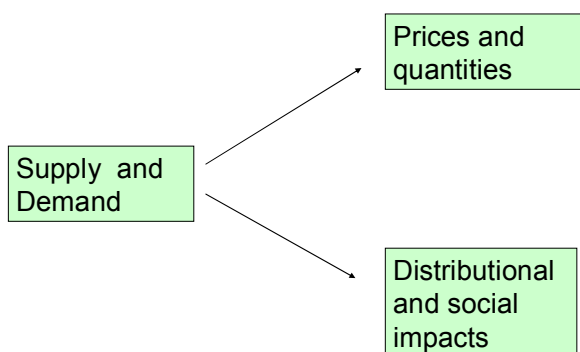
On the supply side, GT alfalfa deregulation will generate two sources of impacts. The first is the adoption of GT alfalfa by conventional farmers. This adoption will impact supply to the extent that GT alfalfa has its own quality and cost properties. The second is the possible comingling of GT alfalfa seeds among non-GT alfalfa seeds and gene flow from GT alfalfa fields to non-GT alfalfa fields. The figure below illustrates the cause-effect links analyzed.



**Figure S-3: Deregulation impact on supply**

Comingling and gene flow may reduce the availability of seeds accepted as organic or free of GE material and may increase the costs of farmers in avoiding comingling and gene flow and in screening for GE material.

The interaction of the impacts on supply and demand will result in impacts on prices and quantities sold, and will impact differently on various segments of farmers. Some farmers may lose business with comingling and gene flow. Others – possibly depending on location – may gain, as may GT alfalfa farmers. Who gains or loses may have impacts on the market structure. It may also have an impact on perceptions of freedom of choice and on perceptions of justice associated with the distribution of the burden (among consumers of organic products as opposed to consumers of GE products, for example). Deregulation may also have social impacts, particularly on organic farmers and consumers.



**Figure S-6: Supply and demand**

### *1.2.2 Data and Information Sources*

Most of our data was obtained from USDA sources, under the assumption that these are the best quality agriculture statistics available. This data was complemented with information obtained from academic journal articles, or from Cooperative Extension services, peer-reviewed whenever possible, under the assumption that these documents are subject to standards that should help reduce if not eliminate any intentional bias.

Our primary source of data for acreage and production was USDA's National Agriculture Statistics Service (NASS). NASS collects data annually through a series of surveys based on representative samples, including area surveys and yield surveys. We also made use of data published by USDA's Economic Research Service, typically also compiled from NASS surveys. In cases where recent survey data was not available, we used the latest Census of Agriculture (2007), comparing with the previous Census of Agriculture (2002 and or 1997) when this was considered informative.

In the case of organic agriculture there is less availability of data. USDA has been collecting data on acreage. As yields vary substantially, production estimates are tentative.



## 2.0 Impacts on Demand

### 2.1 Alfalfa Demand

An analysis of demand for alfalfa should distinguish between demand for alfalfa hay, demand for alfalfa seeds, and demand for alfalfa for human consumption, each with its own particular market and market characteristics. Demand for alfalfa hay (as well as products such as haylage, meal, and pellets processed from hay) derives mostly from the dairy industry, but also from the meat producing industry and from other livestock and pet care. Alfalfa is also available for human consumption in the form of alfalfa sprouts and alfalfa leaves, which can be dehydrated and used as a dietary supplement in tablets, powders, or tea.

In addition, the honey industry utilizes alfalfa fields for honey production. As noted in the Technical Report *Downstream Effects to Organic Production and Marketing of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix T) addressing downstream effects of GT alfalfa deregulation, the honey industry utilizes alfalfa fields for honey production. Alfalfa produces a large amount of nectar, which is attractive to some species of bees, and from which honeybees produce excellent crops of high quality honey (McGregor 1976). The actual market “demand” for alfalfa hay fields by beekeepers appears to be small to non-existent. Alfalfa seed producers contract with bee keepers for pollination services, with honey production being sometimes a co-benefit retained by the bee keeper. Pollination services are an important interstate business. Brady-Myerov (2006) reported that 80 percent of the approximately 2.3 million commercial bee colonies that existed in the United States in 2006 needed to be trucked to California almond orchards just to meet pollination service demand. Brady-Myerov (2006) noted that the going rate for pollination services in 2006 was approximately \$125 to \$150 per hive for six weeks of orchard placement.

In contrast, when alfalfa is cut for hay just at the start of the flowering stage, as is normally practiced, beekeepers get little or no alfalfa honey (McGregor 1976). Beekeepers may keep hives near alfalfa hay fields to access any blossoms prior to cutting, but we found no evidence that beekeepers engage in a commercial market exchange to purchase nectar harvesting services from hay farmers.

Demand for alfalfa seeds is derived primarily from the demand for establishing new stands of alfalfa hay, as well as much smaller demand derived from alfalfa sprout producers and from other processed alfalfa products for human consumption.

GT alfalfa deregulation will affect organic and conventional alfalfa demand to the extent that it affects dairy, livestock, pet care and various forms of human consumption domestically. These impacts are mediated by consumer concerns about consumption of GE foods, or use of GE animal feeds. The extent to which GT alfalfa deregulation will potentially affect conventional and organic alfalfa demand is also influenced by the price, availability, and comparability of substitutes.

### 2.1.1 Domestic Demand for Alfalfa for Forage

There seems to be no complete and systematic data on alfalfa for forage consumption in the US (Klonsky et al, 2007). However, an approximate aggregate value of the demand for alfalfa hay can be obtained through production and trade statistics<sup>70</sup>.

USDA's National Agricultural Statistics Service (NASS) estimates the value of alfalfa hay production in the US to have been approximately US \$9 billion in 2007. This number was obtained by multiplying average prices with volumes produced and does not correspond to actual sales. Sales must have been much less. According to Klonsky et al (2007), most of the alfalfa hay produced in the United States is consumed on farm.

If we discount from these US \$9 billion the US \$171 million in alfalfa hay exports and add the US \$7 million in imports, we have a domestic market for alfalfa hay of approximately US \$8.8 billion in 2007. The same reasoning would lead to a domestic market of US \$7.5 billion in 2006 and US \$7.2 billion in 2005.

**Table S-1. Domestic Alfalfa Hay Market (US \$1,000)**

|             | <b>2007</b> | <b>2006</b> | <b>2005</b> |
|-------------|-------------|-------------|-------------|
| Production  | 8,972,483   | 7,668,870   | 7,342,000   |
| Exports     | 170,925     | 165,192     | 165,087     |
| Imports     | 6,800       | 3,613       | 2,430       |
| Consumption | 8,808,358   | 7,507,291   | 7,179,343   |

Sources: Production data from USDA NASS (2008a); Trade data from USDA Foreign Agricultural Service (FAS); Consumption calculated as production – exports + imports, and assuming change in alfalfa inventories is zero. \* Imports reported of Alfalfa Bales, as opposed to Alfalfa Hay

We found no data on the national distribution of the consumption of alfalfa hay among its various uses. Putnam (2005) states that the three main domestic markets for alfalfa are dairy farms, beef farms and horse farms, with minor uses of alfalfa hay “for small ruminants (sheep, goats), alfalfa meal for processed feeds, and alfalfa pellets for pets and rabbits.” Of these, dairy farms are “by far” the main consumer. Klonsky et al. (2007) estimate dairy farms to absorb between 75%-85% of alfalfa hay in California, with another 10%-15% destined to horses and 5%-10% to beef.

One indication of the role of dairy farms on alfalfa hay consumption can be found by multiplying the number of dairy cows in the United States by an estimate of alfalfa hay intake. If we follow Hoyt (2001) and estimate an intake of 15 pounds of alfalfa hay per day per dairy cow, another 7 pounds a day for milk replacement heifers and another 3 pounds a day for dairy heifers under 500 pounds, and assume the proportion between milk cows, milk replacement heifers and heifers under 500 pounds is roughly 4:2:1, we have an estimated consumption of alfalfa hay for dairy of approximately 177 million pounds per day or 32.8 million tons a year:

9.2 million milk cows in 2007 (USDA ERS, 2008) x 15 lb = 138 million lb

4.6 million replacement heifers x 7 lb = 32.2 million lb

3.2 million heifers under 500 pounds x 3 lb = 9.6 million lb.

<sup>70</sup> Assuming the accumulation of stored alfalfa hay over time is zero.

Total: 179.8 million lb/day or 65,627 million lb/year or 32.8 million tons (short)/year  
This corresponds to roughly 46% of the domestic market estimated at 71.8 million tons in 2007 (72.6 million tons produced, minus exports, plus imports)<sup>71</sup>. These data suggest that the share of alfalfa hay demand deriving from non-dairy sources (beef production, horse care, and secondary processing into meal and pellets) is larger nation-wide than in California, the top dairy-producing state in the US (California Department of Food and Agriculture 2005).

The quality of alfalfa hay is guided by the low presence of weeds, by relatively low content of fiber and high content of protein, and other factors such as color and presence of mold (Klonsky et al, 2007). Categories are classified in different ways. USDA's Agricultural Marketing Service uses the grades of supreme, premium, good, fair and utility to regularly report average prices in various states. They describe each grade as follows:

- Supreme: Very early maturity, pre bloom, soft fine stemmed, extra leafy. Factors indicative of very high nutritive content. Hay is excellent color and free of damage
- Premium: Early maturity, i.e., pre-bloom in legumes and pre head in grass hays, extra leafy and fine stemmed-factors indicative of a high nutritive content. Hay is green and free of damage.
- Good: Early to average maturity, i.e., early to mid-bloom in legumes and early head in grass hays, leafy, fine to medium stemmed, free of damage other than slight discoloration.
- Fair: Late maturity, i.e., mid to late-bloom in legumes, head-in grass hays, moderate or below leaf content, and generally coarse stemmed. Hay may show light damage.
- Utility: Hay in very late maturity, such as mature seed pods in legumes or mature head in grass hays, coarse stemmed. This category could include hay discounted due to excessive damage and heavy weed content or mold. Defects will be identified in market reports when using this category. (USDA AMS, 2008)

Other sources note that alfalfa hay quality grades differ to some degree from state to state (McWilliams et al. (2005), or speak of high quality alfalfa as being “dairy-quality” (Klonsky et al, 2007). According to Klonsky et al (2007), there is no clear cut classification for alfalfa hay quality.

*Hay quality guidelines are published by USDA Hay Market News, but quality factors are generally loosely decided by industry habit and practice, and can be freely modified by individual buyers and sellers, depending on their needs and the realities of the market.*

Dairy cattle and horses both tend to have high forage quality requirements (Van Deynze et al. 2004). Most weeds are lower in forage quality or palatability than alfalfa, and forage with high weed content can adversely affect milk production as well as animal growth and health (Van Deynze et al. 2004). Forage quality requirements for sheep and goats are not as rigorous. Beef producers in particular, facing relatively low margins, are apparently a market for lower quality (and cheaper) alfalfa (Klonsky et al, 2007).

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<sup>71</sup> Production data from USDA ERS, 2007. Trade data from USDA FAS (online searchable database). Trade data is available in metric tons, transformed to short tons by multiplying by 1.10231.

Some states provide data on prices of different hay qualities. Table S-2 below shows some of the price differences expected of different hay qualities in some areas of California. The table also illustrates differences in prices depending upon location. As shown, prices can vary by more than 50 percent depending on quality and location. Distinctive regional alfalfa markets likely reflect the importance of transportation costs in limiting the trucking of relatively high volume, low value alfalfa hay across longer distances.

**Table S-2. Price Differences of Hay Qualities, 10-Year Average, 1997-2006**

| Region                           | Hay Quality Category |         |        |        |
|----------------------------------|----------------------|---------|--------|--------|
|                                  | Supreme              | Premium | Good   | Fair   |
| <b>Southern California</b>       |                      |         |        |        |
| <i>Imperial Valley</i>           | 121                  | 115.24  | 100.29 | 86.35  |
| <i>Blythe/Parker</i>             | 120.14               | 114.52  | 99.38  | 82.56  |
| <i>Chino/LA</i>                  | 148.37               | 140.34  | 125.65 | 110.74 |
| <i>Mojave Desert</i>             | 129.11               | 123.01  | 111.86 | 93.52  |
| <b>San Joaquin Valley</b>        |                      |         |        |        |
| <i>Kern County</i>               | 139.45               | 128.07  | 110.01 | 92.57  |
| <i>Tulare/ Visalia/ Hanford</i>  | 163.54               | 149.42  | 129.83 | 109.13 |
| <i>Hanford/ Corcoran/ Tulare</i> | 146.25               | 132.62  | 113.75 | 94.08  |
| <i>Fresno/ Madera Counties</i>   | 145.24               | 129.77  | 108.48 | 92.27  |
| <i>Los Banos/ Dos Palos</i>      | 147.24               | 136.66  | 116.92 | 96.98  |
| <i>Escalon/ Modesto/ Turlock</i> | 161.69               | 148.94  | 130.23 | 109.20 |

Source: Klonsky et al. (2007)

### 2.1.2 Domestic Demand for Alfalfa Seed

The demand for alfalfa seed derives from the demand for establishing new stands of alfalfa hay, and to a much lesser extent from the demand for alfalfa products destined for human consumption. As in the case of alfalfa hay, the domestic alfalfa seed market can be estimated based on available data for production, exports and imports. The last year for which complete data is available is 2007, the year of the last Census of Agriculture.

**Table S-3. Domestic Alfalfa Seed Market (US \$1,000)**

|             | 2007   | 2002   | 1997    |
|-------------|--------|--------|---------|
| Production  | 93,173 | 66,724 | 104,492 |
| Exports     | 66,094 | 25,963 | 50,372  |
| Imports     | 36,363 | 10,864 | 14,521  |
| Consumption | 63,442 | 51,625 | 68,641  |

Sources: Production data from USDA Census of Agriculture (2007, 2002, 1997); Trade data from USDA Foreign Agricultural Service (FAS); Consumption calculated as production – exports + imports, and assuming change in alfalfa inventories is zero.

Table S-3 suggests the domestic demand for alfalfa seeds in 2007 was approximately US\$ 63 million, up from US\$ 52 million in 1997. Imports represented some 64% of domestic demand, although it is possible that some of these imports were re-exported.

### *2.1.3 Domestic Demand for Alfalfa for Human Consumption*

Some alfalfa seed is used to produce sprouts for human consumption. Seed for sprouting is produced throughout the world, but the major suppliers are in the US, Canada, and Australia. Approximately 80 million pounds of alfalfa seed are produced each year in the United States. 85% of that is produced in five western states – California, Idaho, Oregon, Washington, and Nevada. The balance is from Arizona, Utah, Montana, Wyoming, and other states. The primary market for that seed is planting stock to produce forages to support the livestock industry in the United States and throughout the world. Only a small fraction of the seed produced is used for sprouting (Mueller, Undated).

There does not appear to be any publicly available sales data for alfalfa sprouts. In testimony given in a public meeting convened by the United States Department of Health and Human Services' Food and Drug Administration (1998), sprout industry expert Dr. Earl Hauserman noted that as of 1998 there were about 350 sprouters in the US. He noted that green sprouts (alfalfa, broccoli, clover, mustard, onion, radish, sunflower, and other sprouts) amount to about \$80 million a year in sales. Hauserman also stated that alfalfa sprouts account for about 75-80% of the green sprout market, or \$60-\$64 million in annual sales. Hauserman stated that U.S. sprouters utilize approximately 125,000 to 150,000 pounds of alfalfa seed a month to produce about five to six million four ounce packages a month. On an annualized basis, Hauserman's testimony would imply that 1998 alfalfa sprouters purchased 1.5-1.8 million alfalfa seeds, and produced 15-18 million pounds of alfalfa sprouts. Hauserman estimated that between five and 10 percent of US residents consume sprouts of various kinds.

Dehydrated alfalfa leaf is commercially available as a dietary supplement in several forms, such as tablets, powders and tea. Alfalfa is also believed by some to be useful as an herbal or homeopathic medicine (Foster and Johnson 2006). Once again there does not appear to be any publicly available sales data for alfalfa produced for dietary supplements, herbal remedies, or homeopathic medicines. Nelson (2008) reports an estimate that the total US alfalfa supplement market could be satisfied with 10 tons of alfalfa hay production, which could be produced on 1-2 acres.

### *2.1.4 Domestic Demand for Organic Alfalfa for Forage*

As in the case of non-organic alfalfa for forage, organic alfalfa also faces a derived demand, mainly from the demand for organic dairy and beef (Butler 2002). The higher price of organic hay (described later in this section) will generally deter conventional livestock producers from using organic alfalfa when it is not necessary to do so.

To be sold as organic in the United States, alfalfa hay must meet standards established by the Organic Foods Production Act of 1990 and the National Organic Program (NOP) that became effective in 2001. According to these standards, to be sold as organic, dairy and meat products must come from dairy cows and livestock fed 100% with organic feed, with the exception of vitamin and mineral supplements (USDA NOP 2008). NOP standards also state that dairy animals must be managed organically for at least 12 months in order for milk or dairy products to be sold, labeled or represented as organic. Dairy producers may use land that is transitioning during its third year of transition to organic certification to provide crops and forage for dairy

animals during this 12-month period prior to the sale of dairy products as organic (USDA NOP 2008).

Information on organic alfalfa hay acreage is available from USDA Economic Research Service for 2005 (we cover this in section 3 on alfalfa supply). However, we found no publicly available information on trade in organic alfalfa, making estimates of domestic demand impossible. If domestic demand for organic alfalfa follows the same trend of organic alfalfa hay production, it is a growing demand. As shown in section 3, organic alfalfa hay represented in 2005 0.92% of total alfalfa hay harvested acreage, up from 0.51% in 2000.

There is likely a GE sensitive segment of the market for most organic products. The first version of the National Organic Program published by the USDA in 1997 did not exclude GE organisms. After the over 270,000 comments received to this first version, this was one of the main aspects changed (Hubbard, 2006), even though there are not set tolerance levels for the presence of unintended genetically engineered material (the organic certification standard focuses on the process rather than the product). We found no information on the possible size of the GE sensitive segment of the market for organic products in the United States. We will argue further below, however, that opposition to genetic engineering within the organic market may not translate to reduced demand in the case of alfalfa hay.

Prices and quality requirements are significantly different between organic and non-organic alfalfa hay. In its *Organic Alfalfa Hay* report, the University of California found that prices for organic alfalfa hay will vary depending on season, the market, and quality, but will be approximately 20 percent greater than prices for conventional hay (Long et al., 2007).

Table S-4 shows how prices differ between organic and conventional alfalfa hay in Escalon, Modesto, and Turlock counties in California in 2007. The average premium reported in this particular data set is slightly greater than 20 percent.

**Table S-4. Prices for Organic and Conventional Alfalfa Hay; Escalon, Modesto, Turlock, California 2007**

|                                          | JUL    | AUG    | SEP    | OCT    | NOV    | DEC    | AVG (year) |
|------------------------------------------|--------|--------|--------|--------|--------|--------|------------|
| <b>Alfalfa (Organic) Domestic Cattle</b> |        |        |        |        |        |        |            |
| Supreme                                  | 235.00 | 245.00 |        |        |        |        | 238.33     |
| Premium                                  | 239.17 | 235.00 | 251.33 | 244.51 |        | 277.00 | 242.96     |
| Good                                     | 210.00 | 233.40 | 234.86 |        |        |        | 229.06     |
| <b>Alfalfa Domestic Cattle</b>           |        |        |        |        |        |        |            |
| Supreme                                  | 207.36 | 210.83 | 216.13 | 218.60 | 225.00 | 232.74 | 205.22     |
| Premium                                  | 197.47 | 200.10 | 201.19 | 213.61 | 230.00 |        | 193.85     |
| Good                                     | 179.05 | 190.68 | 195.48 | 201.02 | 202.93 | 214.51 | 182.86     |
| <b>Difference</b>                        |        |        |        |        |        |        |            |
| Supreme                                  | 27.64  | 34.17  |        |        |        |        | 33.11      |
| Premium                                  | 41.70  | 34.90  | 50.14  | 30.90  |        |        | 49.11      |
| Good                                     | 30.95  | 42.72  | 39.38  |        |        |        | 46.20      |

Source: USDA, AMS (2007)

### *2.1.5 Domestic Demand for Organic Alfalfa Seeds*

Demand for organic alfalfa seeds derives from the demand for organic alfalfa hay, as the NOP requires the use of organic seeds to establish organic alfalfa stands (CFR Title 7, §205.204). However, an exception is made to the requirement of using organic seeds in cases where these are not available<sup>72</sup>. In these cases, untreated conventional seeds or seeds treated with substances included in the National List of synthetic substances allowed for use in organic crop production are typically allowed.

We were not able to estimate the demand for organic alfalfa seed, due to the lack of data on production of organic alfalfa seed as well on organic seed trade. It is possible that the fact that non-organic seeds are allowed for the production of organic alfalfa hay has reduced the demand of organic alfalfa seed and incentives for production.

However, some demand is likely to exist and it may be currently supplied by either domestic or imported production (imported seeds were in 2002 approximately 21% of domestic consumption, in 2007, imported seed were 64% of domestic consumption). The Organic Materials Review Institute (OMRI), a nonprofit managed by the organic industry that self-regulates allowed substances in organic production, reports three suppliers of organic alfalfa seed for forage in its seed database (<http://seeds.omri.org/index.php?dosearch=1&terms=alfalfa&submit=Go>). Some of this seed is imported from Canada.

Baker (2008) notes that the main reason reported by organic certifiers to accept farmers claims that organic seeds are not available is the claim that available seeds are not “equivalent” to non-organic available seeds in their desired qualities. When asked what crop was most claimed to not have available organic seeds, certifiers identified alfalfa. This may be an indication of an unfulfilled demand that, given the growth rates in organic alfalfa seed production, is likely to stimulate the development of “equivalent” organic varieties that may now not be available. The supply to satisfy this demand may come from domestic or foreign sources.

### *2.1.6 Domestic Demand for Organic Alfalfa for Human Consumption*

As noted in section 2.1.3 above, some alfalfa seed is used to produce sprouts for human consumption. Seed for sprouting is produced throughout the world, but the major suppliers are in the US, Canada, and Australia. The primary market for alfalfa seed, however, is planting stock to produce forages to support the livestock industry in the US and throughout the world. Only a small fraction of the seed produced is used for sprouting (Mueller, undated). There does not appear to be any publicly available sales data for organic alfalfa sprouts. Using data drawn from the US Department of Health and Human Services’ Food and Drug Administration (1998), it is estimated in section 3.1.3 that 1998 alfalfa sprouters purchased 1.5-1.8 million alfalfa seeds, and produced 15-18 million pounds of alfalfa sprouts. Presumably organic sprout production in 1998 was some fraction of total sprout production.

As noted in section 2.1.3 above, dehydrated alfalfa leaf is commercially available as a dietary supplement in several forms, such as tablets, powders and tea. Alfalfa is also believed by some

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<sup>72</sup> This exception is not made for production of organic edible sprouts.

to be useful as an herbal or homeopathic medicine (Foster and Johnson 2006). Once again there does not appear to be any publicly available sales data for alfalfa produced for dietary supplements, herbal remedies, or homeopathic medicines. Nelson (2008) reports an estimate that the total US alfalfa supplement market could be satisfied with 10 tons of alfalfa hay production, which could be produced on 1-2 acres.

## 2.2 Impact of GT Alfalfa Deregulation

### 2.2.1 *Shifts in Demand*

The quantity of alfalfa hay demanded depends on its price and quality. Quality is mostly influenced by the presence of weeds. The impact of GT alfalfa deregulation on price (and quantities) will be the result of its impact on the remaining determinants of demand and supply. We focus here on the possible impact of GT alfalfa deregulation on the demand for alfalfa hay quality and leave the joint analysis of supply and demand impacts on prices and quantities for section 4.

The main possible impact of GT alfalfa deregulation on the domestic demand for alfalfa hay, conventional or organic, depends on the existence of a GE sensitive market among domestic consumers of alfalfa hay. If GT alfalfa is seen as an undesirable quality of alfalfa hay by some, these consumers will seek to substitute their purchases by: a) seeking imported non-GT alfalfa hay; b) seeking some form of GE-free certification; c) using GE-free hay based on other crops. In the case of GE sensitive consumers of conventional alfalfa hay, a fourth alternative would be to shift to organic alfalfa hay, or to certified conventional seeds that are able to guarantee that any presence of GT alfalfa is kept below certain levels.

In the case of alfalfa seed production, the impact of GT alfalfa deregulation on domestic demand will depend mainly on the impact of GT alfalfa deregulation on the demand for alfalfa for hay, since this is by far its main use.

Throughout our analysis of potential shifts in demand, we assume that presence of non-GT alfalfa occurs or is perceived to occur at a level considered relevant by the markets analyzed. If there is no presence or perception of presence of conventional and organic alfalfa by GT alfalfa, there is no impact on demand.

As demand for alfalfa hay is a derived demand from that for dairy, meat and other animal products, we first summarize the results of our analysis on the impact of GT deregulation on the demand for those products in downstream markets. This analysis is done in our Technical Report *Downstream Effects to Organic Production and Marketing of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix T).

### 2.2.2 *Impact on Downstream Demand*

In the above mentioned report, we analyze the impact of GT alfalfa deregulation on the demand for dairy, meat and other animal products, since alfalfa hay is used as an input in the production



of these products, as well as in the production of nutritional supplements for human consumption, in minor quantities.

The conclusions reached are summarized below.

In the case of downstream demand for conventional products:

- There is an ongoing trend of slow to moderate growth in demand for dairy products, driven mostly by population growth.
- In surveys, U.S. consumers often suggest a preference for non-GE foods;
- There is no evidence that any GE material in animal feed currently in use is actually transmitted to milk or meat;
- U.S. consumers show relatively little knowledge of their own consumption of GE products;
- Product labels in the United States typically do not indicate presence or lack of GE material;
- Other GE crops (e.g., corn, soybeans, canola) have been deregulated in the US for a number of years with no substantial drop in demand for conventionally produced dairy products or meat;

In the review done in our Technical Report *Downstream Effects to Organic Production and Marketing of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix T), we found no evidence to suggest that downstream domestic demand for conventional products is likely to be affected by GT alfalfa deregulation. Existence of a preference for GE-free products manifested in surveys may not translate to actual demand for various reasons, from the lack of GE presence in dairy and meat, to the lack of consumer information regarding GE presence in products consumed, to price differentials between non-GE and GE products.

In the case of downstream organic products we found that organic dairy represents nearly 90 percent of the total sales value of the combined US organic dairy and meat market in 2006. Thus, the dairy market is likely to be a more important downstream market for organic hay than is conventional dairy for conventional hay.

The establishment process of current U.S. standards for organic certification suggests a preference from organic consumers for non-GE products. However:

- Current organic standards do not allow for intentional use of GE feed, so any presence of GE traits in alfalfa used for feed in organic dairy or meat farms would be unintended;
- There is no evidence that any GE material in animal feed currently in use is actually transmitted to milk or meat;
- Consumer preferences for organic over GE foods are influenced in part by ethical and environmental factors that are likely unrelated to unintended presence of feed crops with GE material;

We found no evidence to suggest domestic consumers of organic dairy and meat would shift to substitute products in the event of possible unintended presence of GT alfalfa in feed for dairy and meat.

The above results must be interpreted with care. The absence of any indication of potential negative impacts of GT alfalfa deregulation on the domestic demand for downstream products does not mean that consumers or producers were not negatively impacted, but rather that shifts in domestic demand may not occur and sales of organic alfalfa may not be affected. We analyze other potential impacts in section 4.3.

### *2.2.3 Impact on Conventional Alfalfa Hay and Seed Domestic Demand*

Based on the findings summarized in section 2.2.2 above, we expect no to minor reductions in the demand for conventional alfalfa hay *that derive from no to minor declines in the demand for conventional dairy, meat, eggs, and other animal products*. Due to the minor nature of any negative impact, it is more likely to manifest as a slowing of domestic demand growth, if at all.

As noted in section 2.1.2 above, the demand for alfalfa seed derives from the demand for establishing new stands of alfalfa hay, and to a much lesser extent from the demand for alfalfa products destined for human consumption. It is reasonable to conclude that there will be no substantial impact on domestic conventional alfalfa seed demand *that is derived from shifts in demand for alfalfa for forage*.

There will, however, be shifts in demand for conventional alfalfa seed and conventional alfalfa hay induced by shifts in supply of high quality hay. This will be analyzed further below when we consider the impact of GT alfalfa deregulation on supply.

### *2.2.4 Impact on Organic Alfalfa Hay and Seed Domestic Demand*

To the extent that the demand for organic alfalfa hay is a derived demand, mainly from the demand for organic dairy, we found no evidence to suggest the demand for organic alfalfa hay will decrease with deregulation of GT alfalfa, *as a consequence of shifts in demand for organic downstream products*.

Given the disproportionately large share of organic dairy in the derived demand for organic alfalfa and the importance of alfalfa hay in dairy production it seems reasonable to expect that the demand for organic alfalfa hay will continue growing at a considerable pace, accompanying the growth in the demand for organic dairy.

There are, however, some possibilities of shifts up or down of the domestic demand of organic alfalfa hay. Given that the choice to produce organic products may not only be guided by market incentives but also by personal views of farmers, it is possible that some share of organic farmers may chose to abandon organic production if they feel that GE material has occurred in their seed or hay, or may potentially occur at levels they consider unacceptable. In this case, the demand for organic alfalfa hay would shift downwards. On the other hand, if there is any domestic GE

sensitive market for conventional alfalfa, GT alfalfa deregulation could lead consumers in this market to shift to organic alfalfa (as argued in 1.1.1). This would shift the demand curve upwards. As long as economic incentives prevail in the choice of producing alfalfa organically or not and as long as the GE sensitive domestic market among conventional alfalfa is small, neither of these possibilities should considerably alter the growth trend of the demand for organic alfalfa hay. As in the case of conventional alfalfa, there will likely be some shifts in demand caused by shifts in supply of conventional high quality alfalfa hay. We address this shift in section 3.

As previously noted, the demand for organic alfalfa seeds derives from the demand for organic alfalfa hay. Although the NOP requires the use of organic seeds to establish organic alfalfa stands, it is apparently common to use conventional seeds, given the often lack of organically grown seeds available. In this case, as the organic market is small relative to the conventional market, the impact of shifts in demand in the organic hay market will be likely little to non perceptible in the market for conventional seeds.

The potentially existing unfulfilled demand for organic alfalfa seed may be reinforced by GT alfalfa deregulation and may translate into greater pressure for the growth of organic varieties considered “equivalent” to the presently used conventional ones.

## 2.3 Summary of Findings

The domestic market for alfalfa hay was estimated to be approximately US\$ 8.8 billion in 2007. The domestic market for alfalfa seed was roughly US\$ 63 million in 2007. Alfalfa demand is a derived demand from that for dairy, meat, pet care and human consumption. Some sources indicate dairy is by far the main source of demand for alfalfa. We estimated dairy to be responsible for approximately half of the domestic demand, with meat production presumably consuming much of the rest. The demand for organic alfalfa seems to rely more heavily on dairy. While most of the seed used in organic alfalfa hay production is likely not organically produced, demand for organic alfalfa seeds, whether domestically produced or imported, is likely to grow in the near future.

We found no evidence that consumer sensitivity to GE products may translate into reduced demand for conventional or organic alfalfa hay with GT alfalfa deregulation. Pressure for organic or non-GE certification of alfalfa seeds for organic production may strengthen the current existing and potentially unfulfilled demand.

## 3.0 Impacts on Supply

### 3.1 Alfalfa Supply

In this section we focus on domestic production. Imports are more important for the domestic supply of alfalfa seed (imports have increased from 16% of domestic production in 1997 to 64% in 2007) than for alfalfa hay (0.1% of domestic production). Domestic production of hay is almost all destined to the domestic market, although the same cannot be said of seeds (roughly a third to a half are exported). We consider trade in our Impact on Trade Technical Report (appendix R).

#### 3.1.1 *Domestic Production of Alfalfa for Forage*

Production of alfalfa hay in the United States was in 2007 approximately 69.9 million tons, falling to 69.6 million tons in 2008 (USDA NASS, 2008b)<sup>73</sup>. This corresponds to almost half the production of hay in 2007 and 2008 (approximately 145 million tons for both years). Production statistics for haylage are not available for all states for 2007, but based on the 2002 and 2007 Agricultural Census and more recent USDA NASS data available for 18 states, haylage production adds another 10%-15% in alfalfa acres grown for forage.

Harvested acreage of alfalfa hay was in 2008 approximately 21 million acres (NASS, 2008b) for an average yield of 3.3 tons/ acre.

The alfalfa share of total hay production has been falling in the recent past, as has absolute production of alfalfa hay. In 2008 alfalfa production was at its lowest (69.6 million tons) compared to a high of 84.4 million tons in 1999.

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<sup>73</sup> Including alfalfa hay mixtures.

**Table S-5. Hay Production (1,000 tons)**

| <b>Year</b> | <b>Alfalfa Hay</b> | <b>Other hay</b> |
|-------------|--------------------|------------------|
| 1990        | 83,413.00          | 62,799.00        |
| 1991        | 83,319.00          | 68,754.00        |
| 1992        | 79,140.00          | 67,763.00        |
| 1993        | 80,115.00          | 66,584.00        |
| 1994        | 81,130.00          | 69,006.00        |
| 1995        | 84,138.00          | 70,101.00        |
| 1996        | 79,139.00          | 70,640.00        |
| 1997        | 78,535.00          | 74,001.00        |
| 1998        | 81,992.00          | 69,395.00        |
| 1999        | 84,405.00          | 75,177.00        |
| 2000        | 81,520.00          | 72,083.00        |
| 2001        | 80,354.00          | 76,062.00        |
| 2002        | 73,014.00          | 76,453.00        |
| 2003        | 76,273.00          | 81,312.00        |
| 2004        | 75,481.00          | 82,766.00        |
| 2005        | 76,149.00          | 74,868.00        |
| 2006        | 72,006.00          | 70,330.00        |
| 2007        | 72,575.00          | 77,729.00        |

Source: USDA ERS, 2007

Alfalfa farming has also declined in terms of harvested acres, from as much as almost 24 million acres in 1999 to less than 21 million acres in 2008.

**Table S-6. Alfalfa Hay Harvested Acreage (1,000 acres)**

|                | <b>1999</b> | <b>2000</b> | <b>2001</b> | <b>2002</b> | <b>2003</b> | <b>2004</b> | <b>2005</b> | <b>2006</b> | <b>2007</b> | <b>2008</b> |
|----------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| <b>Acreage</b> | 24,055      | 22,077      | 23,822      | 22,923      | 23,529      | 21,707      | 22,439      | 21,434      | 21,670      | 20,980      |

Source: USDA NASS, Various Years.

Regarding geographic distribution, although alfalfa hay is grown most everywhere across the United States, it is most concentrated in the Midwest and Northwestern States. South Dakota has consistently devoted the most acres to alfalfa hay, with as much as 3 million acres of alfalfa hay in 2001.

**Table S-7. Alfalfa Hay Harvested Acreage by State (1,000 Acres), 2007**

| State        |      | State        |     | State          |     |
|--------------|------|--------------|-----|----------------|-----|
| South Dakota | 2250 | Pennsylvania | 600 | Virginia       | 110 |
| Montana      | 1650 | Washington   | 440 | Maryland       | 40  |
| Wisconsin    | 1650 | Ohio         | 430 | Vermont        | 40  |
| North Dakota | 1650 | Oregon       | 400 | West Virginia  | 25  |
| Minnesota    | 1150 | New York     | 420 | Tennessee      | 25  |
| Nebraska     | 1150 | Missouri     | 400 | New Jersey     | 20  |
| Idaho        | 1200 | Oklahoma     | 380 | Arkansas       | 20  |
| Iowa         | 1140 | Illinois     | 380 | North Carolina | 9   |
| California   | 990  | Indiana      | 320 | Maine          | 9   |
| Kansas       | 800  | Kentucky     | 300 | Connecticut    | 8   |
| Michigan     | 800  | Nevada       | 265 | Massachusetts  | 7   |
| Colorado     | 800  | New Mexico   | 260 | New Hampshire  | 6   |
| Wyoming      | 570  | Arizona      | 250 | Delaware       | 5   |
| Utah         | 560  | Texas        | 140 | Rhode Island   | 1   |

Source: USDA NASS, 2008b

In terms of value of production, California has been the largest producer, thanks to high yields and over-average prices.

**Table S-8. Alfalfa Hay Production by State, 2007**

| State        | Harvested Acres | Yield (tons) | Production (tons) | Price per Unit (/ton) | Value of Production |
|--------------|-----------------|--------------|-------------------|-----------------------|---------------------|
| California   | 990,000         | 7.2          | 7,128,000         | 163                   | 1,161,864,000       |
| Idaho        | 1,200,000       | 4            | 4,800,000         | 141                   | 676,800,000         |
| Iowa         | 1,140,000       | 4.2          | 4,788,000         | 111                   | 531,468,000         |
| South Dakota | 2,250,000       | 2.25         | 5,063,000         | 98.5                  | 498,706,000         |
| Minnesota    | 1,150,000       | 3.1          | 3,565,000         | 115                   | 409,975,000         |
| Colorado     | 800,000         | 3.7          | 2,960,000         | 138                   | 408,480,000         |
| Nebraska     | 1,150,000       | 3.65         | 4,198,000         | 91.5                  | 348,117,000         |
| Washington   | 440,000         | 5.4          | 2,376,000         | 144                   | 342,144,000         |
| Pennsylvania | 600,000         | 3            | 1,800,000         | 180                   | 324,000,000         |
| Utah         | 560,000         | 4.2          | 2,352,000         | 131                   | 308,112,000         |
| Kansas       | 800,000         | 3.5          | 2,800,000         | 112                   | 313,600,000         |
| Arizona      | 250,000         | 8.3          | 2,075,000         | 148                   | 307,100,000         |
| Nevada       | 265,000         | 4.9          | 1,299,000         | 144                   | 187,056,000         |

Sources: columns 2-4 from USDA NASS, 2008b; columns 5-6 from USDA NASS 2008a.

Table S-9 shows the number of farms and tons of output broken down by alfalfa hay acreage and table S-10 shows the share of the total number of farms and tons of alfalfa hay for each group.

**Table S-9. Farms per Acreage Size of Farm**

| <b>Alfalfa acreage</b> | <b>Number of farms</b> | <b>Production (tons)</b> |
|------------------------|------------------------|--------------------------|
| 1-14.9                 | 92,193                 | 1,719,486                |
| 15-99.9                | 148,668                | 17,079,793               |
| 100-999.9              | 48,331                 | 35,723,978               |
| >1,000                 | 1,534                  | 10,825,845               |

Source: Census of Agriculture, 2007

**Table S-10. Share of Farms/Production per Acreage Size of Farm**

| <b>Alfalfa acreage</b> | <b>Percentage of farms</b> | <b>Percentage of Production</b> |
|------------------------|----------------------------|---------------------------------|
| 1-14.9                 | 31.71%                     | 2.63%                           |
| 15-99.9                | 51.14%                     | 26.14%                          |
| 100-999.9              | 16.62%                     | 54.67%                          |
| >1,000                 | 0.53%                      | 16.57%                          |

Source: Census of Agriculture, 2007

Approximately 83% of farms grew less than 100 acres of alfalfa hay and less than 18 percent of the farms accounted for 71 percent of the alfalfa production in 2007. Many farms may grow relatively small plots of alfalfa as an input for dairy or other farm industries, particularly for own consumption.

Intermediation between alfalfa hay growers and dairy farms seems to be done largely by individual brokers (often the hay or dairy farmers themselves) or by farmer associations, at least in California (Klonsky et al, 2007)

### *3.1.2 Domestic Production of Alfalfa Seed*

The latest complete information on alfalfa seed production comes from the 2002 Census of Agriculture. In 2007, approximately 62 million tons of alfalfa seeds were produced, compared to almost 58 million tons from the previous Census in 2002. Table S-11 below shows how this reflected largely an increase in acreage of harvested alfalfa for seeds.

**Table S-11. Alfalfa Seed Production and Acreage**

|                   | <b>2007</b> | <b>2002</b> |
|-------------------|-------------|-------------|
| Production (tons) | 62,115,239  | 58,020,460  |
| Acreage           | 121,467     | 110,617     |

Source: Census of Agriculture, 2007, 2002.

More frequent data is available for some states who report voluntarily to the NASS.

**Table S-12. Alfalfa Seed Acreage by State (1,000)**

|      | California | Idaho | Montana | Nevada | Washington | Wyoming |
|------|------------|-------|---------|--------|------------|---------|
| 2007 |            | 15    | 12      |        |            |         |
| 2006 | 36         | 15    | 11      |        | 14         | 6       |
| 2005 |            | 16    | 6       |        | 13         | 6       |
| 2004 | 32         | 22    | 6       | 5      | 13         | 4       |
| 2003 | 26         | 15    | 6       | 5      | 13         | 2       |
| 2002 | 26         | 18    | 7       | 6      | 14         | 4       |
| 2001 | 39         | 27    | 9       | 10     | 15         | 7       |
| 2000 | 75         | 46    | 19      | 14     | 17         |         |
| 1999 | 100        |       | 20      | 13     | 19         |         |
| 1998 | 67         | 39    | 18      | 13     | 18         |         |
| 1997 | 49         | 39    | 14      | 12     | 13         |         |
| 1996 | 46         | 33    | 12      | 13     | 13         |         |
| 1995 | 44         | 35    | 12      | 12     | 15         |         |

Source: USDA NASS, 2005, 2006, 2007. Numbers are rounded.

This data also show a fall in acreage dedicated to alfalfa seeds until 2002-2004 with some recovery in some states in recent years.

Mueller (2008) attributes recent reduction in alfalfa seed acreage in California to “changes in economics, environmental constraints, and regulatory issues.” Mueller (Undated a) lists among difficulties of alfalfa seed farming in California scarcity of water for crop irrigation and lack of development of new chemicals for insect control due to high registration costs

Production of seeds is largely concentrated in the Northwest. The top eight producing states are from that region.

**Table S-13. Alfalfa Seed Production by State (1,000 tons)**

|            | 2007   |                   | 2002   |                   |
|------------|--------|-------------------|--------|-------------------|
|            | Acres  | Production (tons) | Acres  | Production (tons) |
| California | 36,625 | 19,083,458        | 27,160 | 15,543,144        |
| Washington | 17,127 | 10,860,608        | 14,161 | 11,887,387        |
| Idaho      | 12,788 | 9,346,709         | 17,126 | 13,910,135        |
| Wyoming    | 10,548 | 5,915,816         | 4,049  | 2,400,315         |
| Nevada     | 6,498  | 4,237,101         | (D)    | 4,695,737         |
| Montana    | 10,338 | 3,729,635         | 6,824  | 2,024,033         |
| Oregon     | 4,959  | 3,183,375         | 5,605  | 3,783,887         |
| Utah       | 3,803  | 2,077,813         | 2,596  | 830,889           |
| Arizona    | 5,206  | 1,902,669         | 2511   | 574020            |

Source: Census of Agriculture, 2007, 2002.

Mueller (Undated a) suggests California’s share of production has fallen in recent years and a larger share is coming from the Northwestern states. In 2007, US production of alfalfa seed came from 806 farms, about 70% from farms with over 250 acres of alfalfa seeds and 90% from farms with over 100 acres of alfalfa seeds.



Alfalfa seed constitutes a small portion of total alfalfa production in all of these states, though it appears to be more significant in California and Washington, making up between 3 and 7 percent of total alfalfa acreage from 2000-2007.

### 3.1.3 Domestic Production of Organic Alfalfa for Forage

There are no publicly available sources of data on US organic alfalfa production, so an estimate is derived here for illustrative purposes only. The USDA ERS reports that there were 411,342 acres on which organic hay (all types) was produced in 2005. According to the USDA NASS, 61,729,000 acres were in hay (all types) in 2005, of which 22,439,000 acres were in alfalfa hay in 2005. Thus alfalfa hay acreage is 36.35 percent of total hay acreage in 2005. In 2005 the national average yield per acre for alfalfa was 3.39 tons.

If we assume that the proportion of alfalfa hay to total hay acreage is the same for organic as for conventional, then we can estimate that  $411,342 \times 0.3635 = 149,526.2$  acres were in organic alfalfa hay in the US in 2005. Based on differences in organic and conventional alfalfa yield from Long et al. (2007), we get total US organic hay production in 2005 of  $149,526.2 \times 3.39 \times 0.875 = 443,532.1$  tons. By way of comparison, if instead one assumes that two-thirds of all organic hay is alfalfa (perhaps driven by demand from organic dairies requiring alfalfa rather than grass or some other type of hay), then we get total US organic hay production in 2005 of  $274,242 \times 3.39 \times 0.875 = 813,470$  tons. Based on these estimates, organic alfalfa hay production tonnage in 2005 may represent between 0.58% and 1.07% of total alfalfa production. These estimates are rough, however, and should only be used for illustrative purposes.

In terms of acreage, the number of acres devoted to growing organic alfalfa hay increased every year between 2000 and 2005, except for 2003. The share of all alfalfa hay acres that grew organic hay increased from 0.51 percent in 2000 to 0.92 percent in 2005.

**Table S-14. Organic Alfalfa Hay Harvested Acreage**

|                               | 2000    | 2001    | 2002    | 2003    | 2004    | 2005    |
|-------------------------------|---------|---------|---------|---------|---------|---------|
| <b>Acreage</b>                | 113,157 | 116,608 | 155,437 | 135,717 | 175,260 | 204,380 |
| <b>Share of Total Acreage</b> | .51%    | .49%    | .67%    | .58%    | .81%    | .92%    |

Source: USDA ERS, 2005; USDA NASS, 2007

Organic alfalfa hay production is distributed geographically similarly to conventional hay. However, production of organic alfalfa hay is more significant in proportion in some states than others. In 2005, for example, of all alfalfa hay acreage in Idaho, more than 4 percent was organic, compared to a national proportion of .92 percent.

**Table S-15. Geographic Distribution of Organic Alfalfa Hay Acreage (2005)**

| State        | Organic Acreage |
|--------------|-----------------|
| Idaho        | 49,497          |
| Wisconsin    | 29,389          |
| Minnesota    | 21,339          |
| North Dakota | 20,614          |
| South Dakota | 13,930          |
| California   | 13,246          |
| Iowa         | 9,193           |

|          |       |
|----------|-------|
| Colorado | 8,943 |
| Nebraska | 8,192 |
| Oregon   | 6,592 |

Source: USDA ERS, 2005

Organic alfalfa also seems to be grown in pockets, with 72 percent of organic acreage being found in just six states: Idaho, Wisconsin, Minnesota, North Dakota, South Dakota, and California (these six states only account for about 41 percent of total acreage).

### 3.1.4 Domestic Production of Organic Alfalfa Seed

There are no publicly available sources of data on US organic alfalfa seed production. To the extent that conventional alfalfa seeds are used in organic production (NOP permits in the lack of available organic seeds) a rough estimate of the production of seeds for the organic market follows. In section 3.1.3 it was estimated that US organic hay production in 2005 may range between 0.58% and 1.07% of total alfalfa hay production. If stand establishment demand for organic alfalfa seed (expressed as a percentage of total alfalfa seed demand from section 2.1.2) is roughly in the same proportion, then U.S. consumption of alfalfa seed for organic production in 2002 would range between \$300,700 and \$551,500. These demand estimates are rough and should only be used for illustrative purposes.

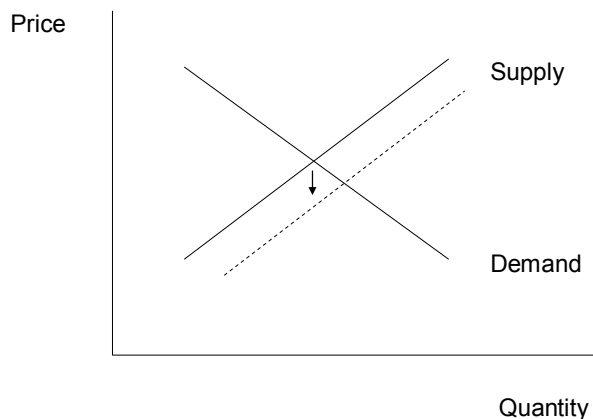
In section 2 we suggested that the production of organic alfalfa seeds may lag behind demand. This may be due to difficulties in producing organically the preferred varieties for organic alfalfa hay production, given the evidence we previously presented on complaints of non-availability of organic alfalfa seeds “equivalent” to the conventional ones used.

## 3.2 Impacts of GT Deregulation

### 3.2.1 Shifts in Supply

GT alfalfa deregulation will introduce a new cultivar that will compete with others in the conventional alfalfa seed and forage markets. As the main economic characteristics of the GT alfalfa cultivar are its reduced use of herbicide with potentially improved quality of alfalfa forage (reviewed in Technical Report *Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa* in appendix K) GT alfalfa will likely compete with the high quality alfalfa forage market. The domestic supply of conventional alfalfa for forage and conventional alfalfa seeds in the domestic market will then be impacted by GT alfalfa deregulation to the extent that the availability of GT alfalfa changes costs and returns to alfalfa farmers that choose to plant GT alfalfa.

The overall impact of the introduction of GT alfalfa in the market will be a shift downwards in the supply of alfalfa. This shift is caused by the reduction in average costs necessary to produce alfalfa of a given quality. This is represented in figure S-5 below and would imply a decrease in prices and increase in quantity of alfalfa sold, as dairy and meat farmers substitute alfalfa for other feeds.



**Figure S-5: Overall impact on supply of introduction of GT alfalfa**

Within the alfalfa market, however, there are segments: conventional and organic, domestic and international, high and low quality alfalfa and possibly GE sensitive and non-GE sensitive. The impact of GT deregulation on each of these segments will not be the same. There are two main possible sources of shifts in supply introduced by GT alfalfa deregulation:

- 1) Changes in production costs for those adopting GT alfalfa
- 2) Changes in production costs for those not adopting GT alfalfa and that are associated with presence of GT alfalfa material in non-GT alfalfa (cross-contamination or gene flow).

The supply of organic alfalfa hay and organic alfalfa seeds will not be directly affected by changes in cultivar adoption. Organic alfalfa growers cannot adopt GT alfalfa because GE crops may not be certified as organic. Organic certification may also not be affected given that presence of GE material is tolerated by organic certification that presently does not test for GE material and focuses on process rather than on product. However, to the extent that conventional and organic alfalfa are substitutes, a decrease in the price of conventional alfalfa will affect the demand of organic alfalfa.

Shifts in domestic production may or may not be partially offset by imports. We leave any analysis of impacts on imports for another report and assume for now that there is no change in imports of alfalfa.

Throughout this section we do not analyze shifts in demand, but assume there is some demand for GE-free alfalfa. Although we have not found much evidence of this demand in analyzing the domestic market, we expect this will be the case of export markets.

We analyze the impact of each possible sources of shifts in supply below.

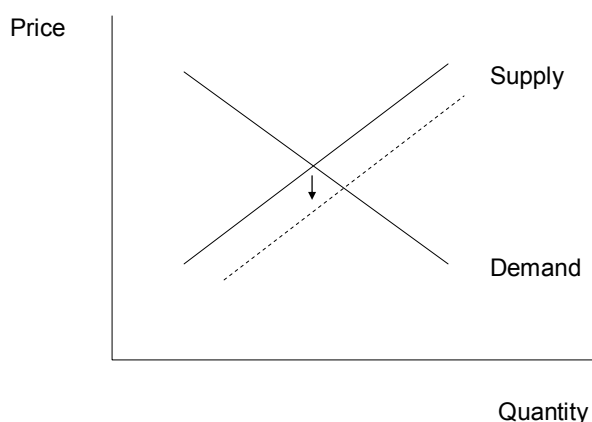
### 3.2.2 Impacts on Supply from Adoption of GT alfalfa

Changes in production costs for those adopting GT alfalfa were reviewed in our Technical Report *Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa* (Appendix K). We argued that, at least in the short run (during the planning horizon of the life of a stand) there were likely higher returns to be expected from GT alfalfa hay as compared to conventional alfalfa hay, given potential improvements in hay quality (lesser weed content). We did not have enough information to draw any conclusions regarding costs and returns in alfalfa seed production.

We suggested in section 3.2.1 that the overall impact on supply of the introduction of GT alfalfa would be a reduction in prices and an increase in quantities of alfalfa sold in the marketplace. As noted, however, the alfalfa market is segmented in various ways and the impact on producers of various alfalfa varieties and for various markets will not be the same.

We analyze the impact of shifts in supply in the various alfalfa market segments below. In doing so, we should not lose sight of the fact that the sum of the supply of alfalfa in the various markets will add to the total alfalfa supply. Thus, shifts in supply in one segment are likely to be compensated by shifts in supply in another to the extent that they add up to the total supply shift suggested in section 3.2.1.

In the case of those adopting GT alfalfa for forage, a reduction in costs of production of GT alfalfa as compared to conventional alfalfa, or an equivalent improvement in quality of alfalfa forage for a given production cost will have the impact of a shift down in the supply curve in the market for high quality alfalfa forage with reduction in prices and increases in quantities bought and sold in the market



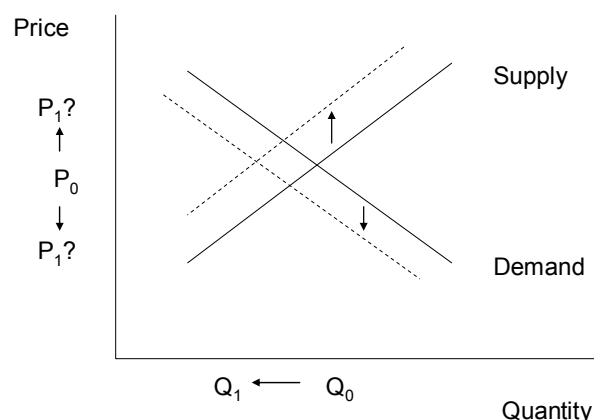
**Figure S-6: Impact of adoption of GT alfalfa on the market for high quality alfalfa forage**

Despite no shift in the demand curve, the quantity of alfalfa forage of high quality demanded in the market increases given the lower prices induced by the production of GT alfalfa and its consequential shift in the supply curve. How much the price will fall and how much the quantity of high quality alfalfa sold will increase, we do not know. This depends on the extent to which the demand curve is sensitive to decreases in prices, that is, the inclination of the demand curve portrayed in figure S-6 (price-elasticity of demand).

The reduction in the price of high quality alfalfa hay will likely have an impact on the demand for alfalfa hay of lower quality, as well as on the demand for alfalfa hay of high quality that is only available at higher costs (non-GT alfalfa). To the extent that high quality and low quality (or higher cost) alfalfa hay are substitutes, a reduction in the price of high quality alfalfa hay shifts the demand for low quality alfalfa hay downwards.

The supply curve may or may not shift upwards. If only farmers already producing high quality alfalfa adopt GT alfalfa, there will be no change in the supply curve of low quality alfalfa. However, if adoption of GT alfalfa is widespread, farmers currently producing low quality alfalfa will also adopt GT alfalfa and the supply curve of low quality alfalfa will move upwards.

Figure S-7 illustrates these movements. The result is clearly a reduction in the quantity of low quality alfalfa commercialized in the marketplace. The impact on prices, though, is undetermined and will depend on the magnitude of change of each factor described above, as well as on the sensitivity of the demand and supply curves to prices (price elasticity of supply and demand).



**Figure S-7: Impact of adoption of GT alfalfa on the market for low quality alfalfa forage**

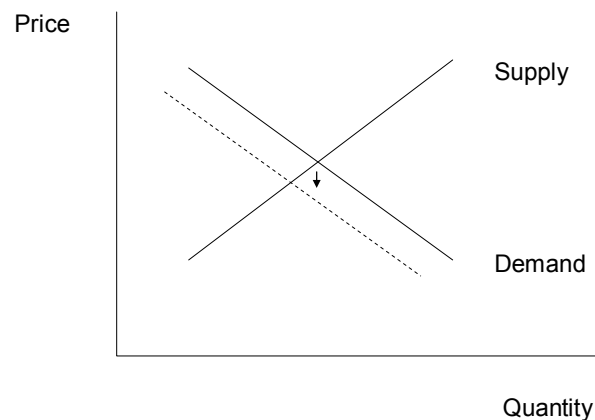
The organic alfalfa hay market may suffer a similar shift in its demand as does the low quality alfalfa hay market. This would happen under two possible scenarios.

- (3) If organic dairy and meat farmers will consider shifting to conventional farming in the face of the decreased costs of high quality conventional alfalfa (and presumably increased returns);
- (4) If the decreased costs of high quality conventional alfalfa are transmitted to conventional dairy and meat costs, increasing the price differential between conventional and organic

dairy and meat, stimulating organic dairy and meat consumers to purchase conventional products.

We have no evidence on the likelihood that the first scenario will occur. To the extent that organic farmers have chosen organic production out of philosophical values, the economic incentive to switch to conventional farming should not have an impact. The likelihood of the second scenario is also not clear. In our Technical Report *Downstream Effects to Organic Production and Marketing of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix T), we argue that governmental intervention in the pricing of milk and the low share of alfalfa in total meat production cost suggest the transmission of lower alfalfa costs to prices of conventional dairy and meat should be minor.

The remaining analysis in this chapter considers the case in which a downwards shift in demand for organic alfalfa does occur to some extent, since this is a scenario of particular concern to organic farmers. Figure S-8 reflects the shift in demand for organic alfalfa.



**Figure S-8: Impact of GT alfalfa adoption on organic alfalfa for forage**

In the case of alfalfa farmers producing GT alfalfa for seed, we were not able to find sufficient information on the returns in the production of conventional alfalfa seed as compared to the production of GT alfalfa seed in our Technical Report *Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa* (appendix K). It is likely that, given sufficient time, there will be no distinction in market returns to alfalfa seed producers for those agreeing to produce GT varieties or other varieties, and that any monopolistic rents will benefit the plant breeding company that has the property right to those varieties. However, there could be transitory effects, if there is demand for GT alfalfa seeds from alfalfa forage producers that is not being met by a corresponding increase in GT alfalfa seed production. In this case, returns to GT alfalfa seed producers could be higher than for producers of other varieties during a period of adjustment in the market.

### 3.2.3 Impacts on Supply from Presence of GT alfalfa

Changes in production costs and returns for those not adopting GT alfalfa are associated with the presence of GT alfalfa in non-GT alfalfa material. Non-GT alfalfa farmers may be a subset of either the high or low quality alfalfa segments considered above, or a subset of both these segments.

Changes in costs associated with the presence of GT alfalfa in non-GT alfalfa material must assume there is some market for GE-free alfalfa, whether domestic or foreign, whether having zero tolerance or accepting some degree of presence. If there is no such market, GT alfalfa stands treated as conventional or organic will perform similarly to other varieties and we expect no impact on costs and returns.

By presence of GT alfalfa in non-GT alfalfa material, we mean both comingling (no exchange of genetic material, e.g. same equipment used for GT and non GT alfalfa and equipment was not properly cleaned) or gene flow (through cross-pollination). The literature we found focuses on gene flow and we understand this reveals a lesser concern for comingling. Van Deynze et al. (Undated) argue that “best practices in the cleaning and management of seed harvesting and processing equipment are effective in managing admixtures between GE and conventional alfalfa seed.”

The extent of presence – number of acres or tons of non-GT alfalfa hay and seed that will be contain GT alfalfa every year in a scenario of GT alfalfa deregulation – will depend on:

- a) *Gene flow.* Gene flow is defined as “the incorporation of genes into the gene pool of one population from one or more other populations” (Putnam, 2007). We review the current U.S. research on gene flow in alfalfa in a separate Technical Report (appendix Q). Gene flow depends on many factors including stewardship. In that report we conclude that Forage Genetics International’s Best Practices are expected to maintain the presence of GT alfalfa at a rate considerably below 0.5 percent, within some distance from the areas of adoption of GT alfalfa<sup>74</sup>, although the role of feral alfalfa as a possible reservoir for the GT trait and its role in GT alfalfa population dynamics may require further exploration;
- b) *Geographic distribution of adoption of GT alfalfa.* If adoption rates were high but concentrated in certain regions of the country, this would increase the possibility that locations would be available for production of GE-free alfalfa that would be beyond the reach of gene flow from GT alfalfa. In the case of hay, this is highly unlikely. As previously noted, alfalfa hay production is distributed throughout much of the country. On the other hand, gene flow to alfalfa hay is considered relatively unlikely. In the case of alfalfa seed, the likelihood of gene flow is greater. However, production is not dispersed throughout the country, but rather concentrated in areas where the climate is favorable, mostly in Western States. The feasibility and benefits of isolating areas for production of non-GT alfalfa seed are thus likely to be greater for seeds. If this were possible, however, it would come at a cost. The cost would be either that of creating

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<sup>74</sup> Forage Genetics International’s validation study of its own Best Practices, used isolation distances from 900 feet (the minimum isolation distance in their Best Practices) to “more than 10 miles” (Forage Genetics International, 2007) during the 2006 growing season. The longest distance in which gene flow was observed in that study was 2.75 miles from a GT alfalfa seed field where 0.008% of conventional seed fields presented GT traits (standard error of 0.006).

extended buffer zones or of relocation of alfalfa seed production. These costs would translate into higher land rents. As shown in our Technical Report *Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa* (appendix K), land rents are a considerable cost of seed production;

- c) *Geographic distribution of non-GE production.* Of particular interest is the geographic distribution of production for GE sensitive markets. If the location of alfalfa production for forage and for seed destined to GE sensitive markets is concentrated, it would be presumably easier to distance this sensitive production from that of GT alfalfa. In our review of the domestic demand for alfalfa in section 2 we found no evidence that some portion of it is likely to be sensitive to GT alfalfa. Sensitivity to GE traits in export markets has not yet been analyzed and will be considered in depth in our Technical Report *Impacts to United States Trade of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix R).

In addition, the rate of adoption of GT alfalfa will have an impact on the number of years it will take for the level of GT alfalfa in the marketplace to reach the levels anticipated in non-GT alfalfa.

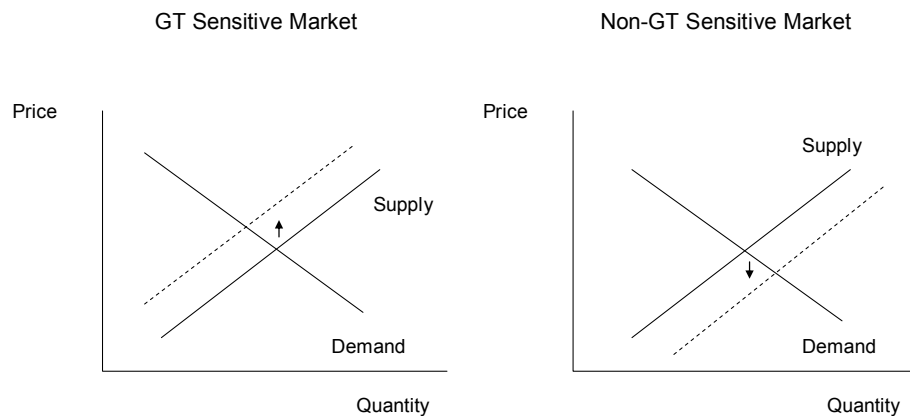
There are two ways in which presence of GT alfalfa in non-GT alfalfa material may affect producer costs and returns, given an existing demand for GE-free alfalfa:

- a) *Loss in production.* If producers cannot avoid GT alfalfa material above those levels found acceptable by the market, any alfalfa seeds or forage previously destined to those markets will have to be shifted to salvage markets that may pay a lower price.
- b) *Avoidance costs.* If producers can avoid the accidental presence of GT alfalfa, whether through adopting buffer zones, relocating to non-deregulated areas (if deregulation was not done on a national level), or requiring testing for GT alfalfa traits in alfalfa seeds used for production, there is a cost of avoidance that must be incorporated into its production costs.

In either case, the impact on supply is best understood by imagining two separate market segments: a GE sensitive market and a non-GE sensitive one. In analyzing shifts in these separate market segments, we should keep in mind that the sum of supply in these segments will add up to the supply of non-GT alfalfa that is in turn a share of total alfalfa supply.

If there is loss in production destined to the GE sensitive market or an increase in costs of supplying that market, the supply curve for that market will shift upwards. If non-GT alfalfa material containing GT-alfalfa is then destined to the non-GE sensitive market (loss in production) or if some farmers are not able to continue supplying the existing market given the increased costs and shift to the non-GE sensitive market (avoidance costs), the supply curve for that market will shift downwards. These shifts are illustrated in figure S-9 below.





**Figure S-9: Impact of unintended presence of GT alfalfa**

In the case of the supply of alfalfa seeds for organic production, avoidance costs may result from pressure for new organic seed requirements – such as seed certification – for organic alfalfa hay production, as a means of guaranteeing the presence of GT alfalfa is below a desired threshold.

### 3.3 Summary of Findings

Production of alfalfa hay in the United States was in 2007 approximately 72.6 million tons, while that of seeds was in 2007 approximately 62 million tons. Production of alfalfa hay is distributed in much of the United States while seed is highly concentrated in Northwestern states. The alfalfa share of total hay production has been falling in the recent past, as has been the absolute production of alfalfa hay. Organic alfalfa hay acreage was quickly approaching 1% of total alfalfa hay acreage in 2005. Domestic production of organic alfalfa seed seemed to be lagging behind.

GT alfalfa deregulation is likely to impact the supply of conventional alfalfa in at least two ways. First, there will be a reduction in the supply of conventional low quality/high cost (non-GT) alfalfa hay as producers adopt GT alfalfa. Second, the potential of GT alfalfa to be present in non-GT alfalfa material will move the supply of alfalfa for GE sensitive markets even further upwards, while it will bring some supply back to the non-GE sensitive market, only partially compensating for the initial reduction in supply.

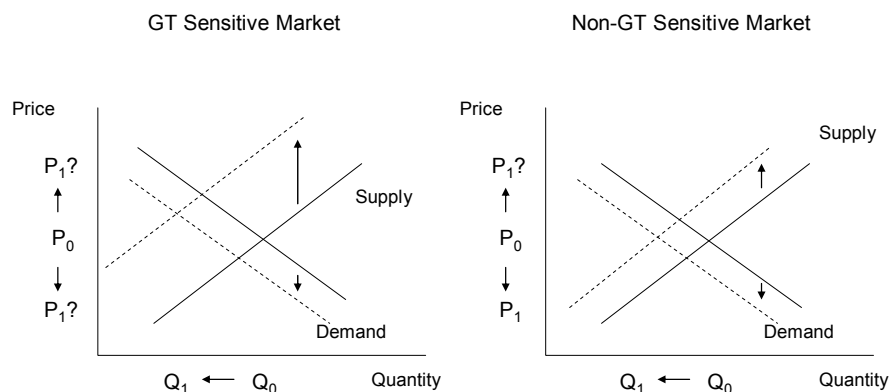
In the case of organic alfalfa, assuming some GE sensitivity in domestic organic markets, presence of GT alfalfa in non-GT material may reduce the supply of organic alfalfa for GE sensitive organic markets with a possible increase in supply for non-GE sensitive organic markets.

## 4.0 Impacts on Conventional and Organic Alfalfa Farmers

### 4.1 Impacts on Non-GT Alfalfa Farmers

In section 2 we argued that GT alfalfa deregulation is likely to have little to no impact on domestic demand of conventional alfalfa, *derived from downstream demand*. However, in Section 3 we noted that GT alfalfa deregulation will likely have a negative impact on the demand of low quality or high cost (non-GT) alfalfa to the extent the increased supply of GT alfalfa with high quality forage and lower costs reduces the demand for substitute varieties. The result will be a downward shift in demand for non-GT alfalfa.

On the supply side, there are at least two different effects. First, there will be a reduction in the supply of conventional low quality/high cost (non-GT) alfalfa hay as producers adopt GT alfalfa. Second, potential presence of GT alfalfa in non-GT alfalfa material will move the supply of alfalfa for GE sensitive markets even further upwards, while it will bring some supply back to the non-GE sensitive market, only partially compensating for initial reduction in supply. The results are shown in figure S-10 below. The move upwards in the supply curve is larger for GE sensitive markets than for non-GE sensitive ones.



**Figure S-10: Impact on non-GT alfalfa farmers**

What figure S-10 shows is that non-GT farmers producing for GE sensitive markets are likely to lose more markets than non-GT farmers producing for non-GE sensitive markets. In either case, whether the resulting market prices for non-GT alfalfa will be higher or lower than pre-deregulation prices for low quality alfalfa, we cannot say, but prices in GE sensitive markets will be likely higher than in non-GE sensitive markets.

In section 2 we found no evidence of a domestic GE sensitive market for conventional alfalfa. In this case, the resulting impact will look like the non-GE sensitive market in figure S-10. The market for non-GT alfalfa will be reduced as farmers switch to producing GT alfalfa and demand for non-GT alfalfa falls. The resulting final price for non-GT alfalfa is not clear but it will likely be lower than it otherwise would, pushed down by the lower cost of its substitute: GT alfalfa. During a period of adjustment to the new market segmentation between GT alfalfa and non-GT

alfalfa, prices will tend to fall if demand shifts faster than farmers, or will tend to rise if farmers shift faster than demand.

A numerical estimation of the impact of GT alfalfa deregulation on the non-GT alfalfa market under this scenario would require being able to estimate:

- a) What the level of adoption of GT alfalfa is;
- b) What is the sensitivity of the demand curve to increases in prices (the price-elasticity of demand) since this will determine how much the price of non-GT alfalfa will increase as producers shift to GT alfalfa reducing supply;
- c) The sensitivity of low quality alfalfa demand with respect to a reduction in price of high quality alfalfa (cross-elasticity) since this will determine how much the demand curve for low quality alfalfa will shift downward
- d) What is the sensitivity of the supply curve to increases in prices (the price-elasticity of supply) since this will determine how much the price of alfalfa will fall as demand shifts to GT alfalfa;

We do not have sufficient information to provide any reliable numerical estimate.

The market for seed will likely follow the tendency of the market for alfalfa hay, since it is a derived demand. In the case of seeds, reductions in supply are likely to considerably raise prices since the price-elasticity of demand seems to be very low. Myer et al. (1998) use panel data from seven states and conclude that the demand for alfalfa seed is highly inelastic. This is to be expected given the importance of appropriate seed choice for alfalfa hay yields and quality and the relatively low share of total production costs represented by seeds.

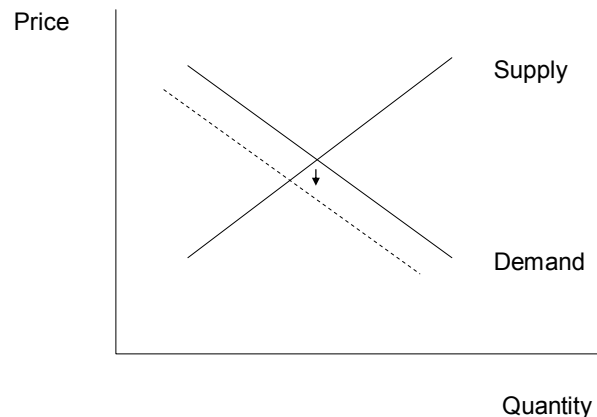
## 4.2 Impacts on Organic Alfalfa Farmers

In section 2 we explain that we found no evidence that GT alfalfa deregulation would directly cause a shift in the demand for organic alfalfa hay. However, in section 3 we argued that the demand for organic alfalfa could shift downwards with the reduction in costs of conventional hay, to the extent that organic and conventional farming are substitutes or to the extent that the reduction in conventional alfalfa hay costs are transmitted to prices of conventional dairy and meat..

On the supply side, unintended presence of GT alfalfa in non-GT alfalfa material would have the effect shown in figure S-9: a reduction in supply for GE sensitive organic markets with a possible increase in non-GT sensitive organic markets. This result, however, relies on the assumption that some degree of GT sensitivity exists in domestic organic markets.

As we have not been able to find any evidence of GT sensitivity of demand in domestic organic markets, we first consider the case in which the only impact of GT alfalfa deregulation is the demand reduction that follows the reduction in prices of conventional GT alfalfa. We also consider what the impact would be in case there actually was GT sensitivity of domestic organic demand.

With no GT sensitivity of demand, the only impact on organic markets is the downward shift in demand that follows the reduction in prices of conventional alfalfa. This is portrayed in figure S-8 and reproduced again below.



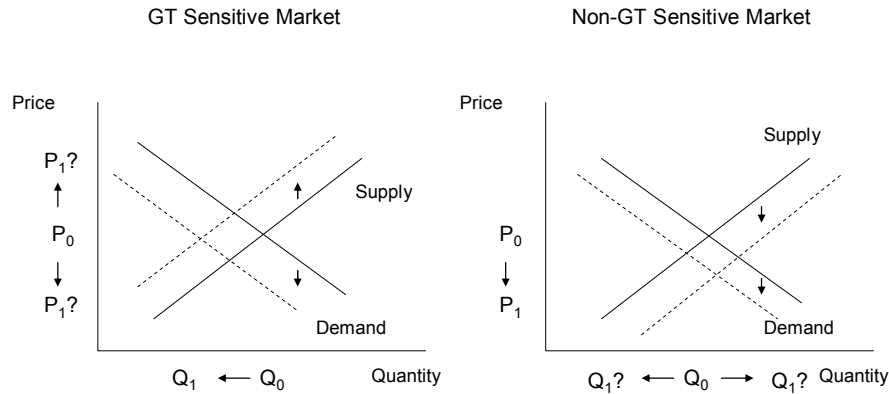
**Figure S-11: Impact of GT alfalfa adoption on organic alfalfa for forage with no GT sensitive domestic markets**

To estimate numerically the impact for organic farmers under this scenario, we need to know:

- a) The magnitude of the decrease in prices expected of conventional alfalfa;
- b) The cross-elasticity of demand between conventional and organic alfalfa. This will tell us how much the demand for organic alfalfa will fall in response to the decrease in prices of conventional alfalfa;
- c) The price-elasticity of supply of organic alfalfa. This will tell us how much organic market quantities and prices will fall in response to the shift in demand downwards.

We do not have sufficient information to provide any reliable numerical estimate.

In the case of any GT sensitivity in the domestic organic market, the reduction in demand will be complemented by the shifts in supply shown in figure S-9. The result of these shifts is shown in figure S-12 below.



**Figure S-12: Impact of GT alfalfa adoption on organic alfalfa for forage with GT sensitive domestic markets**

The result of GT alfalfa deregulation under this scenario depends on the extent of the GT sensitive market within the organic market. The larger the GT sensitive market is, the more likely quantities sold will fall, although with unclear effect on prices. The larger the non-GT sensitive market is, the more likely prices will fall but with unclear effect on quantities.

Once again, we do not have enough information to estimate numerically the impact for organic farmers under this scenario. In addition to the elasticities of supply and demand we would need to know the share of the organic market that is GT sensitive and the magnitude of the decrease in prices expected for conventional alfalfa.

### 4.3 Distributional and Social Impacts

GT alfalfa adoption by farmers, presence of GT alfalfa in non-GT alfalfa fields, and the demand response to GT alfalfa deregulation will have several distributional and social impacts:

*Businesses lost and gained.* In our above discussion we mentioned that farmers adopting GT alfalfa will likely face decreased costs or improved markets while organic farmers may face a reduction in demand. Early GT alfalfa adopters may gain markets while conventional non-GT alfalfa farmers producing high quality alfalfa may lose, due to potentially higher costs when compared to GT alfalfa. Organic farmers most affected by the presence of GT alfalfa may lose markets while organic farmers less affected may gain, if there is GT sensitivity in the market for organic alfalfa.

*Market Structure.* Increased land costs that may affect non-GT alfalfa farmers attempting to avoid GT alfalfa. This may benefit larger alfalfa farmers. In our Technical Report *Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa* (appendix K) we showed that land costs are a major factor in generating economies of scale in alfalfa grown for forage, and we also showed that land costs are a major cost factor in alfalfa seed production.

The impact of increased land costs on seed production will likely be mitigated by the fact that the elasticity of demand for seed seems to be highly inelastic. In other words, as seed quality is

important for alfalfa forage producers and seed costs are a small part of their total production costs, increases in seed costs should not significantly affect sales of seed.

If adoption rates of GT alfalfa are high, alfalfa seed farmers will face increased demand for GT alfalfa seed and will shift to production of this variety. There will likely be an increased market concentration in the supply of alfalfa seed technology.

To the extent that organic farming is more suitable for small farms than conventional farming (less economies of scale related to greater dependency of labor), a reduction in the demand for organic products may favor larger farmers.

*Distribution of Costs of Loss of Production and Avoidance.* To the extent that there is presence of GT alfalfa in the organic market, we argued that producers would bear a cost in either loss of production or measures (typically land costs) to reduce the likelihood of unintended presence of GT alfalfa.

Organic certification typically requires producers to take measures to avoid pesticide contamination or the unintended presence of GE material from conventional farming. However, who should bear the costs of preventing the unintended presence of GT alfalfa in non-GT alfalfa material is debatable. Movement of GT alfalfa into non-GT alfalfa fields would be considered an externality in economics: a cost to third parties of producing GT alfalfa that is not being internalized in the cost of production of GT alfalfa.

*Social aspects of organic farming.* In section 2 we noted that we were unable to identify a GT sensitive domestic demand for organic products. This does not mean that GE products are welcome by organic consumers, but rather any sensitivity to GE products will likely not translate into a decrease in sales of organic alfalfa. Organic producers (and consumers) may still be unhappy with the outcome. To the extent that organic farming involves broader life choices related to philosophical attitudes, this discontent is a negative impact.

This situation may conceal a market for GE-free products in need of development.

#### 4.4 Summary of Findings

The impact of GT alfalfa deregulation on non-GT conventional alfalfa farmers will likely be a reduction in the market for non-GT alfalfa as farmers switch to producing GT alfalfa and as the demand for non-GT alfalfa falls. The resulting final price for non-GT alfalfa is not clear but it will likely be lower than the present prices, pushed down by the lower cost of its substitute: GT alfalfa. During a period of adjustment to the new market segmentation between GT alfalfa and non-GT alfalfa, prices will tend to fall as the demand shifts faster to GT alfalfa than farmers, or will tend to rise if farmers shift faster than demand.

The impact of GT alfalfa deregulation on organic alfalfa farmers depends on whether there is a GE sensitive share of the domestic organic alfalfa markets. With no GT sensitivity of demand, the only impact on organic markets is the downward shift in demand that follows the reduction in

prices of conventional alfalfa, leading to a reduction in prices and quantities sold domestically of organic alfalfa. In the case of GT sensitivity of demand in organic alfalfa markets, the result of GT alfalfa deregulation depends on the extent of this GT sensitivity: the larger the GT sensitive market is, the more likely quantities sold will fall, although with unclear effect on prices. The larger the non-GT sensitive market is, the more likely prices will fall, but with unclear effect on prices.

GT alfalfa adoption by farmers, presence of GT alfalfa material in non-GT alfalfa fields, and the demand response to GT alfalfa deregulation will have several distributional and social impacts: the loss and gain of businesses, changes in market structure, distribution of the costs of loss of production and avoidance in GT sensitive markets, and potential negative impacts on the environment preferred by organic farmers (one free of GE products).

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## Appendix S-2. Literature Search

### 1.0 Literature Search Strategy

Most data was obtained from USDA websites.

Much of the remaining information was obtained from university (and cooperative extension) linked alfalfa portals and alfalfa symposium proceedings such as:

- The California Alfalfa Workgroup: <http://alfalfa.ucdavis.edu/>
- The University of California Alfalfa Seed Production Homepage: <http://alfalfaseed.ucdavis.edu>
- University of Wisconsin Forage Research and Extension: <http://www.uwex.edu/ces/forage/>
- 2007 37<sup>th</sup> California Alfalfa and Forage Symposium: <http://alfalfa.ucdavis.edu/2007AlfalfaConference>
- 2006 Western Alfalfa and Forage Conference: <http://alfalfa.ucdavis.edu/2006AlfalfaConference>
- San Joaquin University of California Cooperative Extension: [http://cesanjoaquin.ucdavis.edu/Agriculture/Publications,\\_Research\\_Reports.htm](http://cesanjoaquin.ucdavis.edu/Agriculture/Publications,_Research_Reports.htm)

Other papers were obtained from internet searches; others from academic journals such as *Agronomy Journal* and *Agribusiness*.

Some of the conclusions are based on our Technical Report *Downstream Effects to Organic Production and Marketing of Deregulation of Glyphosate-Tolerant Alfalfa*.

Direct personal communication with extension experts was also used and is detailed in the References.

## Appendix S-3. Probability of Alfalfa Seed Acres Using Herbicide

One policy option to address the impacts of presence of GT alfalfa material in non-GT alfalfa is to guarantee the possibility of producing non-GT alfalfa seeds at a distance from GT alfalfa sufficient to reduce the likelihood of unintended presence to virtually zero.

In this appendix we build on the exercise constructed in our Technical Report *Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa* (appendix K). By listing U.S. counties that currently produce alfalfa seed by acreage and multiplying this acreage by the likelihood of an acreage in that county not having alfalfa grown for forage with herbicides, we obtain a ranking of counties that could produce alfalfa seeds while losing relatively little by not being able to adopt GT alfalfa hay. The process for obtaining this ranking was as follows:

1. We listed all U.S. counties for which alfalfa seed is grown and ranked them by alfalfa seed acreage. The ranking by acreage is taken as an indicator of economic interest in producing alfalfa seed.
2. We listed our ranking of counties growing alfalfa for forage with herbicide, as presented in the Technical Report *Changes in the Economics of Alfalfa Farming with Deregulation of Glyphosate-Tolerant Alfalfa* (appendix K), and subtracted the values from that ranking from 1: this gives us the likelihood of randomly selecting an acre in a county that does not have alfalfa grown for forage with herbicide use.
3. We multiplied the two lists above to obtain a ranking of counties with economic interest in producing alfalfa for seed, while relatively little in producing alfalfa for forage with herbicide.

The ranking is presented below.

The top counties are also counties that actually do produce considerable acreage of alfalfa for forage under herbicide. This reflects the fact that there are counties that produce both seed and forage with intense use of herbicide. Other counties with relatively low likelihood of alfalfa grown for forage under herbicide may find it in their interest to give preference to growth of alfalfa seeds under special conditions, if these conditions generate particularly high returns, as those that may be obtained by the exploration of specialized niche markets.

**Table S-16. Probability of Acres in Alfalfa Seed not in Hay with Herbicide**

| <b>Geographic area</b> | <b>Harvested Acres of Alfalfa Seed</b> | <b>Acres in Farm</b> | <b>% of Seed Acres to Total Farm Acres</b> | <b>% Acres low-alfalfa, low herbicide use</b> | <b>% High rates alfalfa seed w/ low rates alfalfa hay and herbicide use</b> |
|------------------------|----------------------------------------|----------------------|--------------------------------------------|-----------------------------------------------|-----------------------------------------------------------------------------|
| California\Imperial    | 25848                                  | 427349               | 6.05%                                      | 85.0851%                                      | 5.15%                                                                       |
| Idaho\Canyon           | 7018                                   | 260247               | 2.70%                                      | 93.2410%                                      | 2.51%                                                                       |
| Washington\Walla Walla | 10759                                  | 682350               | 1.58%                                      | 99.0729%                                      | 1.56%                                                                       |
| California\Kings       | 5779                                   | 680662               | 0.85%                                      | 95.5090%                                      | 0.81%                                                                       |
| Nevada\Pershing        | 1960                                   | 244249               | 0.80%                                      | 98.5559%                                      | 0.79%                                                                       |
| Arizona\Yuma           | 1723                                   | 210480               | 0.82%                                      | 92.3251%                                      | 0.76%                                                                       |
| Nevada\Humboldt        | 4206                                   | 756313               | 0.56%                                      | 99.6056%                                      | 0.55%                                                                       |
| Wyoming\Park           | 4560                                   | 881736               | 0.52%                                      | 99.7311%                                      | 0.52%                                                                       |
| Washington\Grant       | 4249                                   | 1087952              | 0.39%                                      | 95.4597%                                      | 0.37%                                                                       |
| Idaho\Jerome           | 707                                    | 188753               | 0.37%                                      | 87.0995%                                      | 0.33%                                                                       |
| Oregon\Malheur         | 3565                                   | 1170664              | 0.30%                                      | 99.6496%                                      | 0.30%                                                                       |
| Idaho\Payette          | 496                                    | 166179               | 0.30%                                      | 98.1103%                                      | 0.29%                                                                       |
| Utah\Cache             | 580                                    | 251550               | 0.23%                                      | 95.9822%                                      | 0.22%                                                                       |
| Idaho\Owyhee           | 1179                                   | 569305               | 0.21%                                      | 99.2854%                                      | 0.21%                                                                       |
| California\Fresno      | 3287                                   | 1636224              | 0.20%                                      | 98.1028%                                      | 0.20%                                                                       |
| Utah\Millard           | 1118                                   | 566692               | 0.20%                                      | 98.5740%                                      | 0.19%                                                                       |
| Arizona\Maricopa       | 776                                    | 485469               | 0.16%                                      | 94.8906%                                      | 0.15%                                                                       |
| South Dakota\Dewey     | 2113                                   | 1449585              | 0.15%                                      | 99.6978%                                      | 0.15%                                                                       |
| Montana\Powder River   | 2187                                   | 1620068              | 0.13%                                      | 99.9531%                                      | 0.13%                                                                       |
| Idaho\Gem              | 233                                    | 190757               | 0.12%                                      | 99.5692%                                      | 0.12%                                                                       |
| Nevada\Churchill       | 162                                    | 131448               | 0.12%                                      | 98.4587%                                      | 0.12%                                                                       |
| South Dakota\Bennett   | 759                                    | 753263               | 0.10%                                      | 99.3163%                                      | 0.10%                                                                       |
| California\Lassen      | 377                                    | 459126               | 0.08%                                      | 99.7695%                                      | 0.08%                                                                       |
| Michigan\Mecosta       | 74                                     | 114715               | 0.06%                                      | 95.1494%                                      | 0.06%                                                                       |
| South Dakota\Marshall  | 324                                    | 534178               | 0.06%                                      | 98.3376%                                      | 0.06%                                                                       |
| Idaho\Twin Falls       | 258                                    | 439537               | 0.06%                                      | 94.1855%                                      | 0.06%                                                                       |
| Minnesota\Stearns      | 404                                    | 708284               | 0.06%                                      | 94.4371%                                      | 0.05%                                                                       |
| Washington\Franklin    | 311                                    | 609046               | 0.05%                                      | 94.8114%                                      | 0.05%                                                                       |
| Missouri\Adair         | 126                                    | 279855               | 0.05%                                      | 99.8259%                                      | 0.04%                                                                       |
| Oklahoma\Grady         | 275                                    | 608373               | 0.05%                                      | 99.1076%                                      | 0.04%                                                                       |
| Washington\Yakima      | 713                                    | 1649281              | 0.04%                                      | 99.7611%                                      | 0.04%                                                                       |
| Montana\Carter         | 560                                    | 1698363              | 0.03%                                      | 99.8857%                                      | 0.03%                                                                       |
| Idaho\Washington       | 130                                    | 417092               | 0.03%                                      | 99.5383%                                      | 0.03%                                                                       |
| Montana\Rosebud        | 749                                    | 2714024              | 0.03%                                      | 99.9732%                                      | 0.03%                                                                       |
| Nebraska\Dawes         | 204                                    | 848753               | 0.02%                                      | 99.6518%                                      | 0.02%                                                                       |
| Arizona\Graham         | 304                                    | 1345629              | 0.02%                                      | 99.9980%                                      | 0.02%                                                                       |
| Montana\Big Horn       | 619                                    | 2899620              | 0.02%                                      | 99.8683%                                      | 0.02%                                                                       |
| New York\Yates         | 27                                     | 126118               | 0.02%                                      | 95.6047%                                      | 0.02%                                                                       |
| Nebraska\Merrick       | 46                                     | 247927               | 0.02%                                      | 98.3646%                                      | 0.02%                                                                       |
| Oklahoma\Alfalfa       | 96                                     | 542813               | 0.02%                                      | 99.0123%                                      | 0.02%                                                                       |
| South Dakota\Tripp     | 175                                    | 1014336              | 0.02%                                      | 98.0914%                                      | 0.02%                                                                       |
| California\Kern        | 367                                    | 2361765              | 0.02%                                      | 99.1788%                                      | 0.02%                                                                       |
| California\Modoc       | 65                                     | 597740               | 0.01%                                      | 99.5080%                                      | 0.01%                                                                       |
| Washington\Okanogan    | 129                                    | 1205229              | 0.01%                                      | 99.9259%                                      | 0.01%                                                                       |
| Montana\Fallon         | 105                                    | 978818               | 0.01%                                      | 99.6674%                                      | 0.01%                                                                       |
| Utah\Duchesne          | 60                                     | 1076470              | 0.01%                                      | 99.9718%                                      | 0.01%                                                                       |

**Appendix T:       Downstream Effects to Organic  
Production and Marketing of  
Deregulation of Glyphosate-Tolerant  
Alfalfa**

# **Downstream Effects to Organic Production and Marketing of Deregulation of Glyphosate-Tolerant Alfalfa**

## **Executive Summary**

There is a trend of moderate overall growth in downstream markets for conventional alfalfa and stronger growth in organic downstream markets.

The deregulation of glyphosate-tolerant (GT) alfalfa may affect organic and conventional dairy, meat, livestock and pet care domestic markets in two ways: a) through reduced demand; b) through reduced costs/ improved quality of feed. The latter could have impacts on the price differential between organic and conventional dairy and meat products, since organic production cannot make use of improved quality GT alfalfa.

Although there is evidence of some claimed consumer preference for foods free of genetically engineered organisms in the United States, we found no evidence that deregulation of GT alfalfa may translate into reduced demand in downstream markets. There is actually a possibility that the demand for organic foods may increase as consumers concerned with genetically engineered foods may switch to organic products.

Expected lower prices/ higher quality of alfalfa hay will likely benefit dairy farmers and to a lesser degree cow-calf production.

The reduced costs in dairy farming and cow-calf production may not be transmitted to dairy and meat products, however, because of price regulation in dairy markets and the low share of alfalfa production costs in the case of meat production.



## 1.0 Introduction

### 1.1 Scope of Report

This report analyses the potential impact on downstream markets of the deregulation of glyphosate-tolerant (GT) alfalfa. Main downstream markets are those for dairy, meat, livestock and pet care. The report is limited to domestic downstream markets, and impacts on foreign markets are left for the Technical Report *Impacts to United States Trade of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix R).

Below we explain the methodology upon which this analysis is based. In section 2 we focus on the impact of GT deregulation through GT sensitivity of demand in downstream markets. In section 3 we focus on the impact of GT deregulation through reduced production costs and substitution effects.

### 1.2 Methodology

Some alfalfa is produced for human consumption. In our Technical Report *Economic and Social Impacts to Conventional and Organic Farmers of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix S) we argue that alfalfa for human consumption, whether for sprouts or in the form of leaves for dietary supplements, is likely a very small portion of total demand for alfalfa and thus is not included in the analysis.

Honey is also produced from alfalfa fields. However, in our Technical Report *Economic and Social Impacts to Conventional and Organic Farmers of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix S) we argue that honey production does not generate an actual “demand” for alfalfa to the extent that alfalfa producers pay honey producers for use of honeybees in alfalfa pollination and not the other way around. This suggest any impact of alfalfa on honey producers will have a small effect on honey production and that producers are likely to have access to good substitutes for alfalfa as a sources of nectar for honeybees<sup>75</sup>. We thus also do not include any analysis of honey markets in this report.

Alfalfa downstream markets are mainly those for dairy, beef, livestock and pet care, and alfalfa is by far mainly used for forage, whether in the form of hay or haylage, as well as processed in meal and pellets for animal feed. We thus focus on the dairy, beef, livestock and pet care downstream markets. Alfalfa processors are not treated as a separate market to the extent that they are intermediaries between alfalfa producers and dairy, beef or livestock producers.

#### 1.2.1 Assumptions

GT alfalfa production is assumed to potentially affect organic and conventional dairy, meat, livestock and pet care domestic markets in two ways<sup>76</sup>:

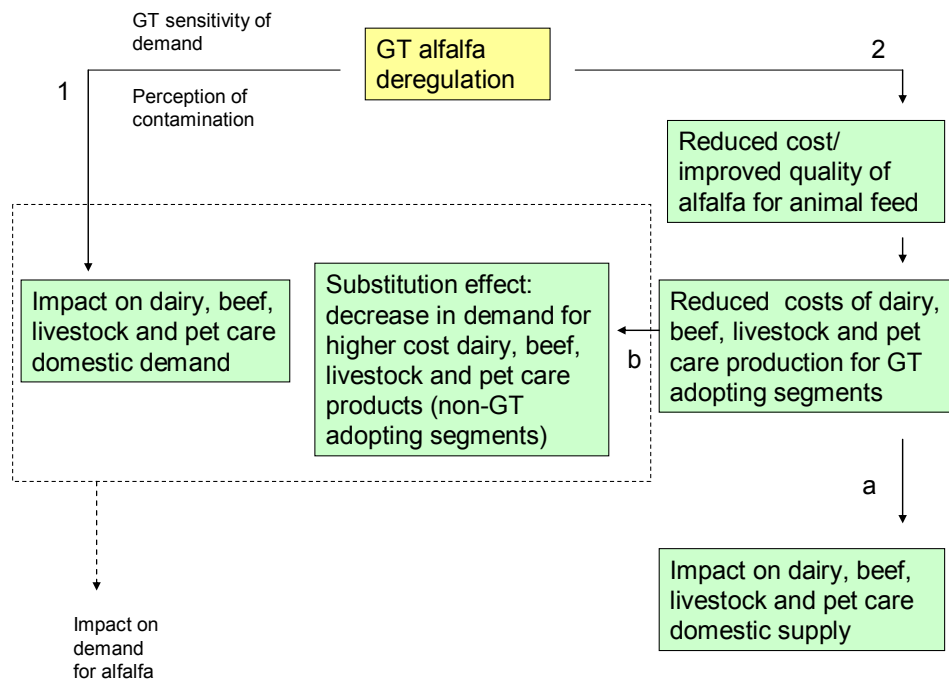
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<sup>75</sup> Although there may be some impact on the income of honey producers to the extent that these producers count on pollination as a source of income.

<sup>76</sup> In this report, conventional dairy, meat, livestock and pet care products are those produced with conventional or GT alfalfa. Organic dairy, meat, livestock and pet care products are those where any alfalfa used is organic. When a distinction is needed in conventional downstream markets, among production systems using or not GT alfalfa, this distinction will be made explicit by expressions such as “GT adopting segments, ” or “GMO free” products.

1. To the extent that the domestic demand for downstream products is sensitive to the presence of genetically engineered (GE) organisms and to the extent that there is a perception of presence of GE material in downstream products, the domestic demand for dairy, meat, livestock and pet care will be affected;
2. Reduction in costs/ improvements in quality of alfalfa through the adoption of GT alfalfa will affect downstream markets to the extent that alfalfa production cost changes are transferred to the price of alfalfa. Production costs of some downstream market segments utilizing alfalfa will decrease (those segments adopting GT alfalfa). This will have two possible impacts:
  - a. The supply curve of dairy, beef, livestock and pet care will shift downwards, with potential increases in quantities produced and decreases in prices.
  - b. To the extent that decreases in production costs of some downstream market segments are reflected in decreased prices, consumers will substitute dairy, meat, livestock and pet care produced at lower prices for dairy, meat, livestock and pet care producers at higher costs.

These assumptions are illustrated in figure T-1 below:



**Figure T-1: Deregulation impact on downstream markets**

The dashed lines represent the downstream impacts that will affect the demand for alfalfa. These impacts were incorporated in the analysis done in the Technical Report *Economic and Social*

*Impacts to Conventional and Organic Farmers of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix S).

In section 2 we focus on the impact of GT deregulation through GT sensitivity of demand in downstream markets (labeled “1” in the figure above). In section 3 we focus on the impact of GT deregulation through reduced production costs and substitution effects (labeled “2” in the figure above).

### *1.2.2 Data and Information Sources*

Our basic data were obtained from USDA sources, under the assumption that these are the best quality agriculture statistics available. These data were complemented with information obtained from articles, typically of an academic nature and peer-reviewed whenever possible, under the assumption that these documents are subject to standards that should help reduce if not eliminate any intentional bias.

## 2.0 Impacts of Sensitivity to GE Organisms

Demand in downstream markets will be impacted by deregulation of GT alfalfa to the extent that some consumers will seek to avoid consumption of dairy and meat (and egg products) from animals fed GT alfalfa, or to avoid feeding livestock and pets with GT alfalfa. The result may be a reduction in demand for dairy, meat and livestock and pet feed that is not produced using organic production methods, due to the likelihood of these goods having been produced with GT alfalfa. This could result in an increase in demand for similar goods believed to be largely or completely free of GE content, such as goods produced using organic production methods. This could take various forms.

One form would be an increase in imports from countries where GT alfalfa is not used.

A second form could be a shift towards organic production if this is perceived as at least free of intentional use of GT alfalfa. The demand for organic products in downstream markets, however, may also be negatively affected if consumers perceive the possibility of GT alfalfa being present in organically produced products.

A third possibility would be increased pressure for the development of new niche market certification standards for foods free of any GE content. This type of niche market is more likely to develop:

- a) the more costly it is to shift to other substitutes (e.g., other forms of animal feed) that do not include GE material;
- b) the less costly it is to produce goods with equivalent quality characteristics for the niche market that are completely or largely free of GE material, whether through domestic production or through imports.

If both a) and b) are costly, consumers sensitive to GE products may still find themselves reluctantly consuming GE products.

In section 2.1 we consider current trends in alfalfa downstream markets. In section 2.2 we consider the possible impacts, as outlined above.

### 2.1 Trends in Downstream Demand

#### 2.1.1 *Dairy*

Consumption of dairy products in the United States has grown steadily in the last 20 to 30 years at rates above population growth thanks to increases in per capita consumption (LaDue et al, 2003). There has been actually a decrease in per capita consumption of fluid milk, more than compensated by an increase in per capita consumption of cheese.

U.S. per-capita consumption data for all dairy products (calculated on a milk equivalent basis) are given in table T-1 below.

**Table T-1. Trends in U.S. Per-Capita Consumption of All Dairy Products**

| <b>Year</b> | <b>Pounds, Milk<br/>equivalent, Milkfat<br/>basis</b> | <b>Year</b> | <b>Pounds, Milk<br/>equivalent, Milkfat<br/>basis</b> |
|-------------|-------------------------------------------------------|-------------|-------------------------------------------------------|
| 1975        | 539                                                   | 1991        | 564                                                   |
| 1976        | 540                                                   | 1992        | 563                                                   |
| 1977        | 540                                                   | 1993        | 569                                                   |
| 1978        | 544                                                   | 1994        | 580                                                   |
| 1979        | 548                                                   | 1995        | 576                                                   |
| 1980        | 543                                                   | 1996        | 566                                                   |
| 1981        | 541                                                   | 1997        | 567                                                   |
| 1982        | 555                                                   | 1998        | 572                                                   |
| 1983        | 573                                                   | 1999        | 584                                                   |
| 1984        | 582                                                   | 2000        | 593                                                   |
| 1985        | 594                                                   | 2001        | 587                                                   |
| 1986        | 592                                                   | 2002        | 587                                                   |
| 1987        | 601                                                   | 2003        | 595                                                   |
| 1988        | 583                                                   | 2004        | 594                                                   |
| 1989        | 564                                                   | 2005        | 597                                                   |
| 1990        | 568                                                   | 2006*       | 606                                                   |

Source: USDA ERS, 2008a; \* Preliminary

The data in table T-1 above includes fluid milk as well as milk used in the manufacture of products such as butter, cheese, yoghurt, ice cream, and powdered milk. The data in the table above indicate a relatively slow annual average growth rate of 0.38 percent in per-capita consumption of all dairy products in the United States. Much of that increase in per-capita consumption seems to have happened in the early to mid 80s.

Milk production grew in the United States from approximately 147.7 billion pounds in 1990 to an estimated 185.6 billion pounds in 2007 (USDA ERS, 2008a). This growth has been relatively continuous and reflects growth in productivity rather than growth in the number of milk cows. The number of milk cows has actually fallen from an average of roughly 10 million in 1990 to less than 9.2 million in 2007 (USDA ERS, 2008a). USDA data on the past 10 years of total milk production and average prices are shown in table T-2.

**Table T-2. Production and Prices for All Milk**

| <b>Year</b> | <b>Production (billions of lbs)</b> | <b>Price (\$/cwt)</b> |
|-------------|-------------------------------------|-----------------------|
| 1997        | 156.1                               | 13.36                 |
| 1998        | 157.3                               | 15.46                 |
| 1999        | 162.6                               | 14.38                 |
| 2000        | 167.4                               | 12.40                 |
| 2001        | 165.3                               | 15.05                 |
| 2002        | 170.1                               | 12.18                 |
| 2003        | 170.4                               | 12.55                 |
| 2004        | 170.9                               | 16.13                 |
| 2005        | 176.9                               | 15.19                 |
| 2006        | 181.8                               | 12.96                 |
| 2007        | 185.6                               | 19.21                 |

Source: USDA ERS (2008a)

USDA ERS production and price projections through 2017, are shown in table T-3 below. The USDA ERS production forecasts through 2017 above are based on a nearly 1 percent annual average production growth rate. This forecast is consistent with La Due et al (2003), who argue

that the main driver of dairy demand growth in the United States is likely to be overall population growth.

**Table T-3. Projected U.S. Production and Prices for All Milk**

| <b>Year</b> | <b>Production (billions of lbs)</b> | <b>Price (\$/cwt)</b> |
|-------------|-------------------------------------|-----------------------|
| 2008        | 190.1                               | 18.15                 |
| 2009        | 192.3                               | 17.05                 |
| 2010        | 193.7                               | 17.30                 |
| 2011        | 195.4                               | 17.60                 |
| 2012        | 197.8                               | 17.85                 |
| 2013        | 199.4                               | 18.10                 |
| 2014        | 201.3                               | 18.35                 |
| 2015        | 203.2                               | 18.65                 |
| 2016        | 205.9                               | 18.95                 |
| 2017        | 207.5                               | 19.25                 |

Source: USDA ERS (2008b)

California, Wisconsin, New York, Pennsylvania and Minnesota have been the top five dairy producing states in country for over 30 years, although not always in that order and with a growing importance of Western states among the top dairy producers, including Idaho, New Mexico and Washington State (Short, 2004).

### 2.1.2 Meat

Beef production is another important source of demand for alfalfa hay. Table T-4 below provides trend beef consumption data for the US.

**Table T-4. US Domestic Beef Consumption**

| <b>Year</b> | <b>Millions of Pounds</b> |
|-------------|---------------------------|
| 1997        | 25,944                    |
| 1998        | 26,568                    |
| 1999        | 27,172                    |
| 2000        | 27,562                    |
| 2001        | 27,229                    |
| 2002        | 28,080                    |
| 2003        | 27,205                    |
| 2004        | 27,926                    |
| 2005        | 27,919                    |
| 2006        | 28,294                    |
| 2007        | 28,285                    |
| 2008        | 28,281                    |

Source: USDA FAS, 2008.

Total US domestic beef consumption has increased moderately since 1997. Looking back even further, to 1987, the trend annual average growth rate in US domestic beef consumption from 1987 to the current year is about 0.46% a year, or somewhat less than that for all dairy products.

Beef cows represent a much larger portion of total cattle in the US than do milk cows. As of January 2008, there were 96.7 million cattle in the US and just less than ten percent were dairy cows. About 32.6 million were considered beef cows. Only female cattle that have already calved are counted as beef or dairy cows. Male cattle and females who have not calved are not

included. Some of these cattle may be used for beef, but their purposes are not designated by the USDA. There were 54.9 million “other” cattle in the U.S. as of January 2008 (USDA NASS, 2008)

The population growth of beef cows has hovered between -1% and 1% a year for most of the past decade. The overall trend has been slightly negative, registering an average annual growth rate of -0.33% from 1998 to 2008. After a positive spike in 2005 and 2006, beef cow population growth rates have taken a dive in the past two years (-1.21% in 2007 and -0.92% in 2008). Other non-milk cattle have demonstrated a similar long term trend, with a -0.32% average annual growth rate, but with slightly larger ups and downs. These cattle have not, however, seen the same recent population decrease as beef cows have. Growth rates for 2007 and 2008 respectively were 0.46% and -0.18%. The 2008 combined growth rate for all non-dairy cattle was -0.45%, indicating a slight negative population trend at present (USDA NASS, 2008)

Meat production appears to not have been significantly affected so far by the recent decrease in beef cattle. Production has been increasing each year since 2004, but is expected to decrease in 2009 (USDA ERS, 2008a).

**Table T-5. Beef Production**

| Year                         | 2004   | 2005   | 2006   | 2007   | 2008   | 2009   |
|------------------------------|--------|--------|--------|--------|--------|--------|
| <b>Beef (Million Pounds)</b> | 24,548 | 24,683 | 26,153 | 26,421 | 26,827 | 26,385 |
| <b>% Change</b>              | n/a    | 0.55%  | 5.78%  | 1.02%  | 1.52%  | -1.66% |

Source: USDA ERS, 2008a

### 2.1.3 Livestock and Pet Care

Alfalfa hay is also used to feed horses and other domestic equids (domestic equids include horses, ponies, mules, burros, and donkeys). Of the total US equine population in January 1998, 88 percent were horses, 5 percent were ponies, and about 6 percent were mules, donkeys, burros, or miniature horses (USDA APHIS 2008). Table T-6 below provides information on the US on-farm horse inventory.

**Table T-6. On-Farm U.S. Horse and Pony Inventory**

| Year     | Number    |
|----------|-----------|
| 1987     | 2,456,951 |
| 1992     | 2,049,522 |
| 1997 (1) | 2,427,277 |
| 1997 (2) | 3,020,117 |
| 2002     | 3,644,278 |
| 2007     | 4,028,827 |

Source: 1987, 1992, 1997(1): USDA 1997 Census of Agriculture; 1997 (2), 2002: USDA 2002 Agricultural Census, USDA 2007 Census of Agriculture

There is no single consistent source that provides trend U.S. on-farm horse inventory information going back to 1987. While the Census of Agriculture data show little to no horse inventory growth between 1987 and 1997, the USDA 2002 Agricultural Census data shows a consistent increasing growth rate between 1997 and 2007. Moreover, there is no accurate estimate of the current total number of equids in the United States because a count of equids on nonfarm operations does not exist (USDA APHIS 2007).

There are several other categories of livestock and pets that consume alfalfa hay, haylage, meal, or pellets. Table T-7 shows trend US domestic broiler chicken consumption.

**Table T-7. U.S. Domestic Broiler Chicken Consumption**

| <b>Year</b> | <b>Million Pounds</b> |
|-------------|-----------------------|
| 1997        | 22,679                |
| 1998        | 23,151                |
| 1999        | 24,804                |
| 2000        | 25,296                |
| 2001        | 25,481                |
| 2002        | 27,051                |
| 2003        | 27,646                |
| 2004        | 28,836                |
| 2005        | 29,608                |
| 2006        | 30,139                |
| 2007        | 30,036                |
| 2008        | 30,627                |

Source: USDA FAS, 2008.

Domestic broiler chicken consumption is growing at a relatively rapid rate. Looking back even further to 1987, the trend annual average growth rate in broiler chicken consumption is about 3.5 percent. Alfalfa meal and pellets may be included in chicken feed mix, but as there are likely a wide variety of feed substitutes, it is not clear that alfalfa plays as central a role in chicken feed mixes as in hay feed to cattle and horses.

According to Nelson (2008), alfalfa meal and pellets for livestock and pet feed is primarily supplied by mills in Nebraska, Kansas and Ohio. Nelson reports that there is no publicly available dataset on meal and pellet production. She estimates that the alfalfa meal and pellet market totals approximately 110,000 tons. Nelson notes that even if these estimates were off by a factor of 2, these niche markets would represent far less than 1% of total US alfalfa hay production.

Nelson (2008) also argues that the alfalfa nutritional supplement market (for human consumption) is far smaller than the meal and pellet market, and that likewise no publicly available dataset exists. She reports an estimate that the total US alfalfa supplement market could be satisfied with 10 tons of alfalfa hay production, which could be produced on 1-2 acres.

#### *2.1.4 The Organic Segment*

The organic sector is rapidly growing both in the European Union (EU) and the United States (Dimitri and Oberholtzer 2005). Together, consumer purchases in these two regions made up 95 percent of the \$25 billion in estimated world retail sales of organic food products in 2003 (Willer and Geier, 2005). In reporting the results of their annual manufacturer survey, the Organic Trade Association (2007) reports that US organic food sales were estimated to be \$16.67 billion in 2006, up 22% from 2005 (table T-8).



The Organic Trade Association (2007) goes on to note that organic foods have shown consistent annual growth rates of 15% to 21% since 1997, when fairly comprehensive data were first available. Moreover, they report growth rate data based on historical surveys and interviews with long-time participants in the organic foods business in a similar range of nearly 20% annually since 1990. Organic food sales are projected to continue growing at a similar pace through 2010 (table T-8).

**Table T-8. U.S. Organic Food Sales and Sales Growth Forecasts**

| Category of Food | Sales (Millions of \$) |        |        | Annual Sales Growth Rates (%) |           |                             |
|------------------|------------------------|--------|--------|-------------------------------|-----------|-----------------------------|
|                  | 2004                   | 2005   | 2006   | 2004-2005                     | 2005-2006 | Forecasted Annual 2007-2010 |
| Organic Dairy    | 1,731                  | 2,140  | 2,668  | 24                            | 25        | 20                          |
| Organic Meat     | 195                    | 256    | 334    | 31                            | 30        | 27                          |
| All Organic      | 12,460                 | 13,831 | 16,673 | 11                            | 22        | 18                          |

Source: For 2005-2006, Organic Trade Association Manufacturers Survey (2007); For 2004, Organic Trade Association Manufacturers Survey (2006). Data rounded to the nearest integer value.

Of total 2006 organic food sales reported by the Organic Trade Association (2007), 16% were made up of organic dairy products, while another 2% came from organic meat. Moreover, organic dairy product sales in 2006 were reported to represent an increase of 25% over 2005 levels (table T-8). Table T-8 also provides recent trend sales data for organic meat, indicating an even faster growth rate than organic dairy products, though from a much lower base sales level. The Organic Trade Association (2007) notes that overall consumer purchases of organic foods in 2006 represented only 2.79% of total U.S. food sales, though this figure is up from 0.81% in 1997. The Organic Trade Association (2008) reports that while organic dairy sales in the United States represented 0.79% of all dairy sales in 1997, by 2006 that figure had increased to 4% of all dairy sales.

Organic production may be somewhat lagging the growth in demand – the Organic Trade Association (2006) indicated that 52% of respondent firms reported that a lack of dependable supply of organic raw materials has restricted their company from generating more sales of organic products. Willer et al 2008 report that organic agricultural land represented 0.5 percent of all agricultural land in the US in 2006, somewhat below the worldwide average.

There is evidence that perceptions of higher organic food safety may be an important driver for consumer substitution of organic for conventionally produced food. In particular, Dimitri and Oberholtzer (2005) argue that changes in organic and conventional food demand are driven in part by “food scares.” They note, for example, that mad cow disease (Bovine Spongiform Encephalopathy - BSE) was considerably affected to the European organic livestock and dairy industry. Dimitri and Oberholtzer (2005) report that in response to news reports on BSE, many consumers substituted organic dairy and meat products (which European consumers perceived as safer) for conventionally raised dairy and meat products. For example, they report that organic food sales in Germany increased by 30 percent in 2001 as a result of BSE.

Moreover, Dimitri and Oberholtzer (2005) report that other food scares that caused European consumers to substitute organic for conventionally produced food include episodes of contaminated chicken feed in Belgium in 1999, feed contaminated by dioxin in 2004, and more

recently, carcinogenic food dyes in TV dinners in Ireland in 2005. It is interesting to note, however, that Dimitri and Oberholtzer (2005) do not find evidence that U.S. consumers are as strongly affected by food scares.

## 2.2 Consumer Sensitivity to Genetically Engineered Content in Food

Most U.S. consumers are unaware of the prevalence of GE products in the US food supply (Anderson et al. 2006; Hallman and Hebden 2005; Thomson and Dininni 2005). Hallman et al. (2003) found that only one-fourth of US residents believed that they had ever consumed food containing GE ingredients. There seems to be no estimate available of consumer demand for GE-free food products (Noussair et al, 2004).

However, in the last decade, there has been a considerable number of attempts to identify consumer preferences regarding GE foods, in and outside the United States, most of them based on consumer surveys, done under various conditions, asking consumers to express their preferences under hypothetical situations. The results overwhelmingly show lack of information regarding GE foods and considerable resistance towards their consumption (Hallman and Aquino, 2003).

For example, various Eurobarometer<sup>77</sup> surveys have reported that most Europeans are not able to correctly answer whether the phrase “ordinary tomatoes do not contain genes, while genetically modified tomatoes do” is true or false (Rigby et al, 2004). Anderson et al. (2006) argue that while the specifics differ, in general the literature indicates that US consumers have relatively little knowledge of biotechnology.

Many contingent valuation studies exist for Europe, United States, Japan and Australia reporting that consumers are typically willing to pay a higher price for GE-free foods, and various articles review this literature (Lusk et al, 2004; Rigby et al, 2004).

Contingent valuation studies and surveys based on hypothetical situations are known to be very poor predictors of actual behavior in the market (Noussair et al, 2004; Fernandez-Cornejo and Caswell, 2006). To address this deficiency, a number of studies have implemented experiments, in which consumers actually get to choose among products and benefit from their choices. Lusk et al (2004) develop a meta-analysis of 25 studies including 57 valuations of GE foods. Most of the studies analyzed are for the United States, a third is for Europe and other studies include Asia, Canada and Australia. Seventeen of the studies are based on consumer surveys while eight are based on experiments. They find that the willingness to pay for GE-free foods was lower in experimental studies, although still positive.

A number of other studies have investigated whether the resistance to GE foods and the lack of information regarding biotechnology are correlated. Chern and Rickertsen (2002) conducted a student survey in four countries (United States, Japan, Norway and Taiwan) and a national phone survey in the United States and Norway. Willingness to consume GE foods increased when it was explained that GE foods could include benefits such as the reduced use of pesticides.

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<sup>77</sup> Surveys conducted on a regular basis for the European Commission, executive branch of the European Union

Bertolini et al (2003) compared attitudes towards GM foods in the US, Japan and Italy in random surveys of food shoppers. They also found a positive impact of familiarity with GE products on acceptance. On the other hand, Hallman and Aquino (2003) conducted a survey of a random sample of US households and found out that improved information on GE foods did not necessarily mean increased approval. Those most knowledgeable about genetic engineering tended to have more extreme opinions, in favor or against, than those less knowledgeable. Noussair et al (2004) also found that prior beliefs regarding GE foods had a stronger influence on consumer choice than information.

Studies also exist investigating how consumers value varying levels of content of GE products in their foods. In an experiment in France, where consumer surveys reveal very strong resistance to GE products, Noussair et al (2004) found that 89% of consumers were willing to purchase a product with up to 1% GE content and 96% with up to 0.1% GE content. They also found that consumers differentiated between GE-free and 0.1% of GE content. Rigby et al (2004), on the other hand, in a nationwide study of the United Kingdom found that consumers did not distinguish between 0% and 0.5% GE levels and did not place a value in having products with 0% GE content as opposed to 0.5%.

In response to consumer concerns, over forty countries have adopted labeling regulations for GE products (Guère et al, 2007)<sup>78</sup>. In Europe, the main impact of labeling requirements has been the virtual disappearance of many GE products, given that the cost differentials in production are small (since often GE ingredients are a minor share of total ingredients in products) and the risk of loss of market share is high given the perceived consumer resistance (Guère et al, 2007). In addition, to the extent that labeling requirements require segregation of GE and non-GE products throughout the production process, labeling may imply considerable costs (Noussair et al, 2004).

### *2.2.1 United States*

There is relatively little literature specifically assessing purchase motivations associated with genetically engineered foods in the United States, which Anderson et al. (2006) attribute in part to the current lack of genetically engineered content labeling. In their summary of 25 valuation studies relating to GE food, Lusk et al. (2005) found that U.S. consumers are more receptive to GE foods than their European counterparts, although a preference for non-GE foods remains, suggested by various estimates of willingness to pay for GE-free foods.

Lusk and Rozan (2005) attribute differences in GE product receptivity by consumers in France and the United States, partially to differences in information about GE foods and partially to different levels of trust in the sources providing information. While the United States showed greater knowledge of GE foods, there was also greater trust in the institutions delivering the information (food regulatory agencies, universities, agribusiness). Rigby et al (2004) find similar results for the United Kingdom as Lusk and Rozan (2005) find for France regarding the lack of trust of consumers towards institutions concerning information about GE products. The only institutions that more than 10% of consumers were willing to trust for information were universities/educational organizations.

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<sup>78</sup> Some of these regulations have not yet been implemented or only partially so.

There is some evidence that consumers support genetic engineering for use in crops to a greater extent than in animals from which dairy, meat, and other food products derive (Ganiere et al. 2006). Hallman et al. (2003) reported that one-half of US residents surveyed approved of plant-based genetic engineering, while only one-quarter approved of it for use in animal agriculture.

Lusk et al. (2003) developed a mail survey sent to consumers in France, Germany, the United Kingdom, and the United States concerning preferences relating to the use of growth hormones and GE corn feed in cattle from which ribeye steaks were produced. The survey contained a choice experiment in which consumers made choices between ribeye steaks with varying levels of price, marbling (intramuscular fat), tenderness, and use/ non-use of growth hormones and genetically engineered corn in livestock production. Lusk et al. (2003) found that European consumers were more concerned about the use of genetic engineering and biotechnology than consumers in the United States. On a scale of 1 (not at all concerned) to 5 (very concerned), Lusk et al. (2003) found that consumers in France, Germany, and the United Kingdom reported average levels of concern of 4.73, 4.53, and 4.24, whereas the average US level of concern was 4.00. They also found that US consumers are more averse to hormone use than use of GE animal feed.

Fernandez-Cornejo and Caswell (2006) argue that there are many products in the United States that contain GE ingredients, and that the demand for these products apparently has been unaffected by negative opinions about biotechnology expressed in surveys. Putnam (2005) makes this same point, arguing that GE crops such as corn and soybeans have been used as animal feed for years with no perceptible impact on the marketing of beef. He observes beef consumers are more concerned with hormones and antibiotics or diseases such as Mad Cow disease.

The evidence so far suggests that although US consumers prefer to avoid GE foods, they are less concerned than their European counterparts. Other GE crops (e.g., corn, soybeans, canola) have been deregulated in the US for a number of years with no substantial drop in demand for conventionally produced dairy products or meat.

In the case of organic foods, one of the unique attributes of organic foods, and one reason consumer demand for organic foods is increasing, is the intended absence of GE ingredients in the process of producing them (Anderson et al. 2006; Dhar and Foltz 2005; Larue et al. 2004).

The USDA National Organic Program (NOP) standards currently require that goods labeled “100% organic” must be produced and handled without the use of excluded methods, one of which is the form of genetic engineering used to produce GT alfalfa cultivars. Livestock standards applied to animals used for meat, milk, eggs, and other animal products call for animals to be fed 100% organic feed, with vitamin and mineral supplements excepted (USDA NOP 2008). At the present time, however, there is no policy regarding the unintended presence of GE material in organic products or food, consistent with the fact that the NOP is process-based, not product-based. By way of comparison, the NOP has a content threshold for synthetic pesticide residues equal to 5% of the EPA’s specific tolerance level for each type of pesticide residue detected (Ronald and Fouche 2006).

## 2.3 Discussion

The evidence above suggests a preference for GE-free foods among some U.S. consumers is often detected in consumer surveys. However, there is little evidence that this stated preference translates into decreased demand for conventional foods.

There is some debate on whether the absence of mandatory labeling for GE foods in the U.S. leaves the consumer less informed about the available choices than the current system of voluntary labeling with various authors suggesting this is not the case (Bansal and Ramaswami, 2007; Huffman et al, 2002).

Some suggest, however, that preference for GE-free foods may be correlated with the growth of organic foods. Anderson et al. (2006) argue that along with ethical considerations, the potential motivators for GE-free foods will likely mirror those of the organic industry, linking acceptance to perceptions of the benefits and risks associated with human health, safety, ethics, and the environment (Larue et al. 2004; Onyango and Nayga 2004). Much of the information that US consumers currently have regarding purposeful GE content in the foods they eat comes from the presence or absence of organic labels (Ganiere et al. 2006). There is some evidence that attitudes about organic foods can be a useful indicator of attitudes about foods with GE content, at least outside of the United States (Burton et al. 2001).

There is some evidence of higher levels of consumer confidence in organic foods, particularly in comparison to conventionally produced foods made in the absence of restrictions or content labels indicating GE content (e.g., Anderson et al. 2006; Owen et al. 2005). In the context of deregulating GT alfalfa as livestock feed, there is thus the potential for an additional increase in demand for organic foods as a substitute for conventional foods.

Successful marketing of NOP certified foods has already had to contend with the risk of GE material accidentally spreading from deregulated cultivars of soybeans, corn, and canola to organic crops. Despite the potential for unintended presence of GE material, however, the evidence cited above indicate that organic food sales in the United States continue to grow at a rapid rate.

As noted earlier, one reason may be that most US consumers do not appear to have strong or well-formed adverse opinions regarding health or safety impacts from GE foods deregulated for US production. Another is that ethical and environmental factors largely unrelated to unintended presence of GE material are important drivers of organic demand (Anderson et al. 2006). While there is the potential that organic food sales would have grown even more rapidly in the absence of this risk, no published studies have been found that document or estimate this effect.

Will organic food sales continue to grow at current trend rates in the context of the deregulation of GT alfalfa? In the absence of published studies documenting prior adverse impacts on organic food demand from previously deregulated genetically engineered crop cultivars, we cannot conclude that this will or will not occur.

One niche sector that may potentially benefit from consumer concerns regarding unintended presence of GE material is farmers' markets, to the extent that they serve as an outlet for dairy and meat products. However, most states regulate or prohibit the sale of fresh meat and milk due to food safety concerns at Farmers' Markets ([http://www.ksda.gov/food\\_safety/content/318](http://www.ksda.gov/food_safety/content/318), <http://www.vermontagriculture.com/agdev/documents/farmersMarketRegulations.pdf>, <http://www.agr.state.ne.us/pub/daf/farmmkt.htm>, <http://www.cga.ct.gov/2006/ACT/PA/2006PA-00052-R00SB-00294-PA.htm>, <http://www.portlandmaine.gov/voter/farmerrules.pdf>, [http://www.ccdeh.com/commtee/food/documents/Guidelines/Certified\\_Farmers\\_Markets.pdf](http://www.ccdeh.com/commtee/food/documents/Guidelines/Certified_Farmers_Markets.pdf)). Kremen et al. (2004) find, for example, many customers at farmers' markets value having direct access to farmers that use ecologically sensitive agricultural techniques—such as organic production methods—on their farms. The trust relationships and repeated direct interaction between local small-scale farmers and consumers at farmers' markets may serve as an alternative to conventional grocery store purchases in the context of concerns about the presence of GE material in foods. As organic farmers make disproportionately high use of farmers' markets as sales outlets (Kremen et al. 2004), again it isn't clear that the overall organic food sector will suffer a decline in demand.

Taken as a whole, there is no evidence to suggest that deregulation of GT alfalfa will reduce demand for organic foods. The evidence presented in section 2.2 suggests that the deregulation of GT alfalfa may in fact increase demand for organic foods.

## 2.4 Summary of Findings

There is evidence of moderate overall growth in key downstream markets for alfalfa. There is also evidence of some consumer preference for GE-free foods in the United States. Growth trends in downstream markets, however, occurred in the context of the US deregulation of other GE feed crops such as corn and soybeans. There is no evidence on whether these trends would have been higher or lower in the absence of GE feed.

Consumer preference for GE-free foods may have contributed to strong growth in the organic sector. There is no evidence to suggest that deregulation of GT alfalfa will reduce demand for organic foods. The evidence presented indicates that consumer preferences for organic over GE foods are influenced in part by ethical and environmental factors that are likely unrelated to minor unintended presence of GE material in feed crops. Moreover, there is no evidence that any GE material (either the transgenic DNA or the transgenic protein) in animal feed currently in use is actually transmitted to milk or meat (Phipps et al. 2006), and there is no evidence that the GT trait in alfalfa has an effect on the composition of the milk (Combs and Hartnell, 2007). Therefore, no tests can be conducted on the milk or meat to confirm the presence or absence of GE material. The demand for organic foods has steadily grown at double-digit rates throughout the period of time in which other GE animal feeds have been deregulated for use in the US. The evidence presented above suggests that there is actually the possibility that deregulation of GT alfalfa may in fact increase demand for organic foods as consumers concerned with GE foods may switch to organic products, in the absence of GE labeling.

## 3.0 Impacts of Changes in Production Costs

### 3.1 The Role of Alfalfa Feed Costs in Downstream Production

#### 3.1.1 Dairy

USDA estimated production costs for dairy farms in the United States based on the 2005 Agricultural Resources Management Survey (ARMS). According to these data, feed corresponds to 30%-60% of total production costs per hundredweight (100 pounds) sold. The weight of feed on total costs is larger for smaller farms given the lower productivity and relatively larger overheads. As farmers may choose to attribute overhead costs to other farm products or abdicate from covering them for short periods of time, it is relevant to also look at the share feed costs represent on operational costs: roughly 70-85%. This suggests the price of feed is a major determinant of the cost of dairy production for dairy farms.

**Table T-9. Weight of Feed Costs in Dairy Farms**

| <b>Farm Type</b>               | <b>Feed costs/ Operational costs</b> | <b>Feed costs/ Total costs</b> |
|--------------------------------|--------------------------------------|--------------------------------|
| Conventional U.S.              | 73.3%                                | 44.1%                          |
| Conventional California        | 79.7%                                | 57.8%                          |
| Conventional Wisconsin         | 72.0%                                | 40.4%                          |
| Conventional <50 cows          | 73.4%                                | 30.0%                          |
| Conventional 1000 cows or more | 83.3%                                | 44.1%                          |
| Organic U.S.                   | 77.8%                                | 41.9%                          |
| Organic <50 cows               | 76.9%                                | 33.7%                          |
| Organic 200 cows or more       | 79.6%                                | 42.8%                          |

Source: USDA ERS, 2005

Alfalfa is likely a considerable share of feed costs. Short (2004) reports hay and straw, presumably mostly alfalfa, representing roughly a third of feed costs. Alfalfa may additionally be used in cubes or pellets. In some regions (Wisconsin, Minnesota) haylage is also a significant share of feed.

In our Technical Report *Changes in the Economics of Alfalfa Farming with the Deregulation of Glyphosate-Tolerant Alfalfa* (appendix K) we argued that adoption of GT alfalfa is likely to increase the quality of alfalfa for forage without an increase in costs. This should increase productivity of dairy farms and allow for an increase in production without an increase in costs. We argued that this would correspond to a shift downwards (increased production at lower prices) in the supply curve of alfalfa for forage.

The impact on dairy farms will be to increase the feasibility of operations. MacDonald et al (2007) report that currently many small dairy farms are operating with incomes above operational costs but below total costs (they are not covering overhead and capital recovery costs). The impact on reduced costs will, however, impact farms of all sizes, since feed seems to be of similar importance to all farms. If GT alfalfa requires less household labor, this may come to the advantage of smaller farms where household labor is a greater share of costs.

Whether decreased dairy farm production costs and a potential increase in production will reflect in reduced prices for dairy is not clear. A report by the United States General Accounting Office (2001) studied the factors influencing farm and retail dairy prices. The report notes that changes

in milk production costs do not necessarily reflect in changes in retail prices of dairy. Farmer milk prices represent roughly 40% of retail milk prices and are affected by Federal and State programs establishing minimum prices. The process of transmission of dairy farms costs to prices is not a simple one to determine.

### *3.1.2 Meat*

USDA ERS produces cost estimates annually for a variety of farm products. According to the latest estimates (2005-2006), feed corresponds to an average of 56.8% of operational costs and 28.8% of total costs of cow-calf production (USDA ERS, updated 2008). Harvested forages correspond to almost half of feed costs (46.9%). Short (2001) reports somewhat lower figures: 35% of operational costs and 20.8% of operational and ownership costs (capital recovery, taxes insurance) are attributes to feed and only between 10-20% of feed costs would correspond to purchased harvested forages.

Alfalfa is likely a lower share of feed costs in cow-calf production than it is in dairy production since the main source of feed is grazing (Short, 2001). As cattle move on to feedlots (sometime through stocker operators) feed becomes mostly grain based ration.

The impact of potentially reduced alfalfa costs on meat production may be important for cow-calf production, particularly in areas where supplementary feeding is more important in winter, such as the North Central region – Iowa, Illinois, Missouri (Short, 2001). If the alfalfa used is often of lower quality (Klonsky et al, 2007) this impact would depend on the extent to which reduction in prices of high quality alfalfa also brings down that of lower quality alfalfa.

Short (2001) argues that prices paid for cattle tend to be similar across the country, despite differences in cow-calf production costs because cattle are routinely transported. This suggests that any transfer of cost changes to prices down the chain is unlikely.

### *3.1.3 Livestock and Pet Care*

Of the remaining potential sources of demand for alfalfa hay, the most important is likely horses. Putnam (2005) estimates that horses may consume between 5%-15% of alfalfa hay in California. He also, however, describes the horse market for alfalfa hay as idiosyncratic, subjective, and supplied by alternative hay such as timothy and grass. We have not found sufficient reliable information – budgets and potential substitutability within horse feed – to generate an informed analysis of the impact of GT alfalfa deregulation on the horse market.

## **3.2 Substitution Effects**

One reason why the extent to which potentially reduced alfalfa costs affect downstream market prices is important, is that it may cause substitution of products produced with lower cost/higher quality alfalfa for product produced with higher cost/ lower quality alfalfa. As an example, if lower GT alfalfa costs translated into lower conventional dairy prices, the price differential between organic dairy products and conventional dairy products would increase, reducing the



number of consumers willing to pay higher prices for organic dairy. This would trickle back to organic alfalfa farmers that would face reduced demand for organic alfalfa.

In the case of dairy products there may be a shift towards the use of GT alfalfa as forage and a shift towards higher quality alfalfa hay, as argued in our Technical Report *Economic and Social Impacts to Conventional and Organic Farmers of Deregulation of Glyphosate-Tolerant Alfalfa* (appendix S). To the extent that alfalfa and other forms of feed are substitutes, there may also be some shift towards alfalfa based feed. However, beyond the farm gate, we are unable to tell whether there will be any transmission of lower costs to dairy prices. As previously explained, the establishment of milk prices is regulated by federal and state programs and its response to shifts in costs, as well as to changes in supply and demand is not clear.

To the extent that any increases in milk production are allowed by decreased feed costs, and to the extent that dairy prices response to shifts in milk production, there could presumably be some pressure downwards in dairy retail prices. However, as previously noted, dairy retail prices suffer a greater influence from other factors.

In the case of meat, we found little reason to believe changes in costs will be transmitted down the production chain such as to significantly impact meat prices.

Impacts of decreased costs of alfalfa on downstream markets for livestock and pet care will likely not significantly reflect back on the demand for alfalfa hay, given the minor share of these downstream markets in overall demand for alfalfa.

### 3.3 Summary of Findings

Expected lower prices/ higher quality of alfalfa hay will likely benefit dairy farmers and to a lesser degree cow-calf production.

The reduced costs in dairy and meat farming may not be transmitted to dairy and meat products. In the case of dairy, this is because of dairy price regulation. In the case of meat, this is because of the relatively low weight of alfalfa in total costs. The result is that price differentials between organic and conventional dairy and meat products may not be affected by the increased supply of high quality alfalfa hay expected with GT alfalfa deregulation.

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## **Appendix T-2. Literature Search**

### **1.0 Literature Search Strategy**

For data on downstream markets we searched mostly USDA sources.

For the literature on GE sensitivity of demand, the search started with general internet searches and then snowballed from references found in various papers. Most of the references come from academic journals and conferences.

Cost studies for dairy and meat production were found with USDA's Economic Research Service using information from the Agricultural Resources Management Surveys.





## **Appendix U: Character and Quality of Glyphosate-Tolerant Alfalfa Traits**

# Character and Quality of Glyphosate-Tolerant Alfalfa Traits

## 1.0 Introduction

Monsanto Company and Forage Genetics International (FGI) have developed varieties of Roundup Ready<sup>®</sup> alfalfa using *Agrobacterium*-mediated transformation to stably incorporate into the alfalfa genome a coding sequence that produces a glyphosate-tolerant (GT) form of the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS). The production of the CP4 EPSPS protein in plant tissues is the basis of the Roundup Ready, glyphosate-tolerant trait in alfalfa varieties. GT alfalfa is tolerant to foliar applications of glyphosate allowing for post emergent control of most weeds in alfalfa fields. The methodology for plant transformation and subsequent product characterization data are described in detail in Petition Number 04-110-01p ([http://www.aphis.usda.gov/brs/aphisdocs/04\\_11001p.pdf](http://www.aphis.usda.gov/brs/aphisdocs/04_11001p.pdf)). GT alfalfa varieties have been commercialized using a combination of the two different *cp4 epsps* insertion events (J101 and J163) combined through a conventional breeding process.

### 1.1 Weed Potential (Phenotypic Assessment)

Monsanto and FGI have performed a characterization of GT alfalfa populations containing events J101 and J163. Information was developed to assess whether the trait, the transformation process, or ensuing tissue culture process produced alfalfa events that would impact the plant pest characteristics of alfalfa differently than those observed for the control or conventional alfalfa varieties. Phenotypic, agronomic and compositional information also were provided to assess whether other plant characteristics were affected by the transformation as a means to detect if any unintended effects may be involved. For alfalfa, characteristics that may impact plant pest risk include enhanced growth, vigor or stand longevity; changes in susceptibility to plant pests and diseases; increases in seed yield; and changes in seed dormancy. The overall conclusions from the characterization were that there are no biologically meaningful differences between alfalfa populations that contain event J101 or J163 and the nontransformed alfalfa control or alfalfa reference variety populations (USDA EA for petition 04-110-01p, [http://www.aphis.usda.gov/brs/aphisdocs2/04\\_11001p\\_com.pdf](http://www.aphis.usda.gov/brs/aphisdocs2/04_11001p_com.pdf)). Crop compositional data and other phenotypic and agronomic data also led to the conclusion that alfalfa populations containing event J101 or J163 were not different from the nontransformed control or conventional alfalfa populations (USDA EA for petition 04-110-01p, [http://www.aphis.usda.gov/brs/aphisdocs2/04\\_11001p\\_com.pdf](http://www.aphis.usda.gov/brs/aphisdocs2/04_11001p_com.pdf)). The phenotypic evaluation was based on both laboratory experiments and replicated, multi-site field trials conducted over five years (1999-2003) by agronomists and scientists who are familiar with the production and evaluation of alfalfa. In each of these assessments, event J101 and event J163 were compared to an appropriate alfalfa control. Detailed information may be found in section VI of Petition Number 04-110-01p. As a result of this assessment, it was concluded that there were no

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meaningful changes in the phenotype of J101 and J163 and no increased pest potential (USDA EA for petition 04-110-01p, [http://www.aphis.usda.gov/brs/aphisdocs2/04\\_11001p\\_com.pdf](http://www.aphis.usda.gov/brs/aphisdocs2/04_11001p_com.pdf)). Broad data categories evaluated as part of the phenotypic and familiarity assessment are presented in table 1. The vast majority of this information was previously submitted to USDA in Petition Number 04-110-01p. A summary of the characterization data developed to support the food, feed and environmental safety assessment as well as additional relevant information developed after deregulation is provided in the following sections.

**Table U-1. Data Categories Evaluated for Assessment of Weed Potential and Familiarity of Glyphosate-Tolerant Alfalfa**

|                              |                                                                                                                                                                                                                                                                                                                                                                                                        |
|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Phenotype/agronomic          | Comparative information on the growth and development characteristics listed below was collected on test or control alfalfa populations to determine whether the trait or transformation process altered alfalfa's weed potential. Except where noted, data were collected from alfalfa established at four locations over three seasons using a randomized complete block design with four replicates |
| Seedling emergence           | Number of emerged seedlings two to three weeks after establishment. (Faster seedling emergence may result in greater weediness potential)                                                                                                                                                                                                                                                              |
| Seedling vigor               | Evaluation of seedling vigor three to four weeks after establishment. (Greater seedling vigor may result in greater weediness potential)                                                                                                                                                                                                                                                               |
| Spring vigor                 | Evaluation of spring re-growth in the second and third season at the 4-6 inch stage. (Higher spring vigor may result in greater weediness potential)                                                                                                                                                                                                                                                   |
| Spring stand                 | Determination of the percentage of plants surviving winter at the beginning of the second and third season. (Better spring stand may result in greater weediness potential)                                                                                                                                                                                                                            |
| Forage/seed yield            | Forage yield taken at approximately 4-6 week intervals throughout the season. Seed yield taken from greenhouse and field grown plants. (Higher forage yield (faster growing plant) and higher seed yield (more and or larger seeds) may result in greater weediness potential)                                                                                                                         |
| Crop growth at cutting       | For selected cuttings, crop growth stage was determined using the Mean Stage by Count (MSC) method (Kalu and Fick, 1981). (Changes in plant growth and structure may result in greater weediness potential)                                                                                                                                                                                            |
| Regrowth after cutting       | Regrowth at 10 to 15 days after each cutting in the second and third season. (Faster regrowth may result in greater weediness potential)                                                                                                                                                                                                                                                               |
| Fall plant height            | Fall plant height measurements taken in the second and third seasons as an indicator of fall dormancy. (Changes in fall plant height may result in greater weediness potential)                                                                                                                                                                                                                        |
| Fall growth habit            | Categorical score of selected plants for fall growth habit as upright, prostrate, or a mixture of both types. (Changes in fall growth habit may result in greater weediness potential)                                                                                                                                                                                                                 |
| Biotic and abiotic stressors | Observation of alfalfa response to insects, diseases, weeds and abiotic stressors during growing season. (Greater tolerance to stressors may result in greater weediness potential)                                                                                                                                                                                                                    |
| Reproductive characteristics | Assessment of flower morphology, pollen morphology, and pollen viability in greenhouse grown plants. (Changes in reproductive characteristics may result in greater weediness potential)                                                                                                                                                                                                               |
| Stand longevity              | Census of plants remaining in the stand taken at the end of each season (three seasons, one location). (Greater stand longevity may result in greater weediness potential)                                                                                                                                                                                                                             |
| Allelopathy                  | Evaluation of allelopathic potential of alfalfa through laboratory analyses of plant root exudates and field observations of rotational crop growth and development. (Higher level of allelopathy may result in greater weediness potential)                                                                                                                                                           |
| Crop composition             | Compositional evaluation of forage as a measure of lack of unintended effects (McCann, et al., 2006; Steckel and Hayes., 2006))                                                                                                                                                                                                                                                                        |
| Dormancy/germination         | Germination and dormancy potential measured over multiple temperatures using seed industry standard testing methods (AOSCA, 2003). (Faster germination and changes in seed dormancy may result in greater weediness potential)                                                                                                                                                                         |
| Gene flow                    | Determination of amount of gene flow using <i>cp4 epsps</i> as a marker (Fitzpatrick, et al., 2003)                                                                                                                                                                                                                                                                                                    |
| Plant biogeography           | Census of feral alfalfa populations present in six U.S. alfalfa producing states (Kendrick, et al., 2005)                                                                                                                                                                                                                                                                                              |
| Symbiotic organisms          | Measurement of nodule numbers and morphology in greenhouse and field grown plants to assess symbiotic relationship between <i>M. sativa</i> and <i>Sinorhizobium meliloti</i>                                                                                                                                                                                                                          |

## 2.0 Crop Compositional Assessment

Crop compositional data were reviewed and analyzed by USDA APHIS as part of the familiarity assessment and to confirm that there were no unintended effects. These data also were provided to the FDA to confirm food and feed safety comparable to conventional alfalfa varieties. A brief summary of the information reviewed by USDA and FDA follows. GT Alfalfa varieties were grown at five replicated field sites across the alfalfa-producing regions of the U.S. during the 2001 field season. Field sites were located in the states of California, Illinois, New York, Washington and Wisconsin. Plots containing GT alfalfa lines were treated with a Roundup agricultural herbicide at 1.5 lbs a.e./acre/application. Multiple applications were made to each field site (up to 7.5 lb a.e./acre). Forage samples were collected from all plots and analyzed for nutritional components. Compositional analyses of the forage samples included proximates (protein, fat, ash and moisture), acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin, amino acids, and minerals (calcium, copper, iron, magnesium, manganese, phosphorous, potassium, sodium and zinc), as well as carbohydrates by calculation. In all, 35 different components were analyzed to assess the composition of GT alfalfa.

Components measured are consistent with those suggested by the OECD consensus document (OECD, 2005). To confirm the nutritional equivalence and evaluate whether the trait or transformation process had any unintended effects on alfalfa, the following components were measured: proximates (moisture, protein, fat and ash; carbohydrates), concentration of individual amino acids, ADF, NDF, lignin, and minerals (calcium, copper, iron, magnesium, manganese, phosphorus, potassium, sodium and zinc). Components were selected after consideration of the role alfalfa plays as a source of nutrients in the diet and on the basis of what animal nutritionists consider is important from a feeding value perspective. Protein, ADF, NDF, fat, ash and lignin are used to determine the feeding value of alfalfa. Lignin is also usually the major factor limiting digestion of cell walls which in-turn impacts digestibility. High concentrations of lignin may reduce digestibility and can be an anti-quality factor. The feeding value of alfalfa exceeds that of other perennial grasses primarily because alfalfa has higher intake potential associated with faster digestibility. Minerals present in alfalfa can contribute significantly to meeting the mineral requirements of animals. The mineral content of alfalfa is taken into account by livestock nutritionists when formulating diets to meet or exceed National Research Council guidelines for maintenance, growth and lactation. Measurement of individual amino acids was included because CP4 EPSPS is involved with the synthesis of aromatic amino acids, which are important as a source of protein in alfalfa animal feed.

Statistical evaluation of the composition data involved comparison of the forage from the alfalfa test lines to the nontransgenic control. Statistically significant differences were determined at the 5% level of significance ( $P \leq 0.05$ ). Compositional data on forage derived from the GT alfalfa plants containing event J101, J163, or the confirmatory synthetic population, J101XJ163, were reviewed and analyzed by USDA APHIS (data found in section VI, subsection H of Petition Number 04-110-01p). It was concluded that forage derived from J101 and J163 was compositionally equivalent to forage produced by conventional alfalfa (USDA EA for petition 04-110-01p [http://www.aphis.usda.gov/brs/aphisdocs2/04\\_11001p\\_com.pdf](http://www.aphis.usda.gov/brs/aphisdocs2/04_11001p_com.pdf)).

Additional compositional analyses conducted after deregulation of GT alfalfa support these same conclusions. McCann et al (2006) summarized compositional data derived from GT alfalfa harvested in the establishment year and in the third year of the stand. These data are the same as those reported in Petition Number 04-110-01p. Forage analyses of samples collected from the third year included coumestrol, an important phytoestrogen. In this study, GT alfalfa had been treated multiple times with Roundup Agricultural herbicide at 1.5 lbs a.e./acre with cumulative doses of up to 7.5 and 16.5 lbs a.e./acre for the 2001 and 2003 growing seasons, respectively. It was concluded that forage derived from the 2001 and 2003 plots was compositionally equivalent to that derived from the control and conventional alfalfa plots, thus confirming compositional equivalence between GT alfalfa and conventional alfalfa forage. Furthermore, cumulative glyphosate treatments had no effect on the quality of forage harvested from GT alfalfa. Similarly, Steckel and Hayes (2007) concluded that forage quality and yield were unchanged over a three year period where GT alfalfa was treated numerous times at various single application rates (0.75 to 3 lbs a.e./acre) with a cumulative dose of 9 lbs a.e./acre.

### **3.0 Nutrient/Water Uptake**

Agriculture is a major user of ground and surface water in the United States, accounting for over 80 percent of fresh water in the U.S. and exceeding 90% in some western states, which is the major area for irrigated agriculture (USDA-ERS, 2007). Where agricultural lands are irrigated, alfalfa is one of the crops contributing to the use of water. As noted in the EA (USDA EA for petition 04-110-01p [http://www.aphis.usda.gov/brs/aphisdocs2/04\\_11001p\\_com.pdf](http://www.aphis.usda.gov/brs/aphisdocs2/04_11001p_com.pdf)) and the petition, there are no phenotypic or compositional changes in GT alfalfa; therefore, it is expected that the impact on water use due to cultivation of GT alfalfa would be no different than the water used in cultivating conventional alfalfa. In the petition, data were not developed to specifically address water uptake.

Compositional data included the measurement of micronutrients in forage and, with the exception of iron, there were no biologically meaningful differences between GT alfalfa and control or conventional alfalfa. See section VI, subsection H of Petition Number 04-110-01p and McCann et al. (2006). According to McCann et al. (2006), the increase levels of iron were not associated with nutrient uptake because they were concluded to be due to environmental contamination. Previous reports on the yellow flash in soybean (Gordon, 2005; Ebelhar et al., 2005) suggest that application of glyphosate to GT soybean may effect manganese uptake or metabolism in soils with low levels of manganese, that are on bottomlands, are sandy, or that have high pH levels (pH 6.5 or greater). GT alfalfa varieties were not specifically tested under these conditions; however, levels of manganese were measured in forage and were not significantly different from the control. Since soybean and alfalfa are both legumes, an assumption can be made that yellow flash may occur in alfalfa under special circumstances; but as with soybean, this condition can be expected to not be considered serious with alfalfa.

Alfalfa is a plant that provides nitrogen to the soil due to a *Rhizobium*-legume symbiotic relationship, and high rates of nitrogen fixation are typically observed in alfalfa (Vance et al., 1988). Information reviewed and analyzed by USDA APHIS found in Petition Number 04-110-

01p (section VI, subsection I) showed that there were no differences in the number of nodules or gross morphology of nodules associated with GT alfalfa compared to control alfalfa. Furthermore, when glyphosate agricultural herbicides were applied to GT alfalfa, no differences in nitrogen fixation indicators including total protein levels, amino acids asparagine and aspartate, and forage yield, were observed in GT alfalfa compared to control. Thus, it is not expected that cultivation of GT alfalfa with subsequent applications of glyphosate will impact nitrogen fixation and subsequent nitrogen credits. In soybean, a temporary decrease in the level of *Rhizobia* has been noted after glyphosate application (King et al. 2001, USDA EA GT soybean). Since soybean and alfalfa are both legumes, an assumption can be made that a temporary decrease in *Rhizobia* may occur in alfalfa under special circumstances, but as with soybean, this condition can be expected to not be considered serious with alfalfa.

### 3.1 Disease and Pest Susceptibility

During confined release field trials and after commercialization of GT alfalfa in 2005, GT alfalfa was grown and tested at a broad geographic distribution of sites in the U.S. exposing the varieties to a wide range of naturally occurring diseases and disease complexes. The major diseases of economic importance in the U.S. are those alfalfa pathogens that impact the foliar, crown, root, vascular and seedling health of alfalfa plants. The majority of alfalfa diseases are caused by fungi. However, nematodes, bacteria, viruses and other microbes also incite economic losses in alfalfa production (Leath et al. 1988). The major economic diseases that occurred in the test locations included, but were not limited to: seedling damping-off (e.g., fungal genera such as *Pythium*, *Phytophthora*, *Aphanomyces*); foliar diseases (e.g., fungal genera such as *Leptosphaerulina*, *Colletotrichum*, *Peronospora*, *Phoma*, *Stemphylium*, *Cercospora*, and stem nematodes like *Ditylenchus*); and root rots, vascular wilts and crown diseases (e.g., fungal genera such as *Phytophthora*, *Verticillium*, *Fusarium*, *Phoma*, and bacterial wilt caused by *Clavibacter*).

The major insect pest species that are economically important in alfalfa vary widely among regions in the U.S. The broad geographic distribution of the GT alfalfa test sites in the U.S. and even broader exposure since deregulation in 2005 has exposed GT alfalfa to a wide range of naturally occurring insect pests. The major economic insects included, but were not limited to: potato leafhoppers (*Empoasca fabae*), aphids [pea (*Acyrtosiphon pisum*), blue (*A. kondoi*) and spotted alfalfa aphids (*Therioaphis maculata*)], alfalfa weevil (*Hypera postica*), lygus bugs (*Lygus* species), other plant bug species (family *Miridae*) and alfalfa caterpillars (various Lepidopteran species). The results of the disease and pest susceptibility observations were provided in the final reports submitted to USDA APHIS at the conclusion of the notification period for each field trial. The results from these observations consistently showed no meaningful differences in the disease and insect susceptibility between events J101 and J163 or synthetic populations developed using both events and the conventional control lines or commercial reference varieties. While occasional differences were noted at some field sites, there were no concurrent trends of differences across field sites or years, which indicate that these differences were likely due to random variation. Additional disease ratings taken as part of the phenotypic comparative studies (section VI, subsection D, Petition Number 04-110-01p) support these same conclusions that diseases and pest incidence are unchanged in GT alfalfa compared to the control and that GT alfalfa is not more or less susceptible to pests or diseases.

Commercial experience and additional research conducted since the 2005 deregulation decision further supports previous observations made during the regulated period before 2005. Rhodes (2007) showed that treatment of GT alfalfa with Roundup had no impact on its susceptibility to foliar diseases such as downy mildew (*Peronospora destructor*) when compared to the untreated GT alfalfa control. Monsanto, as part of its product stewardship efforts on commercial products, assesses and addresses product performance issues reported by growers. No reports of changes in susceptibility to diseases or pests have been noted for GT alfalfa since it was introduced.

Given the limited experience with GT alfalfa compared to other GT crops, it is worthwhile considering disease and pest susceptibility information reports from other commercialized GT crops. Several reports suggest that currently available glyphosate-tolerant crops may be more susceptible to infestation by soil-borne plant pathogens than untreated conventional soybeans (Kremer et al., 2000; Termorshuizen and Lotz, 2002). While these preliminary studies show that some changes in population levels of pathogens in soil can occur following glyphosate treatment, there is no evidence of increased incidence of disease in the crop. Other reports in the literature indicate that stress imposed by herbicide application or other common factors experienced in the field can indirectly lead to increased disease in crops (Kawate et al., 1997; Altman and Rovira 1989; Giesler et al., 2002; Dissanayake et al., 1998). Potential differences in the incidence and severity of plant diseases in glyphosate-treated and untreated glyphosate-tolerant soybeans compared to untreated varieties have also been investigated (Sanogo et al., 2000; Sanogo 2001; Lee et al., 2000). Results indicate that the disease susceptibility of glyphosate-tolerant soybeans is no different than that of conventional varieties following application of selected herbicides (Lee et al., 2000; Sanogo et al., 2000).

On the basis of pest and disease susceptibility data reviewed by USDA APHIS, GT alfalfa populations were not different from control or conventional alfalfa populations in the prevalence of disease or pests or in their response to pests or diseases (USDA APHIS 2009). After the deregulation of GT alfalfa in 2005, 200,000 to 300,000 acres of GT alfalfa were established throughout the USA (USDA APHIS 2007). No reports were received or could be found that indicated a change in disease and pest interactions in GT alfalfa compared to conventional alfalfa.

## **4.0 Herbicide Susceptibility**

Considerable data were provided in the Petition to demonstrate that GT alfalfa was susceptible to herbicides that may be used to terminate alfalfa stands (See section VII, subsection F of Petition Number 01-110-04p). According to Crop Data Management System's (CDMS) Ag Product Label Service database indicated that 2,4-D, clopyralid, dicamba, glufosinate, glyphosate, and rimsulfuron-methyl were labeled for control of alfalfa. Independent research has demonstrated that dicamba, 2,4-D, tank mixtures of dicamba and 2,4-D, and clopyralid were often more effective than glyphosate for terminating alfalfa stands (Endres, 1999; Mayerle, 2002; Manitoba Agriculture and Food, 2002). Additional data presented in the Petition (Addendum 1) demonstrated that early postemergence applications of herbicides used to control weeds in corn (Harness XTRA (acetochlor + atrazine), Degree (acetochlor), and Degree XTRA (acetochlor +



atrazine) applied in tank mixtures with broadleaf herbicides Banvel (dicamba), 2,4-D, Marksman (atrazine + dicamba) and Hornet (clopyralid + flumetsulam)) effectively controlled GT alfalfa in a GT corn crop. As expected, J101 and J163 were susceptible to herbicides typically used to control alfalfa.

J101 and J163 are highly tolerant to glyphosate and show no yield loss or loss in forage quality when treated over multiple seasons over and above maximum glyphosate application rates (Pierson and Reyes, 2006). Recommended use rates are provided by Monsanto to growers in Regional Technical Bulletins (appendix U-2 of this technical report) In season maximum application of glyphosate is up to 1.5 lbs a.e./acre at a single application, and total per year applications is 4.5 lbs a.e./acre. These application rates were used by Monsanto when conducting residue studies and for event selection purposes. In practice, these maximum rates will rarely be used since the vast majority of weeds are controlled using recommended rates and it would be uneconomical for growers to apply excess herbicide.

## **5.0 Impact on Agronomic Practices and Changes in Land Use**

The impact on agronomic practices found in section VII of Petition 04-110-01p has been reviewed and analyzed by USDA APHIS. More than 20 million acres of alfalfa have been planted annually since 1950. Acreage peaked in the mid 1960's at 28 million acres and in the last five years has been relatively constant at approximately 22 million acres (USDA NASS, 2006). Based on the adoption of other GT crops, it is expected that GT alfalfa will displace a significant portion of other alfalfa varieties, especially where alfalfa is highly managed (e.g., west and southwestern states). As GT alfalfa is adapted, it is expected that Roundup herbicide will replace other forms of weed control currently used in alfalfa. It is not expected to be adopted in areas where alfalfa is minimally managed and where inputs are low. These areas include pastures, hay fields, and road sides with mixed stands of perennial grasses and other perennial forage legumes and in these same areas in which herbicides are generally not used to control weeds.

Changes in land and the impact of GT alfalfa on land use patterns found in section VII, and Subsections D and F of Petition Number 04-110-01p has been reviewed and analyzed by USDA APHIS. These sections of the petition are relevant to the potential impact of GT alfalfa on land use patterns because they address the impact on agronomic practices and on rotational crops. The impact of GT alfalfa on the overall amount of land devoted to alfalfa cultivation is expected to be minimal. The decision for use of agricultural or other lands for alfalfa production is largely a market-driven decision and the availability of a new weed control option where other options already exist is not expected to impact land use decisions to any great extent. Due to the broad range of weeds controlled by glyphosate, farmers may choose to plant GT alfalfa on fields with greater weed pressure. However, overall land devoted to alfalfa cultivation will be impacted largely by the price of alfalfa hay and not by the availability of GT technology.

Information provided in Petition Number 04-110-01p section VII, subsection F.4 evaluated the impact of GT alfalfa on rotational crop practices including rotations with other GT crops. With the exception of cotton, non-glyphosate-based herbicides are readily available for control of GT alfalfa in common alfalfa rotations; therefore, it was concluded that there would be no impact on

crop rotation practices. Cotton rotations with alfalfa may be managed using mechanical weed control and good stand termination practices.

There has been some speculation that weed-free stands may result in longer stand life resulting in a change in land use. Extended stand life provides positive economic and environmental benefits because a significant amount of the total production costs over the life of the stand are associated with the establishment year. These costs include those associated with seed bed preparation, seed, fertilizer, herbicides and pesticides (Ward, 2007). After the stand is successfully established, costs diminish, and extending a healthy stand will increase profitability. In addition, increased stand life would result in less tillage of agricultural lands and growth of additional alfalfa harvests. Since alfalfa is a plant that provides nitrogen to the soil due to a *Rhizobium*-legume symbiotic relationship resulting in high fixation rates of nitrogen that is usable by the following crop (Vance et al., 1988), growing alfalfa could possibly reduce the need for nitrogen fertilizers obtained through the utilization of fossil fuels.

The introduction of GT alfalfa may provide growers the opportunity to extend the life of a stand because Roundup agricultural herbicides do not cause crop injury like some of the other herbicides currently used on alfalfa. Crop injury caused by an herbicide applied to a crop is described on the label. Herbicide labels are available online at [www.cdms.net](http://www.cdms.net). For instance, the label for Pursuit® (imazathapyr), a commonly used herbicide for control of weeds in alfalfa specifically states that “occasionally, internode shortening and/or temporary yellowing may occur following Pursuit application” and “if applied to alfalfa or clover under cool conditions (40° F or less), temporary stunting or yellowing of the crop may occur.” Similar language is included in the label for Raptor® (imazamox). Eptam® (EPTC: S-ethyl dipropylthiocarbamate) another popular herbicide used in alfalfa also mentions possible crop injury and temporary crop stunting may occur under certain conditions and crop growth stages. Additional information on alfalfa’s tolerance to popular herbicides may be found in state weed control guides (Loux et al. 2007). The tolerance of alfalfa to herbicides commonly used for weed control in alfalfa is presented in table 18 of the guide. The majority of the herbicides are listed as good to fair and only two of the herbicides are listed as excellent. According to the manufacturer’s labels for Pursuit and Raptor, any crop injury is temporary and plants recover with the assumption that there are no impacts on forage nutrition or quality. Thus, removal of weeds in the final years of the stand without crop injury provides the opportunity to maintain a healthy weed free stand. The decision to terminate an alfalfa stand ultimately depends on stand productivity and planned crop rotation practices. Weed pressure is certainly a factor in the decreased production of high quality alfalfa, but they are not the only factor leading to stand decline. Other factors impacting stand life include pest and disease pressure, abiotic stress (e.g., winter kill), harvest practices, rotational crop plans and natural plant senescence as noted in Petition Number 04-110-01p.

## **6.0 Implications to Allergies/Animal and Human Health.**

The U.S. Food and Drug Administration (FDA) is the lead U.S. regulatory agency for review of the food and feed safety of biotechnology-improved crops. FGI and Monsanto completed a

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consultation with the FDA in 2004 (FDA, 2004) on GT alfalfa. The following information relevant to the potential impact on allergies and human and animal health was taken from the FDA submission (Appendix U-2) and from other information reviewed by the USDA (Petition Number 04-110-01p, Addendum 1). The safety assessment of the CP4 EPSPS protein produced in GT alfalfa events J101 and J163 included protein characterization, functional and structural comparisons to ubiquitous plant and microbial EPSPS synthetases with a history of safe consumption, in vitro digestibility in simulated gastric and intestinal fluids, acute oral toxicity in mice, and amino acid comparison to known toxins and allergens. The CP4 EPSPS protein produced by J101 and J163 was isolated from forage and characterized using analytical methods capable of assessing the chemical and functional characteristics of the protein. As a result of the characterization it was concluded that the CP4 EPSPS protein produced by J101 and J163 was biochemically and functionally equivalent to CP4 EPSPSs produced by other GT crops and to the family of EPSPS proteins that naturally occur in crops and microbiologically based processing agents that have a long history of safe consumption by humans and animals. All of these data and information taken together demonstrate a history of safe experience with respect to GT crops which have been consumed in significant amounts, either directly or as processed products, by humans and animals since their initial commercialization in 1996.

Food uses of alfalfa are extremely minor. The majority of limited food uses include consumption of sprouts in many countries throughout the world. Outbreaks of food-borne illness associated with sprouts containing the microbial pathogens *Salmonella* spp, *Escherichia coli* O157:H7 or *Listeria monocytogenes* have been reported. These microbial toxins are associated with alfalfa seed used for sprouting purposes (FDA, 1999; CFIA, 2001) but are not specifically produced by alfalfa. Seed have been identified as the primary source of these microbial contaminants (Puohiniemi et al., 1997; CDC, 1997; Mahon et al., 1997). Therefore, the sprouting industry endorses the use of certified sprouting seed to avoid these outbreaks (International Specialty Supply, 2004).

Documented clinical reactions to alfalfa after ingestion have not been reported. However, respiratory disorders may be exacerbated by alfalfa pollen (Bener et al., 2002; Wilkins et al., 1999). Since alfalfa is not a reported allergenic food and may be a relatively minor contributor to some respiratory allergic diseases, the risk to human health is minimal. The statement that alfalfa is not a reported allergenic food is based on two observations. (1) Alfalfa is not one of the eight foods responsible for the vast majority of food allergic reactions. These foods include peanuts, tree nuts, soy, wheat, milk, eggs, fish, and crustacea (Metcalf et al., 1996). (2) After searching literature databases such as PubMed using key words such as alfalfa and food allergy there were no reports of documented food allergic reactions to alfalfa.

## **7.0 Animal Feeding Studies since the 2005 Deregulation Decision**

*Dairy Cow Feeding Study.* Combs and Hartnell (2007) examined the effect of GT alfalfa forage on feed intake, milk composition and milk production in 16 multiparous lactating Holstein dairy cows. GT or conventional control alfalfa hay was incorporated into diets at 40% of total dry matter. Milk production, milk composition, feed intake and feed efficiency were not different for dairy cows fed GT versus control alfalfa hay ( $P>0.05$ ). GT alfalfa hay has also been fed extensively without incidence since deregulation in 2005. These results confirm those derived

from previously conducted compositional analyses for GT alfalfa where no differences were observed between GT alfalfa and the control, and further confirm the feed safety of glyphosate and the CP4 EPSPS protein.

The safety assessment conducted on J101 and J163 addressed the food, feed, and environmental safety of GT alfalfa. Studies conducted over several years showed that other than tolerance to glyphosate, GT alfalfa populations are no different from conventional alfalfa and are as safe for the environment as conventional alfalfa. The comparative analyses of the composition of GT alfalfa to its conventional counterparts, the safe use of the CP4 EPSPS protein in other GT crops, the practical experience with GT alfalfa by growers, the ongoing use of GT alfalfa as an animal feed, as well as data developed after the 2005 deregulation decision, confirms the environmental and feed safety of GT alfalfa. After reviewing the Monsanto/FGI submission to FDA and other information, APHIS agrees with the FDA assessment and concludes that no concerns exist for the food and feed safety of GT alfalfa vs. conventional alfalfa.

## Appendix U-1.       References

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**Appendix V:       Impacts of Roundup Ready Alfalfa on  
Production Practices and Marketing of  
Alfalfa Seed and Hay**

# Impacts of Roundup Ready Alfalfa on Production Practices and Marketing of Alfalfa Seed and Hay

## 1.0 Biology and Culture of Alfalfa

Alfalfa (*Medicago sativa* L.) is a short-lived perennial herbaceous legume (Lesins and Lesins, 1979) and is exclusively an insect-pollinated crop that is pollinated by a small number of insect species, all of which are bees. *Medicago* is in the tribe Trifolieae, which also includes *Trifolium* (true clovers), *Melilotus* (sweetclover), and *Trigonella* (fenugreek). *Medicago* species members do not hybridize with any of these (or other) genera. The *M. sativa* complex has been successfully hybridized with 12 other perennial *Medicago* species (McCoy and Bingham, 1988). However, many of these interspecific hybrids have been successful only by using embryo culture of the hybrid (McCoy and Smith, 1986), making them highly unlikely to occur in nature. No perennial *Medicago* species are present naturally in the Americas, Australia, New Zealand, or South Africa. Therefore, no risk for interspecific hybridization exists in the U.S. However, natural cross-pollination to the scattered naturalized (feral) populations of *M. sativa* is possible. A detailed discussion of the potential for interspecific gene flow is presented in the petition section 2.5 and 2.6. (pages 18-21) and recently was updated (See Document Number 04-AL-116U).

### 1.1 Biological characteristics

A concise, recent review of several salient features of the biology of alfalfa within the context of gene flow was recently developed by an expert panel assembled by the National Alfalfa & Forage Alliance (Van Deynze et al., 2008). This white paper is an in-depth discussion of the potential risks of pollen and seed mediated gene flow in alfalfa growing under cultivated or feral conditions. The key relevant biological characteristics were summarized by these authors as follows:

#### “Growth and Flowering

An alfalfa plant starts its initial growth from a seed during establishment, but after each harvest or winter, it re-grows from buds arising from the perennial root structure (the crown). The vegetative growth interval (i.e. harvest schedule) during most times of the year is 22 to 40 days, and harvest for forage is typically done three to eight times per year depending upon location and seasonal climate. Most of alfalfa in the US is managed to limit growth to the juvenile (vegetative) state in order to optimize forage phytomass production (yield) and nutritional quality of the hay. Hay with late maturity (presence of open flowers or seed) is of poor feed quality and market value. Thus, at any one time, greater than 98% of alfalfa in the US is likely to be without flowers (vegetative) or in an early stage of flower development. It is therefore atypical, sporadic and rare that farmed hay fields sustain flowers, or subsequent to flowering, produce any viable seed. In seed fields, of course, flowering and seed production are promoted. In most fields, flower buds begin to form on stems approximately 4 to 6 weeks after field mowing during long-day photoperiods and

warm weather. Flowering is not triggered under short days or cool weather (i.e., late summer through mid spring). Once flowering ensues, alfalfa flowers indeterminately, and its duration is dependent upon moisture, temperature and other factors.

#### Pollination

Alfalfa is predominantly cross-pollinated and the flowers are entirely dependent upon bees for cross-pollination. Wind cross-pollination in alfalfa does not occur (Viands et al., 1988). Alfalfa requires bees to “trip” flowers to release pollen for ovule fertilization and seed production. In the U.S., alfalfa seed production fields are pollinated primarily with leafcutter bees (*Megachile rotundata* F.) in the Pacific Northwest and honey bees (*Apis mellifera*) in California. Some growers in niche areas of southern Washington use alkali bees (*Nomia melanderi* C.) and certain seed producers use a blend of cultured species for pollination. Native bees, including *Bombus* spp, *Osmia* spp, and *Agapostomen* spp. and native *Megachile* spp. can be found visiting alfalfa in varying numbers. Other insect pollinators have not shown to be effective pollinators of alfalfa.

#### Seed Formation

Alfalfa flowers are cross-pollinated by bees. After pollination of the flowers, alfalfa seed embryos require 4 to 6 *additional* weeks of adequate growing conditions to ripen. Rainfall, low temperature or snow during the ripening time will cause decreased seed yield and poor seed quality (e.g., reductions in seedling vigor and reduced percent germination because of fungal pathogen infection of the seed, or seed will sprout prematurely and die while it is still in the pod). Alfalfa seed is borne in a coiled leguminous pod, and is non-shattering. Natural, non-mechanized, seed dispersal is very local. Alfalfa seed is too dense and smooth for effective wind dispersal.

#### Hard Seed

It is typical for a proportion of the alfalfa seeds in any seed lot to exhibit post harvest latency (“dormancy”) related to “hard seed”. A hard, water-impervious seedcoat temporarily prevents water uptake and delays germination until the hard seedcoat is weathered, aged or abraded. In contrast, seeds maintained dry in storage may remain viable for decades. Alfalfa does not exhibit true, physiological seed dormancy and in most situations the majority of seeds readily germinate. In alfalfa, hard seed is defined as the percentage of seed that do not imbibe water during a standard 72 hr germination test. However, these hard seed have been commonly observed to germinate under field conditions. Undersander et al. (1993) examined rate and extent of germination of alfalfa seed lots varying in hard seed content and found no correlation between the laboratory hard seed rating (% hard seed) and germination in the field.

#### Autotoxicity

Alfalfa plants and alfalfa debris produce compounds that elicit an autotoxic reaction to germinating alfalfa seeds. The autotoxic reaction and inter-plant competition severely limit germination and seedling vigor of alfalfa sown or dropped into existing or newly terminated alfalfa stands. Cultivated fields do not successfully self-seed. Attempts to thicken existing alfalfa stands by deliberately inter-planting new seed into them typically fail, which is why most agronomists do not recommend the practice (Canevari et al.,

2000). Therefore, secondary seedlings are a very unlikely avenue for effective gene flow into existing solid-seeded alfalfa plantings. A portion of seed growers plant their fields in rows instead of solid plantings. In these situations, in-crop volunteers from dropped seeds occur and the resulting seedlings could be a means of gene flow to subsequent crops. However, in order to maintain required varietal and species purity, these seed growers routinely control germinating alfalfa seedlings and weeds using cultivation, irrigation and or soil-active herbicides that do not impact the pre-established, growing crop. The high likelihood of autotoxicity is one reason why growers must rotate to a different crop for at least one full year following stand take-out.

#### Longevity

Alfalfa is a short-lived perennial. Fields grown for hay production are typically maintained for 3 to 6 years or longer in some areas. Commercial production of the alfalfa seed crop is exclusively confined to the western regions of the United States where late season (post-pollination) rain is unlikely, irrigation is carefully managed and specialized alfalfa seed growers, equipment and infrastructure are available. To assure varietal purity, commercial seed production contracts typically require that stands be terminated after three years. Alfalfa is effectively terminated using a variety of mechanical, cultural and or chemical methods. Glyphosate, although somewhat effective in the control of unwanted conventional alfalfa, is not typically used or it is used in combination with other stand take-out practices. Glyphosate will not control Roundup Ready alfalfa (RRA); however, other herbicides and cultural practices remain effective. After cultivated stands are terminated, both seed and hay farmers rotate the field to a different crop species for one or more years wherein alfalfa volunteers can be controlled, if necessary.

#### Feral Alfalfa

Feral plants are crop plants that grow and reproduce outside of cultivation. Feral alfalfa plants can sometimes be found on road edges, in fence lines and in abandoned fields. In the US, feral alfalfa populations have occurred through unintentional plantings of cultivated varieties (“escapes” from cultivation) or, in some cases, they originated from intentional planting of the abandoned fields, roadsides or marginal lands. Feral alfalfa occurs at very low density and scale relative to cultivated alfalfa grown for seed or hay. Biogeographic survey data from six states indicates that for most agricultural areas feral alfalfa plants do not occur or they are sparse (Kendrick et al., 2005). In a 2001/2002 multi-state survey, feral plants were found as dispersed plants or patches within 1.25 miles (2 km) of cultivated alfalfa at only 22% of the survey sites (Kendrick et al., 2005). Feral alfalfa plants are sometimes managed on roadsides by clipping, either with hay being harvested or simply left on the ground along with the other roadside vegetation. Feral plants are sometimes completely unmanaged and given adequate moisture and timely presence of pollinators, can flower and set seed. Feral plants are susceptible to the environmental (e.g. drought in the irrigated West) and insect (e.g. Lygus bugs in the West and potato leafhopper in the East) stresses common to the local area. Although alfalfa was introduced to North America more than 200 years ago, it is not considered weedy, noxious or invasive in cultivated or feral settings.”

In addition to the biological and cultural characteristics summarized by Van Deynze et al., (2008), other relevant features include the following:

## 1.2 Alfalfa in the landscape (feral alfalfa).

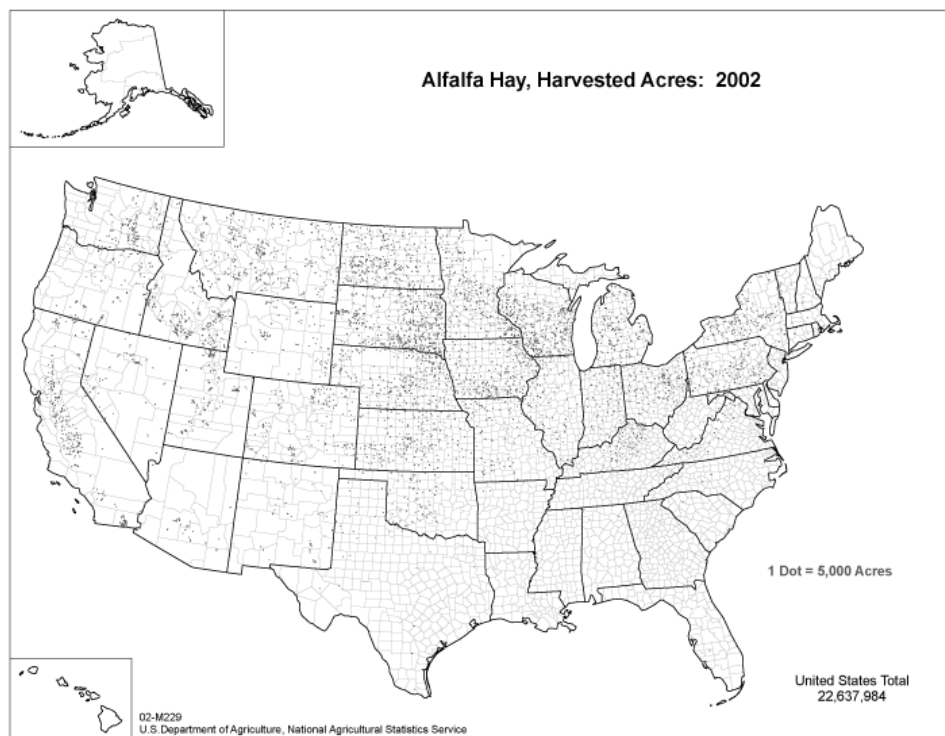
Alfalfa is recognized as the oldest plant grown solely for forage. Alfalfa is an introduced species to the Americas and has become the most important forage crop species in the U.S. and Canada. It is recognized as a widely adapted agronomic crop and grows in all continental states, Alaska and Hawaii. Alfalfa grows optimally in fertile, well-drained soils; however, because of its adaptability, it also survives outside of cultivation. It is not a weedy species and it is not listed as a Federal noxious weed or on other weed lists such as: Federal Noxious Weed List (<http://www.aphis.usda.gov/ppq/weeds/noxwdsa.html>), Washington State Weed Lists ([http://www.nwcb.wa.gov/weed\\_list/weed\\_listhome.html](http://www.nwcb.wa.gov/weed_list/weed_listhome.html)), California Weed Species Lists (<http://www.extendinc.com/weedfreefeed/list-b.htm>), Montana County Noxious Weed List (<http://www.weedawareness.org/weed%20list.html>), North Dakota Noxious Weeds (<http://www.ext.nodak.edu/extpubs/plantsci/weeds/w1103w.htm>).

Where alfalfa exists outside of cultivation, it is typically not targeted for control. In some instances on lands where unmanaged or feral alfalfa now occurs, the planting was intentional (e.g., feral plants exist in relegated sown pastures, abandoned alfalfa fields, or on roadsides once sown with alfalfa seed [see Petition page 375]). All feral alfalfa in the U.S, like alfalfa under cultivation, originated from introduced varieties. Section 5, part 5.5 summarizes the extent of feral populations within six major alfalfa production states of the U.S., confirming that feral populations exist to a minor extent in areas where alfalfa seed or forage is produced. In situations where control of feral alfalfa is desired, just like cultivated alfalfa, it can be controlled or discouraged using cultural or chemical methods (see Petition section VII. Part F and appendix V-4). Because it is unmanaged and genetic resistance to pests is largely absent, feral alfalfa likely is more negatively impacted by endemic pests than alfalfa under cultivation. As a result, the competitiveness and number of viable, vigorous seeds produced by feral alfalfa plants likely are significantly constrained as compared to cultivated alfalfa of improved genetics under management (Van Deynze et al., 2008). Additional discussion of feral alfalfa is presented in section 5 of this document. The issue of the persistence of hard seed and hard seeds contributing to the weed potential of alfalfa is extensively discussed in letters from weed control experts during the USDA public comment period (Docket 04-085-1; e.g., Doll comment #505). Alfalfa does not naturally propagate from vegetative plant parts (e.g., Docket 04-085-1 comment Beuselinck #501).

## 2.0 Forage Production

Alfalfa grown for forage is the third-ranked crop in the U.S. by value and fourth ranked by total acreage. The number and location of alfalfa forage acres are closely associated with livestock operations, especially dairy. Alfalfa is highly valued for animal feed because of its high protein content, high intake potential, and digestibility. It can provide the sole plant component in many livestock feeding programs when supplemented with the proper minerals.

Alfalfa is a deep-rooted perennial that has many economic, soil, and environmental benefits when used alone or in rotation (Hanson et al., 1988). In the U.S. more than 22 million acres currently are grown for forage production (figure V-1). The alfalfa acreage in the U.S. has declined gradually over the past 40 years from a high of approximately 30 million acres (Petition table VII-1, page 255).



**Figure V-1: Geographic distribution of alfalfa forage acres, 2002 (USDA, 2002)**

### 2.1 Stand establishment

Dependent on climate and grower preference, most alfalfa is sown in the spring, except in the western U.S. where fall planting is more common (Hower et al., 1999). Alfalfa can be sown anytime there is available moisture and a sufficient growth period for the seedling that is frost-free (about six to eight weeks). Weeds are the most damaging pest during early stand establishment, especially for spring-sown alfalfa. In order to reduce weed competition, many growers establishing in the spring apply herbicides or co-seed alfalfa with a quick-to-establish

companion cereal crop, such as oat or spring wheat. This practice is especially valuable on wind-swept or sloping land that is prone to erosion. The cereal crop can be maintained until grain set, or more commonly it is harvested immature as forage along with the weeds and the first growth of alfalfa. Companion crops, like weeds, compete directly with the alfalfa seedlings for available moisture, light and space and reduce the amount of harvestable alfalfa forage in the establishment year. Competition or other stress during the establishment period has permanent negative consequences on the overall yield potential of the stand. Therefore, many hay producers “direct-seed” or “clear-seed” alfalfa stands without use of a companion crop. Successful alfalfa sowing requires that the seeds be placed at shallow depth (about one-quarter inch) and that the seedbed is uniform, firm and free of competing weeds.

Most pure-stand alfalfa in the U.S. is established with herbicides, with 52% and 66% of spring and fall planted acres, respectively, treated with herbicides (Hower et al., 1999). About 1.49 M acres of alfalfa are established annually using herbicides (Hower et al., 1999).

## 2.2 Stand longevity

Alfalfa forage production fields remain economically viable for approximately five years after planting. Plants become unthrifty and stands become thin as they age due to the accumulated negative impacts of weed competition, diseases, insects and environmental stress (e.g., excessive cold, heat, drought, and flooding). When terminated, very thin alfalfa stands offer less soil nitrogen to the rotational crop (less rotational benefit) compared to those terminated at higher plant density. Stand longevity is affected by climate, soil type, soil tilth and drainage, autotoxicity, fertility, variety (genetics), and pest impacts. Very short forage harvest intervals generally increase the rate of stand depletion and weed encroachment; very long harvest intervals allow more time for weed seed set. Frequently alfalfa stands may be seriously injured, thinned, or weakened by an interaction between unexpected changes in weather and appropriate use of certain labeled herbicides, resulting in unacceptable weed control.

Often, alfalfa stand length is predetermined according to the grower’s whole-farm crop rotation schedule; typically alfalfa is grown for three to six years followed by at least two years of a non-legume crop (e.g., corn, small grain, cotton, safflower, or vegetables). Expensive-to-control weed infestations can be one reason why forage fields are terminated early.

## 2.3 Stand thinning, impacts of weed encroachment and stand termination

Healthy, productive stands of alfalfa require attention to the management of pests (including weeds), fertilizer inputs, irrigation (if applicable), and harvest timing. Several years after sowing when plants weaken and stands become thin, weeds become more highly competitive with the alfalfa and can contribute to a significant decline in alfalfa yield and forage value. Certain weed species found in alfalfa stands are particularly difficult to control (Hower et al., 1999), are poisonous to livestock, negatively affect palatably or livestock performance, impart off flavors to milk products, and may be noxious to regulated species (e.g., dodder). Alfalfa stands nearly always are terminated using some type of tillage (plowing, disking, roto-tilling, etc.) to help break up roots and crowns, hasten decomposition, relieve soil compaction, and to incorporate this nitrogen-rich plant material as a soil amendment. It is common for many producers to use

tillage integrated with herbicides and or other stand take-out practices (e.g., flooding). Stand take-out is discussed in Petition section VII.B.6 (Pages 259-260). Well-established alfalfa fields or fields undergoing stand renovation are sometimes used for the disposal of livestock manures. Weed seeds present in livestock manure can contribute to an accumulation of weed seeds in the soil and weed problems in alfalfa production systems.

## 2.4 Uses of Alfalfa Hay

In the U.S., the vast majority of alfalfa is harvested as forage for use as animal feed; however, some minor food uses of alfalfa occur such as use of seed for sprout production and the production of forage for human dietary supplements and as tea. In 2005, alfalfa dry hay produced in the U.S. was valued at over \$7.3 billion with 99 percent of it used on-farm or sold within the U.S. (USDA-NASS, 2006) for animal feed. Alfalfa hay export was valued at approximately \$192 million (USDA-FAS, 2006), representing roughly two percent of the total dry hay crop value. Of the domestic use total, less than one percent of alfalfa hay acres were harvested as organic in 2005 (USDA-NASS, 2006). Table V-1 highlights the key export markets for U.S. alfalfa hay. Five countries (Japan, Republic of Korea, Taiwan, Canada and Mexico) account for 98% of the total metric tons exported. Japan imports 74% of the alfalfa exports from the U.S. and is consistently the largest annual importer of U.S. alfalfa hay (table V-1).

**Table V-1. U.S. Forage Export Markets (Metric Tons 1000's)<sup>1</sup>**

| <b>Forage Importing Country</b>                                               | <b>2001</b>    | <b>2002</b>      | <b>2003</b>      | <b>2004</b>      | <b>2005</b>      | <b>2006</b>    | <b>6-year Average Market Share (%)</b> |
|-------------------------------------------------------------------------------|----------------|------------------|------------------|------------------|------------------|----------------|----------------------------------------|
| Japan <sup>2</sup>                                                            | 524,090        | 786,409          | 869,648          | 865,317          | 750,907          | 680,769        | 73.9%                                  |
| Korea, REP <sup>2</sup>                                                       | 122,475        | 133,935          | 127,657          | 109,634          | 100,796          | 128,331        | 11.9%                                  |
| Taiwan <sup>3</sup>                                                           | 35,779         | 72,756           | 55,574           | 58,876           | 62,426           | 68,662         | 5.8%                                   |
| Canada <sup>2</sup>                                                           | 41,251         | 47,517           | 64,683           | 65,113           | 62,114           | 39,447         | 5.3%                                   |
| UAE                                                                           | 9,004          | 10,034           | 4,552            | 13,197           | 15,810           | 19,864         | 1.2%                                   |
| Mexico <sup>2</sup>                                                           | 3,149          | 5,669            | 12,497           | 12,967           | 23,388           | 8,987          | 1.1%                                   |
| Hong Kong                                                                     | 0              | 450              | 923              | 1,065            | 1,070            | 1,087          | 0.1%                                   |
| China                                                                         | 982            | 880              | 611              | 127              | 251              | 420            | 0.1%                                   |
| UK                                                                            | 4,310          | 2,175            | 1,602            | 418              | 776              | 407            | 0.2%                                   |
| Singapore                                                                     | 0              | 0                | 85               | 55               | 327              | 314            | 0.0%                                   |
| Other                                                                         | 2,127          | 6,996            | 5,396            | 9,820            | 2,839            | 2,309          | 0.5%                                   |
| <b>Total</b>                                                                  | <b>743,167</b> | <b>1,066,821</b> | <b>1,143,228</b> | <b>1,136,589</b> | <b>1,020,704</b> | <b>950,597</b> | <b>100.0%</b>                          |
| <b>Countries allowing import of Roundup Ready alfalfa hay (December 2007)</b> |                |                  |                  |                  |                  |                | <b>98.0%</b>                           |

<sup>1</sup> Data Source: Department of Commerce, U.S. Census Bureau, Foreign Trade Statistics

<sup>2</sup> This country has approved the import of Roundup Ready alfalfa for feed and food use.

<sup>3</sup> Taiwan does not regulate genetically modified alfalfa.



Conventional alfalfa forage is grown in pure and mixed-species forage systems where it is harvested as dry hay, haylage/silage, greenchop or a lesser extent, grazed in pasture or rangeland. Alfalfa grown in direct-seeded, pure-stand culture is the most likely receiving environment for Roundup Ready alfalfa. USDA statistics are classified separately for each of the harvesting methods (without summary). Except crop classifications labeled specifically as “alfalfa hay” and “alfalfa haylage,” the other various national or state data classifications count acres and hay from other crop species with, and often without, alfalfa present in the stand (e.g., alfalfa-grass mixtures, forage grasses without alfalfa, small grain forages, tame hays, other forage legume species mixtures, wild hays, natural pastures, etc.). Table V-2 summarizes 2006 total hay (and seed) acreage as the sum of “alfalfa dry hay” and “alfalfa hay and haylage” categories only. Tables V-2 and V-3 present 2006 forage (and seed) crop acreage and yield per acre summaries by region and by state.

Most alfalfa forage (“hay”) is used to feed livestock on the farm of production and is not marketed (table V-2). About 40 percent of the national forage production is sold off-farm and is sometimes referred to as “off-farm” or “cash hay.” The average annual price per ton of conventional dry hay has been approximately \$98 per ton (table V-4) during 2001 to 2005. Significant hay market price fluctuations occur within years and among regions, package size, and forage quality grade classifications. High-forage-quality alfalfa hay prices are approaching record highs (~\$200 or more per ton) due to very low supplies: hay stockpiles are at a 30-year low. Record high prices are occurring across many food, feedstuff and energy feedstock crops. However, over the long term, the on-farm value and cash hay sale price of conventional forage is positively correlated with the lot’s objective feed quality value and the subjective appearance of the hay (i.e., green color, absence of weeds, no rain damage, dirt, or mold). The fiber, nutrient and digestibility of hay determine the feed quality value. Commonly, a hay lot is tested and priced according to its forage quality index value. e.g., relative feed value (RFV), relative feed quality (RFQ), or total digestible nutrients (TDN). Within the hay markets, the index values may be used to group the hay lots into “supreme”, “premium”, “good,” “fair,” and “utility” hay grades (USDA-AMS-LGMR, 2006). Hay of supreme or premium grades is often in short supply and may sell for \$50-60 per ton more than average, good, or fair grade hay (Orloff and Putnam, 2004; USDA-AMS-LGMR, 2006).

Due to transportation and storage costs, bulkiness of the hay and relatively low value per truckload, hay is consumed by local livestock and the cash hay markets are local/regional in nature (USDA-AMS-LGMR, 2007). Cash hay often is purchased directly from the grower or sometimes from a hay brokerage at spot sales or alternatively by forward contracting for the scheduled delivery of hay or silage that meets certain minimum forage-quality criteria. Exported hays are grown near large Western port cities. USDA collects sales volume and price data for regional alfalfa hay markets throughout the U.S. (USDA-AMS-LGMR, 2007). These market reports are fragmented by market region/port, lot size, package (bale) size/type, delivery arrangements, forage quality grade, or organic certification status. From this data, it is evident that hay is sold in identity preserved, forage-quality tested lots; it is not fungible. A very small portion of dry hay is processed into hay cubes, feed pellets or sold as individual bales or in small bags at retail stores for horse or pet food. A smaller proportion of alfalfa is consumed by horses, goats, sheep and beef cattle (Putnam, 2005).

Multi-year national statistics for conventional, organic and exported alfalfa *dry hay* acres and values are presented in table V-4 for the 4-year period 2002 to 2005 and an acreage only

comparison for 2006 is presented in table V-2. (Note: 2005 is the most recent year for which organic alfalfa acreage data is available from USDA. Therefore, 2005 is used as the year of comparison for the relative size of organic, export and domestic markets. Dry hay values are used in table V-4 because exported hay is dried before sale or processing.) During the period 2002 to 2006, the number of conventional acres grown for alfalfa forage was relatively stable (tables V-2 and V-4). The 4-year average conventional alfalfa hay production values were 3.33 tons dry hay per acre, \$98.35 per ton, \$311.40 hay per acre, and total market value of \$7.0 billion annually (table V-4).

**Table V-2. Current Markets for U.S. Produced Alfalfa Hay and Seed (acres in thousands) Using 2006 Alfalfa Acreage Data**

| <b>Alfalfa Hay and Haylage</b>                        | <b>Southwest</b> |                | <b>PNW</b>     |                | <b>InterMountain</b> |                | <b>Plains</b>  |                | <b>MW/East</b> |                | <b>Southeast</b> |                | <b>Total</b>   |                |
|-------------------------------------------------------|------------------|----------------|----------------|----------------|----------------------|----------------|----------------|----------------|----------------|----------------|------------------|----------------|----------------|----------------|
|                                                       | <b>% Acres</b>   | <b>% Acres</b> | <b>% Acres</b> | <b>% Acres</b> | <b>% Acres</b>       | <b>% Acres</b> | <b>% Acres</b> | <b>% Acres</b> | <b>% Acres</b> | <b>% Acres</b> | <b>% Acres</b>   | <b>% Acres</b> | <b>% Acres</b> | <b>% Acres</b> |
| <b>Hay and Haylage produced on the farm</b>           | 14%              | 218            | 20%            | 477            | 50%                  | 1,695          | 35%            | 970            | 80%            | 10,095         | 75%              | 360            | 59.5%          | 13,814         |
| • <b>GM sensitive</b>                                 |                  |                |                |                |                      |                |                |                |                |                |                  |                |                |                |
| Organic                                               |                  | 1              |                | 3              |                      | 11             |                | 6              |                | 68             |                  | 2              | 1%             | 93             |
| Other                                                 |                  | 7              |                | 14             |                      | 51             |                | 29             |                | 303            |                  | 11             | 3%             | 414            |
| • <b>GM insensitive</b>                               |                  | 210            |                | 459            |                      | 1,633          |                | 934            |                | 9,725          |                  | 347            | 96%            | 13,307         |
| <b>Hay produced and sold to third parties in U.S.</b> | 85%              | 1,321          | 74%            | 1,765          | 50%                  | 1,695          | 65%            | 1,801          | 20%            | 2,524          | 25%              | 120            | 39.8%          | 9,225          |
| • <b>GM sensitive</b>                                 |                  |                |                |                |                      |                |                |                |                |                |                  |                |                |                |
| Organic                                               |                  | 9              |                | 12             |                      | 11             |                | 12             |                | 17             |                  | 1              | 1%             | 62             |
| Other                                                 |                  | 40             |                | 53             |                      | 51             |                | 54             |                | 76             |                  | 4              | 3%             | 277            |
| • <b>GM insensitive</b>                               |                  | 1,272          |                | 1,700          |                      | 1,633          |                | 1,734          |                | 2,431          |                  | 116            | 96%            | 8,887          |
| <b>Hay produced and sold to export markets</b>        | 1%               | 16             | 6%             | 143            |                      | 0              |                | 0              |                | 0              |                  | 0              | 0.7%           | 159            |
| • <b>GM sensitive</b>                                 |                  | 15             |                | 140            |                      |                |                |                |                |                |                  |                | 98%            | 155            |
| • <b>GM insensitive</b>                               |                  | 1,272          |                | 1,700          |                      |                |                |                |                |                |                  |                | 26%            | 3              |
| <b>Total acres alfalfa hay and haylage</b>            |                  | 1,554          |                | 2,385          |                      | 3,390          |                | 2,770          |                | 12,619         |                  | 480            |                | 23,198         |
| <b>Total AP sensitive</b>                             | 4.6%             | 72             | 9.3%           | 223            | 3.7%                 | 124            | 3.7%           | 102            | 3.7%           | 463            | 3.7%             | 16             | 4.3%           | 1,001          |

**Assumptions:**

Forage:

- Percent used on farm vs. cash crop hay by region (based on polling of regional alfalfa extension experts)
- 0.67% Organic alfalfa hay percent of total acres (based on 2005 NASS report on percent organic all hay).
- 3.0% Non-organic AP-sensitive hay market, percent of total hay (Putnam, 2006).
- 98% GM-sensitive hay to export market, percent exported hay (note: this is based on current market sensitivity, not regulatory issues).

Seed

- Total alfalfa seed export as mean of 2002-2006, as reported by FAS.
- Seed export quantity to Mexico and Saudi Arabia as coated seed, adjusted to estimated raw seed equivalent.
- Percent of certified organic seed production (industry consensus estimate by region).
- 5% Non-organic AP-sensitive seed for domestic markets, AP<0.5% (industry consensus estimate).

| <b>Alfalfa Seed</b>         | <b>Southwest</b> |              | <b>PNW</b> |              | <b>InterMountain</b> |              | <b>Plains</b> |              | <b>MW/East</b> |              | <b>Southeast</b> |              | <b>Total</b> |              |
|-----------------------------|------------------|--------------|------------|--------------|----------------------|--------------|---------------|--------------|----------------|--------------|------------------|--------------|--------------|--------------|
|                             | <b>%</b>         | <b>Acres</b> | <b>%</b>   | <b>Acres</b> | <b>%</b>             | <b>Acres</b> | <b>%</b>      | <b>Acres</b> | <b>%</b>       | <b>Acres</b> | <b>%</b>         | <b>Acres</b> | <b>%</b>     | <b>Acres</b> |
| <b>Dormant alfalfa seed</b> | 1%               | 0.4          | 92%        | 48.8         | 100%                 | 15.8         | 90%           | 2.1          | 100%           | 7            |                  | 0            |              | 74.1         |
| • <b>GM sensitive</b>       |                  |              |            |              |                      |              |               |              |                |              |                  |              |              |              |
| Organic                     |                  | 0            |            | 0            |                      | 0            |               | 0            |                | 0            |                  |              | 0%           | 0            |
| Export                      |                  | 0            |            | 4            |                      | 1.8          |               | 0            |                | 0            |                  |              | 8%           | 5.8          |
| Other                       |                  | 0            |            | 2.4          |                      | 0.8          |               | 0.1          |                | 0.4          |                  |              | 5%           | 3.7          |
| • <b>GM insensitive</b>     |                  | 0.4          |            | 42.3         |                      | 13.2         |               | 13.2         |                | 6.7          |                  |              |              |              |

|                                     |     |      |     |      |     |      |     |     |     |     |     |       |      |
|-------------------------------------|-----|------|-----|------|-----|------|-----|-----|-----|-----|-----|-------|------|
| ND/SD alfalfa seed                  | 99% | 43.6 | 8%  | 4.2  | 0%  | 0    | 10% | 0.2 | 0%  | 0   | 0   | 48.0  |      |
| • GM sensitive                      |     |      |     |      |     |      |     |     |     |     |     |       |      |
| Organic                             |     | 0    |     | 0    |     | 0    |     | 0   |     | 0   |     | 0     |      |
| Export                              |     | 25.2 |     | 2.4  |     | 0    |     | 0   |     | 0   | 58% | 27.6  |      |
| Other                               |     | 2.2  |     | 0.2  |     | 0    |     | 0   |     | 0   | 5%  | 2.4   |      |
| • GM insensitive                    |     | 16.1 |     | 1.7  |     | 0    |     | 0.2 |     | 0   |     |       |      |
| Total acres alfalfa seed production |     | 44   |     | 53   |     | 15.8 |     | 2.3 |     | 7   |     | 122.1 |      |
| Total AP sensitive                  | 62% | 27.4 | 17% | 9    | 17% | 2.6  | 5%  | 0.1 | 5%  | 0.4 | 0   | 32%   | 39.5 |
| Certified organic                   | 0%  | 0    | 0%  | 0    | 0%  | 0    | 0%  | 0   | 0%  | 0   | 0   | 0%    | 0    |
| AOSCA certification applied for     | 75% | 33   | 80% | 42.4 | 80% | 16.6 | 10% | 0.2 | 0%  | 0   | 0   | 76%   | 93.2 |
| Proprietary varieties               | 55% |      | 75% |      | 75% |      | 0%  |     | 0%  |     |     |       |      |
| Public varieties (certified)        | 30% |      | 7%  |      | 15% |      | 10% |     | 5%  |     |     |       |      |
| Common seed (VNS)                   | 15% |      | 8%  |      | 10% |      | 90% |     | 95% |     |     |       |      |

**Assumptions:**Forage:

- Percent used on farm vs. cash crop hay by region (based on polling of regional alfalfa extension experts)
- 0.67% Organic alfalfa hay percent of total acres (based on 2005 NASS report on percent organic all hay).
- 3.0% Non-organic AP-sensitive hay market, percent of total hay (Putnam, 2006).
- 98% GM-sensitive hay to export market, percent exported hay (note: this is based on current market sensitivity, not regulatory issues).

Seed

- Total alfalfa seed export as mean of 2002-2006, as reported by FAS.
- Seed export quantity to Mexico and Saudi Arabia as coated seed, adjusted to estimated raw seed equivalent.
- Percent of certified organic seed production (industry consensus estimate by region).
- 5% Non-organic AP-sensitive seed for domestic markets, AP<0.5% (industry consensus estimate).

**Table V-3. Alfalfa Forage and Seed Production by State**

| 2006 National Ag Statistics Service Data |       |                           |                            |                              |                             |                             |                             |                       |             |                  | 2007 FAS<br>Report<br>2002-06<br>Mean |
|------------------------------------------|-------|---------------------------|----------------------------|------------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------|-------------|------------------|---------------------------------------|
|                                          | State | Acres by State<br>(1000s) |                            | Hay and Haylage<br>Harvested |                             | Seed<br>Production<br>Acres | Average<br>Yield<br>(lbs/A) | Seed Lbs<br>Harvested | <u>Seed</u> | <u>Harvested</u> | Seed Export                           |
|                                          |       | Dry<br>Hay<br>2006        | Hay and<br>Haylage<br>2006 | Average<br>Yield<br>T/A      | Forage<br>Tons<br>Harvested |                             |                             |                       | Dormant     | ND/SD            |                                       |
| Southwest                                | AZ    | 250                       | 250                        | 8.3                          | 2,075                       | 4.0                         | 500                         | 2,000,000             | 0           | 2,000,000        | 1,000,000                             |
|                                          | CA    | 1,050                     | 1,070                      | 6.9                          | 7,426                       | 38.0                        | 550                         | 20,900,000            | 209,000     | 20,691,000       | 12,885,713                            |
|                                          | NM    | 220                       | 234                        | 51                           | 1,184                       | 2.0                         | 400                         | 800,000               | 0           | 800,000          | 0                                     |
|                                          | Total | 1,520                     | 1,554                      |                              | 10,685                      | 44.0                        |                             | 23,700,000            | 209,000     | 23,491,000       | 13,885,713                            |
|                                          |       |                           |                            |                              |                             |                             |                             |                       |             |                  |                                       |
| PNW                                      | ID    | 1,180                     | 1,230                      | 4.5                          | 5,523                       | 28.0                        | 700                         | 19,600,000            | 18,302,000  | 1,568,000        | 2,500,000                             |
|                                          | NV    | 270                       | 270                        | 5.1                          | 1,377                       | 5.0                         | 600                         | 3,000,000             | 3,000,000   | 0                | 0                                     |
|                                          | OR    | 430                       | 430                        | 4.4                          | 1,892                       | 5.0                         | 650                         | 3,250,000             | 3,250,000   | 0                | 150,000                               |
|                                          | WA    | 440                       | 455                        | 4.9                          | 2,239                       | 15.0                        | 750                         | 11,250,000            | 10,125,000  | 1,125,000        | 2,847,247                             |
|                                          | Total | 2,320                     | 2,385                      |                              | 11,031                      | 53.0                        |                             | 37,100,000            | 34,677,000  | 2,693,000        | 5,497,247                             |
|                                          |       |                           |                            |                              |                             |                             |                             |                       |             |                  |                                       |
| Inter-Mountain                           | CO    | 780                       | 780                        | 3.8                          | 2,964                       | 0.6                         | 200                         | 390,000               | 390,000     | 0                | 0                                     |
|                                          | MT    | 1,550                     | 1,550                      | 2.1                          | 3,255                       | 5.5                         | 200                         | 3,025,000             | 3,025,000   | 0                | 500,000                               |
|                                          | UT    | 560                       | 560                        | 4.0                          | 2,240                       | 2.2                         | 200                         | 1,320,000             | 1,320,000   | 0                | 100,000                               |
|                                          | WY    | 500                       | 500                        | 2.8                          | 1,400                       | 7.5                         | 400                         | 4,125,000             | 4,125,000   | 0                | 1,094,738                             |
|                                          | Total | 3,390                     | 3,390                      |                              | 9,859                       | 15.8                        |                             | 8,860,000             | 8,860,000   | 0                | 1,694,738                             |
|                                          |       |                           |                            |                              |                             |                             |                             |                       |             |                  |                                       |
| Plains                                   | KS    | 950                       | 965                        | 3.8                          | 3,677                       | 0.5                         | 200                         | 100,000               | 100,000     |                  | 0                                     |
|                                          | NE    | 1,250                     | 1,265                      | 3.3                          | 4,212                       | 0.4                         | 200                         | 80,000                | 80,000      |                  | 0                                     |
|                                          | OK    | 380                       | 380                        | 2.1                          | 798                         | 0.4                         | 200                         | 80,000                | 80,000      |                  | 0                                     |
|                                          | TX    | 150                       | 160                        | 4.4                          | 707                         | 1.0                         | 400                         | 400,000               | 40,000      | 360,000          | 0                                     |
|                                          | Total | 2,730                     | 2,770                      |                              | 9,394                       | 2.3                         |                             | 660,000               | 300,000     | 360,000          | 0                                     |
|                                          |       |                           |                            |                              |                             |                             |                             |                       |             |                  |                                       |
| North Central                            | IA    | 1,180                     | 1,230                      | 4.0                          | 4,908                       | 0                           | 0                           | -                     |             | 0                | 0                                     |
|                                          | MN    | 1,350                     | 1,500                      | 3.6                          | 5,460                       | 0                           | 0                           | -                     |             | 0                | 0                                     |
|                                          | ND    | 1,450                     | 1,450                      | 1/2                          | 1,740                       | 0                           | 0                           | -                     |             | 0                | 0                                     |
|                                          | WI    | 1,650                     | 2,400                      | 3.9                          | 9,336                       | 0                           | 0                           | -                     |             | 0                | 0                                     |
|                                          | SD    | 1,800                     | 1,820                      | 1.6                          | 2,930                       | 7                           | 250                         | 1,750,000             | 1,750,000   | 0                | 0                                     |
| Total                                    | 7,430 | 8,400                     |                            | 24,374                       | 7                           |                             | 1,750,000                   | 1,750,000             | 0           | 0                |                                       |
|                                          |       |                           |                            |                              |                             |                             |                             |                       |             |                  |                                       |
| East Central                             | CT    | 7                         | 7                          | 2.1                          | 15                          |                             |                             |                       |             |                  | 0                                     |
|                                          | DE    | 5                         | 5                          | 3.9                          | 20                          |                             |                             |                       |             |                  | 0                                     |
|                                          | IL    | 440                       | 460                        | 4.2                          | 1,918                       |                             |                             |                       |             |                  | 0                                     |

|                  |                  |               |               |     |               |              |                   |                   |                   |          |
|------------------|------------------|---------------|---------------|-----|---------------|--------------|-------------------|-------------------|-------------------|----------|
|                  | IN               | 360           | 360           | 4.1 | 1,476         |              |                   |                   |                   | 0        |
|                  | ME               | 10            | 10            | 1.9 | 19            |              |                   |                   |                   | 0        |
|                  | MD               | 40            | 40            | 3.9 | 156           |              |                   |                   |                   | 0        |
|                  | MA               | 13            | 13            | 2.3 | 30            |              |                   |                   |                   | 0        |
|                  | MI               | 830           | 980           | 4.0 | 3,940         |              |                   |                   |                   | 0        |
|                  | MO               | 390           | 400           | 3.0 | 1,184         |              |                   |                   |                   | 0        |
|                  | NH               | 8             | 8             | 2.4 | 19            |              |                   |                   |                   | 0        |
|                  | NJ               | 25            | 25            | 2.5 | 63            |              |                   |                   |                   | 0        |
|                  | NY               | 370           | 610           | 3.3 | 2,019         |              |                   |                   |                   | 0        |
|                  | OH               | 470           | 550           | 4.0 | 2,195         |              |                   |                   |                   | 0        |
|                  | PA               | 500           | 660           | 3.8 | 2,515         |              |                   |                   |                   | 0        |
|                  | RI               | 1             | 1             | 3.0 | 3             |              |                   |                   |                   | 0        |
|                  | VT               | 45            | 90            | 3.6 | 322           |              |                   |                   |                   | 0        |
|                  | <b>Total</b>     | <b>3,514</b>  | <b>4,219</b>  |     | <b>15,894</b> | <b>0</b>     | <b>0</b>          | <b>0</b>          | <b>0</b>          | <b>0</b> |
| <b>Southeast</b> | AL               |               | 0             |     | 0             |              |                   |                   |                   | 0        |
|                  | AR               | 15            | 15            | 3.6 | 54            |              |                   |                   |                   | 0        |
|                  | FL               |               | 0             |     | 0             |              |                   |                   |                   | 0        |
|                  | GA               |               | 0             |     | 0             |              |                   |                   |                   | 0        |
|                  | KY               | 280           | 280           | 3.7 | 1,036         |              |                   |                   |                   | 0        |
|                  | LA               |               | 0             |     | 0             |              |                   |                   |                   | 0        |
|                  | MS               |               | 0             |     | 0             |              |                   |                   |                   | 0        |
|                  | NC               | 10            | 10            | 3.1 | 31            |              |                   |                   |                   | 0        |
|                  | SC               |               | 0             |     | 0             |              |                   |                   |                   | 0        |
|                  | TN               | 30            | 30            | 3.7 | 111           |              |                   |                   |                   | 0        |
|                  | VA               | 110           | 110           | 3.6 | 396           |              |                   |                   |                   | 0        |
|                  | WV               | 35            | 35            | 2.9 | 102           |              |                   |                   |                   | 0        |
|                  | <b>Total</b>     | <b>175</b>    | <b>480</b>    |     | <b>1,730</b>  | <b>0</b>     | <b>0</b>          | <b>0</b>          | <b>0</b>          | <b>0</b> |
| <b>U.S.</b>      | <b>U.S.Total</b> | <b>21,079</b> | <b>23,198</b> |     | <b>82,964</b> | <b>122.1</b> | <b>72,070,000</b> | <b>45,796,000</b> | <b>26,544,000</b> |          |

## 2.5 Alfalfa hay exports

Certain official statistics for the tonnage of exported alfalfa hay data are highly commingled with and confounded by export statistics for other species crop hays (e.g., USDA-AMS-LGMR, 2007; Woodward, 2006; Putnam, 2005). USDA-FAS (2006) reports estimates for all alfalfa exports, which includes dry hay, cubes, pellets and meal. These hay data are reported by volume (tons), not by acres. Approximately 1.6 percent of the U.S. dry hay crop is exported (table V-4). Most of this exported hay is grown in Washington and California where average yield is 4.9 and 6.9 tons per acre, respectively, and relative to the national average, hay value per ton is high. Using the mean hay yield for these two states (5.9 tons/A), the exported hay represents the equivalent production of approximately 204 thousand acres. It should be noted that an acre producing for the export market during one or more cutting periods likely produces hay for the domestic market at other times of the year (Putnam, 2005) (i.e., fields of alfalfa are not dedicated to the export market per se as they are in organic production). The number of acres from which exported hay is harvested annually is not known (Putnam, 2005). On average, the FAS reported selling price of exported hay is approximately \$160 per ton (table V-5) which is similar to the price for domestically sold hay in the region of production (Pacific Northwest and California). However, using the USDA-AMS-LGMN data, in 2006, within grade, within location, within month, the calculated price paid for export alfalfa hay was approximately 0 to 6 percent lower per ton on average than the price for domestic cattle-use hay of the same grade (calculated from head-to-head comparison of selling prices reported by USDA-AMS-LGMN, 2007). Therefore, in general, export market hay has a similar selling price per ton as other locally available hay; it is not considered a value-added market per se although there is significant value in the ability to contract for a large volume of sales to a few importing customers ahead of harvest time. According to Shewmaker et al. (2006), “The export market helps support and stabilize domestic forage prices in the [Pacific Northwest].” According to a NAFA document addressing coexistence in the alfalfa export markets (NAFA, 2007) the export hay market is of key importance to certain producers in Washington, Oregon and California and coexistence strategies for mitigating the presence of genetically modified (GM) alfalfa should be effective (see table V-5).

Annually, the export hay market is valued at approximately \$192 million (USDA-FAS, 2006) (table V-4). It may be noted that in general, hay sold into the export market channel is of “good,” “good/premium,” or “premium grade. In 2006, no or few “supreme” grade hay lots were exported (USDA-AMS-LGMN, 2007). The highest quality grade hays always are in high demand domestically and locally. The export quality specifications, although affected by objective forage quality grade, can be more sensitive to highly subjective hay attributes (e.g., green color, dirt-free, animal/insect-free) (Putnam, 2005). Approximately three-fourths of U.S. alfalfa hay exports go to Japan each year (table V-1, hay exports; Woodward, 2006); other key alfalfa hay export markets include the Republic of Korea (13 to 16 percent), Taiwan (5 to 7 percent), Canada and Mexico (table V-1, hay exports; Woodward, 2006). More than 85 percent of alfalfa forage exports are hay/compressed bales, with approximately 13 and 1 percent exported as cubes or meal products, respectively (USDA-FAS, 2006).

Table V-4. Total U.S. Alfalfa Hay Acres and Value by Method of Production Practice (2002-2005)

| Practice                                   | Factor | 2002          | 2003          | 2004          | 2006          | Mean          |
|--------------------------------------------|--------|---------------|---------------|---------------|---------------|---------------|
| <b>Conventional</b>                        |        |               |               |               |               |               |
| All alfalfa dry hay, acres                 |        | 22,923,000    | 23,529,000    | 21,707,000    | 22,439,000    | 22,649,500    |
| Change in acres per year                   |        | --            | 2.64%         | -7.74%        | 3.37%         | -0.58%        |
| Average production, tons/acre              |        | 3.19          | 3.24          | 3.48          | 3.39          | 3.33          |
| Total production, tons                     |        | 73,014,000    | 76,273,000    | 75,481,000    | 76,149,000    | 75,229,250    |
| Value (\$) per ton, average                |        | 100.00        | 90.80         | 98.60         | 104.00        | 98.35         |
| Value of production (\$)                   |        | 7,137,469,000 | 6,724,537,000 | 6,973,371,000 | 7,342,000,000 | 7,044,344,250 |
| Value (\$) per acre, average               |        | 311.37        | 285.80        | 321.25        | 327.20        | 311.40        |
| <b>Organic</b>                             |        |               |               |               |               |               |
| Organic alfalfa hay, acres                 |        | 155,437       | 135,717       | 175,260       | 204,380       | 167,698       |
| Change in acres per year                   |        | 33.30%        | -12.69%       | 29.14%        | 16.62%        | 16.59%        |
| Organic (%) of total alfalfa acres         |        | 0.68%         | 0.58%         | 0.81%         | 0.91%         | 0.74%         |
| Average production, tons/acre              | 0.85   | 2.71          | 2.75          | 2.96          | 2.88          | 2.83          |
| Total production, tons                     |        | 421,466       | 373,764       | 518,419       | 588,920       | 475,642       |
| Value (\$) per ton, average                | 1.18   | 118.00        | 107.14        | 116.35        | 122.72        | 116.05        |
| Value of production (\$)                   |        | 49,732,996    | 40,046,621    | 60,316,966    | 72,272,275    | 55,592,215    |
| Value (\$) per acre, average               |        | 319.96        | 295.07        | 344.16        | 353.62        | 328.20        |
| Value-added per ton                        |        | 18.00         | 16.34         | 17.75         | 18.72         | 17.70         |
| Value-added per acre                       |        | 8.59          | 9.28          | 22.91         | 26.42         | 16.80         |
| Value-added as percent of conventional     |        | 2.8%          | 3.2%          | 7.1%          | 8.1%          | 5.3%          |
| <b>Export</b>                              |        |               |               |               |               |               |
| Export alfalfa dry hay, tons (FAS)         |        | 1,176,208     | 1,260,450     | 1,253,130     | 1,125,363     | 1,203,788     |
| Total production (%) of U.S. dry hay total |        | 1.6%          | 1.7%          | 1.7%          | 1.5%          | 1.6%          |
| Value (\$) of export (FAS)                 |        | 180,917,000   | 192,993,000   | 202,372,000   | 193,789,000   | 192,517,750   |
| Value (\$) per ton, average                |        | 153.81        | 153.11        | 161.49        | 172.20        | 160.16        |



**Table V-5. 2006 Alfalfa and other hay exports from California, Oregon and Washington Ports  
(Tons)**

| Port                           | Destination |                 |           |      |
|--------------------------------|-------------|-----------------|-----------|------|
|                                | Japan       | Other Countries | Total     | %    |
| <b>California Ports</b>        | 694,516     | 241,333         | 935,849   | 35%  |
| <b>Oregon-Washington Ports</b> | 1,246,055   | 486,495         | 1,732,550 | 65%  |
| <b>Total</b>                   | 1,940,571   | 727,828         | 2,668,399 | 100% |

Source: United States Department of Commerce

## 2.6 Organic alfalfa hay

During 2002 through 2005, the number of acres in certified organic alfalfa hay production increased an average of about 17 percent per year (table V-4). The percentage of total alfalfa hay acres certified as organic per year was 0.58 to 0.91 percent nationally (table V-4). During 2005 (the most recent year for which certified organic alfalfa acres are reported), there were 204,380 acres which was 0.91% of the U.S. alfalfa dry hay total (tables V-4 and V-6). Considering a 17 percent average acreage growth rate per year, the percentage of organic hay acres currently is approximately 1 percent (table V-2). Although the organic dairy and livestock industries are growing very rapidly, organic hay alfalfa acres per se may grow at a slightly slower rate because many of the organic dairy and livestock producers are allowing more access to non-alfalfa (grass) organic pastures (i.e., pure alfalfa is not typically grazed in the U.S. due to the high incidence of bloat). In contrast to conventional hay marketed mainly on forage quality grade, with some exceptions, the main selling criterion apparent for organic hay is often only its organic status per se, irrespective of objective relative feed value (USDA-AMS-LGMR, 2007).

Table V-6. U.S. alfalfa hay (dry) acreage, ranked by number of certified organic acres by state, 2005

| State<br><br>UNIT | Total                            | Certified Organic | Calculated                        | Percentage        | Percentage       | Organic<br>Practice<br>State's | NASS 2005                          | NASS 2005                                 | NASS 2005                 | Value of            | ESTIMATED**                                                        | ESTIMATED                                                    |
|-------------------|----------------------------------|-------------------|-----------------------------------|-------------------|------------------|--------------------------------|------------------------------------|-------------------------------------------|---------------------------|---------------------|--------------------------------------------------------------------|--------------------------------------------------------------|
|                   | NASS 2005                        | ERS 2005          | Standard                          | Standard          | Certified        | National                       | NASS 2005                          | NASS 2005                                 | NASS 2005                 | Total               | Econ. Value-added                                                  | Econ. incremental                                            |
|                   | Reported<br>Alfalfa Hay<br>Acres | Reported<br>Acres | Practice<br>(NASS - ERS)<br>Acres | Practice<br>Acres | Organic<br>Acres | Rank<br>by \$value<br>(Rank)   | Production<br>Yield<br>(Tons/acre) | Production<br>Yield/State<br>(1,000 Tons) | Unit<br>Price<br>(\$/Ton) | Production<br>(\$1) | for certified organic hay<br>based on<br>18%<br>Price premium (\$) | 2005<br>value-added for<br>organic hay<br>(% of state total) |
| U.S. total        | 22,439,000                       | 204,380           | 22,234,620                        | 99.09%            | 0.91%            |                                | 2.45                               | 76,149                                    | 104                       | 7,342,000,000       | 12,037,080                                                         | 0.16%                                                        |
| Idaho             | 1,140,000                        | 49,497            | 1,090,503                         | 95.66%            | 4.34%            | 2                              | 4.2                                | 4,788                                     | 112                       | 536,256,000         | 4,191,044                                                          | 0.78%                                                        |
| Wisconsin         | 1,550,000                        | 29,389            | 1,520,611                         | 98.10%            | 1.90%            | 3                              | 2.4                                | 3,720                                     | 112                       | 416,640,000         | 1,421,967                                                          | 0.34%                                                        |
| Minnesota         | 1,350,000                        | 21,339            | 1,328,661                         | 98.42%            | 1.58%            | 5                              | 3.5                                | 4,725                                     | 73                        | 344,925,000         | 981,382                                                            | 0.28%                                                        |
| North Dakota      | 1,650,000                        | 20,614            | 1,629,386                         | 98.75%            | 1.25%            | 18                             | 2                                  | 3,300                                     | 55                        | 181,500,000         | 408,153                                                            | 0.22%                                                        |
| South Dakota      | 2,400,000                        | 13,930            | 2,386,070                         | 99.42%            | 0.58%            | 6                              | 2.15                               | 5,160                                     | 65                        | 335,400,000         | 350,418                                                            | 0.10%                                                        |
| California        | 1,040,000                        | 13,246            | 1,026,754                         | 98.73%            | 1.27%            | 1                              | 6.9                                | 7,176                                     | 136                       | 975,936,000         | 2,237,341                                                          | 0.23%                                                        |
| Iowa              | 1,250,000                        | 9,193             | 1,240,807                         | 99.26%            | 0.74%            | 4                              | 4.1                                | 5,125                                     | 80.5                      | 412,563,000         | 546,132                                                            | 0.13%                                                        |
| Colorado          | 800,000                          | 8,943             | 791,057                           | 98.88%            | 1.12%            | 7                              | 3.7                                | 2,960                                     | 101                       | 298,960,000         | 601,563                                                            | 0.20%                                                        |
| Nebraska          | 1,250,000                        | 8,192             | 1,241,809                         | 99.34%            | 0.66%            | 14                             | 3.7                                | 4,625                                     | 50                        | 231,250,000         | 272,777                                                            | 0.12%                                                        |
| Oregon            | 400,000                          | 6,592             | 393,408                           | 98.35%            | 1.65%            | 16                             | 4.4                                | 1,760                                     | 118                       | 207,680,000         | 616,062                                                            | 0.30%                                                        |
| Montana           | 1,750,000                        | 5,318             | 1,744,682                         | 99.70%            | 0.30%            | 8                              | 2.2                                | 3,850                                     | 71                        | 273,350,000         | 149,529                                                            | 0.05%                                                        |
| Nevada            | 260,000                          | 3,000             | 257,000                           | 98.85%            | 1.15%            | 20                             | 4.8                                | 1,248                                     | 120                       | 149,760,000         | 311,040                                                            | 0.21%                                                        |
| Illinois          | 400,000                          | 2,488             | 397,512                           | 99.38%            | 0.62%            | 22                             | 3.5                                | 1,400                                     | 99                        | 138,600,000         | 155,159                                                            | 0.11%                                                        |
| Wyoming           | 600,000                          | 1,726             | 598,274                           | 99.71%            | 0.29%            | 25                             | 2.6                                | 1,560                                     | 75                        | 117,000,000         | 60,597                                                             | 0.05%                                                        |
| Pennsylvania      | 510,000                          | 1,217             | 508,783                           | 99.76%            | 0.24%            | 17                             | 2.6                                | 1,326                                     | 153                       | 202,878,000         | 87,128                                                             | 0.04%                                                        |
| Missouri          | 450,000                          | 1,180             | 448,820                           | 99.74%            | 0.26%            | 23                             | 2.7                                | 1,215                                     | 102                       | 123,930,000         | 58,485                                                             | 0.05%                                                        |
| Washington        | 450,000                          | 1,140             | 448,860                           | 99.75%            | 0.25%            | 10                             | 5.2                                | 2,340                                     | 112                       | 262,080,000         | 119,508                                                            | 0.05%                                                        |
| Texas             | 150,000                          | 1,115             | 148,885                           | 99.26%            | 0.74%            | 27                             | 5.4                                | 810                                       | 127                       | 102,870,000         | 137,640                                                            | 0.13%                                                        |
| Ohio              | 510,000                          | 1,030             | 508,970                           | 99.80%            | 0.20%            | 13                             | 3.6                                | 1,836                                     | 130                       | 238,680,000         | 86,784                                                             | 0.04%                                                        |
| Utah              | 540,000                          | 925               | 539,075                           | 99.83%            | 0.17%            | 15                             | 4.2                                | 2,268                                     | 96                        | 217,728,000         | 67,133                                                             | 0.03%                                                        |
| Michigan          | 900,000                          | 714               | 899,286                           | 99.92%            | 0.08%            | 11                             | 3.1                                | 2,790                                     | 92                        | 256,680,000         | 36,674                                                             | 0.01%                                                        |
| New Mexico        | 240,000                          | 670               | 239,330                           | 99.72%            | 0.28%            | 19                             | 5.1                                | 1,224                                     | 128                       | 156,672,000         | 78,728                                                             | 0.05%                                                        |

|                |         |     |         |         |       |     |     |       |      |             |        |       |
|----------------|---------|-----|---------|---------|-------|-----|-----|-------|------|-------------|--------|-------|
| Kansas         | 850,000 | 661 | 849,339 | 99.92%  | 0.08% | 12  | 4   | 3,400 | 74.5 | 253,300,000 | 35,477 | 0.01% |
| Indiana        | 340,000 | 597 | 339,404 | 99.82%  | 0.18% | 21  | 3.8 | 1,292 | 112  | 144,704,000 | 45,697 | 0.03% |
| Arizona        | 260,000 | 487 | 259,513 | 99.81%  | 0.19% | 9   | 8.4 | 2,184 | 124  | 270,816,000 | 91,307 | 0.03% |
| Maine          | 11,000  | 345 | 10,655  | 96.86%  | 3.14% | 37  | 2.7 | 30    | 167  | 5,010,000   | 28,284 | 0.56% |
| New York       | 450,000 | 321 | 449,679 | 99.93%  | 0.07% | 24  | 2.1 | 945   | 131  | 123,795,000 | 15,910 | 0.01% |
| Virginia       | 110,000 | 276 | 109,724 | 99.75%  | 0.25% | 29  | 3.6 | 396   | 124  | 49,104,000  | 22,177 | 0.05% |
| Connecticut    | 8,000   | 102 | 7,898   | 98.73%  | 1.27% | 38  | 2.4 | 19    | 194  | 3,686,000   | 8,450  | 0.23% |
| Oklahoma       | 320,000 | 90  | 319,910 | 99.97%  | 0.03% | 26  | 3.7 | 1,184 | 97   | 114,848,000 | 5,814  | 0.01% |
| Maryland       | 40,000  | 28  | 39,973  | 99.93%  | 0.07% | 30  | 3.9 | 156   | 169  | 26,364,000  | 3,263  | 0.01% |
| Kentucky       | 260,000 | 13  | 259,987 | 100.00% | 0.00% | 28  | 3.2 | 832   | 118  | 98,176,000  | 884    | 0.00% |
| Massachusetts  | 14,000  | 2   | 13,998  | 99.99%  | 0.01% | 36  | 2.2 | 31    | 183  | 5,673,000   | 131    | 0.00% |
| Alabama        | -       | -   | -       | -       | -     | n/a | -   | -     | -    | -           | -      | -     |
| Alaska         | -       | -   | -       | -       | -     | n/a | -   | -     | -    | -           | -      | -     |
| Arkansas       | 20,000  | -   | 20,000  | 100.00% | 0.00% | 35  | 2.3 | 46    | 147  | 6,762,000   | -      | -     |
| Delaware       | 5,000   | -   | 5,000   | 100.00% | 0.00% | 41  | 3.6 | 18    | 169  | 3,042,000   | -      | -     |
| Florida        | -       | -   | -       | -       | -     | n/a | -   | -     | -    | -           | -      | -     |
| Georgia        | -       | -   | -       | -       | -     | n/a | -   | -     | -    | -           | -      | -     |
| Hawaii         | -       | -   | -       | -       | -     | n/a | -   | -     | -    | -           | -      | -     |
| Louisiana      | -       | -   | -       | -       | -     | n/a | -   | -     | -    | -           | -      | -     |
| Mississippi    | -       | -   | -       | -       | -     | n/a | -   | -     | -    | -           | -      | -     |
| New Hampshire  | 8,000   | -   | 8,000   | 100.00% | 0.00% | 40  | 2.1 | 17    | 197  | 3,349,000   | -      | -     |
| New Jersey     | 25,000  | -   | 25,000  | 100.00% | 0.00% | 34  | 2.7 | 68    | 150  | 10,200,000  | -      | -     |
| North Carolina | 11,000  | -   | 11,000  | 100.00% | 0.00% | 39  | 2.5 | 28    | 130  | 3,640,000   | -      | -     |
| Rhode Island   | 2,000   | -   | 2,000   | 100.00% | 0.00% | 42  | 3   | 6     | 188  | 1,128,000   | -      | -     |
| South Carolina | -       | -   | -       | -       | -     | n/a | -   | -     | -    | -           | -      | -     |
| Tennessee      | 35,000  | -   | 35,000  | 100.00% | 0.00% | 31  | 3.2 | 112   | 120  | 13,440,000  | -      | -     |
| Vermont        | 45,000  | -   | 45,000  | 100.00% | 0.00% | 32  | 1.8 | 81    | 161  | 13,041,000  | -      | -     |
| West Virginia  | 35,000  | -   | 35,000  | 100.00% | 0.00% | 33  | 2.8 | 98    | 108  | 10,584,000  | -      | -     |

\*Sources: Organic acres--USDA, Economic Research Service, based on information from USDA-accredited State and private organic certifiers; standard practice data from NASS.

Most recent year (2005) for which both certified organic and U.S. total alfalfa hay acre data are available for direct comparison.

\*\*Estimate assumes equivalent yield per acre and equivalent forage quality grade for organic and standard practice hays

18% price premium estimate based on median hay selling price for organic vs. non-organic hays of same quality group within the same geography of sale (USDA Livestock, Hay & Grain Market News, 2005 California Annual Hay Report)

The USDA-NASS reports the average conventional hay crop value (\$/ton); however, USDA-ERS does not report the value of organic hay, therefore, it must be estimated. It is commonplace for certified organic feedstuffs to sell for a 10 to 30 percent price premium depending upon demand and local supplies (Long et al., 2005; USDA-AMS-LGMN, 2006). The value-added price per ton for certified organic alfalfa hay is, on average, 18% greater than conventional hay. This price premium was calculated by comparing the mean sale prices of conventional and certified organic hay occurring within each sale location, within each forage quality grade and within each USDA hay market sale reporting period during 2006 (raw data was from USDA-AMS-LGMN, 2006). Certified organic producers often cite that their cost of production is less than for conventional crops, but sometimes there is also a significant reduction in harvestable yield or quality per acre associated with the lessened inputs that limits the value-added profit potential per acre (Long et al., 2005). (Note: Organic forage crop acres are reported to USDA-ERS as “alfalfa dry hay,” “silage,” and “pasture/rangeland.” The latter two categories in ERS count acres of other forage species with-- and largely, without alfalfa. Therefore, silage and pasture/rangeland data used by the ERS are not equivalent in species composition and not directly comparable to similar data categories used by USDA-NASS).

The increased price per ton of hay received by organic growers is partially offset by a substantial reduction in forage quality (due to weeds in the hay) and an approximately 15% reduction of alfalfa yield per acre. (Note: Estimates of 10 to 20 percent (or more) yield reductions were estimated by D. Putnam and D. Undersander, State Forage Extension Specialists from California and Wisconsin, respectively, Personal Communications). The USDA-ERS certified organic alfalfa hay acres were multiplied by these adjustment factors in tables V-5 and V-7. Within each year, calculations were as follows: organic yield per acre = 0.85 x conventional yield; organic price per ton = 1.18 x conventional price per ton; organic value-added = organic value per acre (or per ton) minus conventional value per acre (or per ton). Table V-4 presents organic versus conventional alfalfa hay values for 2002-2005, and, state values are presented in table 6 for 2005. In 2005, only 11 states had more than 5,000 acres of organic hay production. For these 11 states, only seven had more than one percent of alfalfa acres grown as organic, with Idaho representing four percent of the state’s alfalfa hay acres (table V-6). In Idaho, each of eight counties produced more than \$10 million dollars worth of organic certified “other crops and hay” (USDA-NASS, 2002); however, the amount of organic alfalfa hay is not separately reported.

By-region forage (and seed) summary statistics and estimates for 2006 organic acres and regions of production are presented in table V-2, which was compiled by three alfalfa industry experts and presented by McCaslin (2007) to the California Alfalfa Symposium. The panel developed this by-region summary using 2005/2006 official data sets and, when lacking production values, methods or assumptions were estimated, as described in table V-2 footnotes. Contributors to this market summary were alfalfa product leaders of the three largest U.S. alfalfa seed companies: M. McCaslin, Ph.D., President, Forage Genetics International, D. Miller, Ph. D., Alfalfa Research Director, Pioneer Hi-Bred International, and, P. Frey, C.E.O., Cal/West Seeds.

## 2.7 Socioeconomic Factors Influencing Alfalfa Production

Along with its primary value as a high quality livestock feed, alfalfa is a valued rotational crop in U.S. agriculture because it improves soil tilth, fertility and structure. It helps mitigate soil erosion and because alfalfa is a legume, successive crops benefit from residual nitrogen in the soil. Although it is a highly sustainable practice, alfalfa's use in crop rotation is declining in the U.S. because it demands different management, equipment, market channels, and labor schedules not common to other mainstream cropping systems (USDA-ERS, 2002). In addition, livestock to consume the hay may no longer be located in the vicinity. Alfalfa forage-cutting schedules, yield, quality, and persistence are challenged by weather and pests.

In general, alfalfa requires somewhat more complex management and more labor to produce per ton of bulk forage than alternative annual row crops, such as corn silage. In some situations, because of social forces (on-farm labor constraints or other local market changes), forage growers have replaced their alfalfa acres with corn silage, an easier-to-manage, less risky, non-legume forage crop. This has occurred even though the alternative forage crop used is not as environmentally sustainable, is not as nutritionally complete for livestock, and is not as profitable in the long term for many farm systems. The number of alfalfa acres for forage is declining and the number of corn silage acres is increasing. Herbicides routinely are used in corn production, and because corn is grown in rows and is established yearly, there is increased likelihood of more soil erosion compared to alfalfa production. Corn requires nitrogen fertilization; alfalfa does not. Among the corn silage seed choices, forage growers are increasingly adopting varieties with value-added traits, such as herbicide tolerance, insect resistance and other genetically modified attributes that make forage crop production more labor or cost efficient. Therefore, it is likely that such social factors influence a grower's choice to plant alfalfa versus alternative forage species. It is expected that weeds in Roundup Ready alfalfa will be easier, less costly, and less time-consuming to manage compared to weeds in conventional alfalfa plantings.

In part, because of several social and economic reasons, risk-averse producers in much of the U.S. have reduced the number of acres planted to alfalfa. It may be noted that, in contrast to several alternative feedstuff crops, alfalfa crop prices are not directly managed or insured by government programs. Very little hay is transported cross-country and almost none is imported to meet U.S. forage market shortfalls, although dairy and livestock producers require a constant supply. The crop is a perennial that peaks in yield during the second and third year. Relative to annual crops, alfalfa demand and supply are more prone to serious within-season imbalance, price volatility, and the selling price of the alfalfa crop is not known at planting time. Alfalfa growers face the risk of weather interacting with weed competition or herbicide application outcomes that can lead to unpredicted stand failure, stand depletion and or temporary or permanent loss of hay quality or stand yield potential.

In parallel and for several of the same reasons, the numbers of alfalfa seed growers, and seed acres have declined in the U.S. Most alfalfa seed is grown on highly valued irrigated land in the West where there is much competition for the limited number of skilled growers and suitable acres for alfalfa seed growing. U.S. alfalfa seed growers compete with their conventional seed producing counterparts in Canada, Australia and elsewhere, where

comparative production costs are significantly lower (e.g., USDA Docket 04-085-1; public comment by M. Wagoner). Alfalfa seed yield is highly influenced by grower inputs, weeds and insect pests and seasonal weather fluctuations. The cost and availability of required cultured pollinator bees is highly variable (many cultured bees are imported from western Canada).

Similar economic, social and competitive challenges face both U.S. alfalfa seed and forage growers. Weeds increase the level of risk for all alfalfa producers. As has occurred in other agricultural crops, herbicide tolerance in alfalfa may be adopted by producers as a means to mitigate certain weed-associated crop-production risks. The development of new technologies, including but not limited to, herbicide tolerance (e.g., Roundup Ready alfalfa) could act to foster alfalfa culture (in total) so that current production levels are sustained. The Roundup Ready alfalfa technology already has been rapidly adopted and accepted by approximately 4,000 U.S. forage and seed growers who are challenged by a highly dynamic and competitive global marketplace (see numerous USDA Docket 04-085-1 public comments from forage and seed growers).

### 3.0 Seed Production

Alfalfa grown for seed production purposes occurs exclusively in niche areas of the Western U.S. on approximately 100 to 120 thousand acres (figure V-2). Although alfalfa forage is grown in all continental states, the crop value is highest in the West, Plains and upper Midwest.

Additional information on by-county seed production may be found at:

[http://www.nass.usda.gov/Census/Pull\\_Data\\_Census](http://www.nass.usda.gov/Census/Pull_Data_Census)

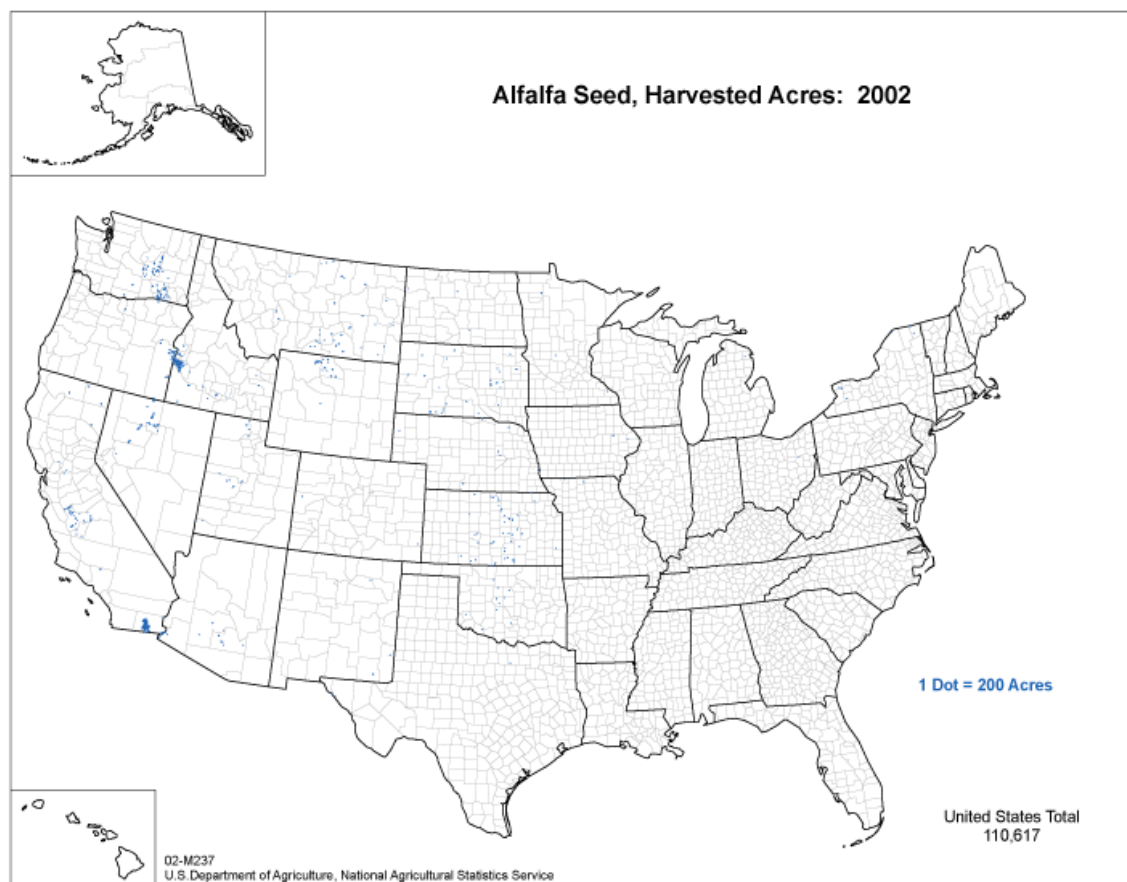


Figure V-2: Geographic distribution of alfalfa seed acres, 2002 (USDA, 2002).

### 3.1 Breeding systems cultivar development

Cultivated alfalfa is an autotetraploid crop that is exclusively bee cross-pollinated. Forage production does not require bees or pollination and seed maturation in forage systems reduces crop nutritional value. Alfalfa is not wind pollinated and it is rarely self-pollinated. Most genotypes do not form any self-seed. Self-progeny are of very low vigor and agronomic value. Discussion of the breeding system for alfalfa was presented in the Petition, section II.

Alfalfa cultivars typically are developed by plant breeders using a combination of phenotypic and or genotypic recurrent selection to identify parent plants. Cultivars are, with few exceptions, open-pollinated synthetic varieties. Seed of the cultivar (or variety) is produced

commercially using bee pollination in isolation from other cultivars (AOSCA, 2003). More than 250 registered conventional alfalfa cultivars are commercially available for planting, and multiple varieties are available from numerous U.S. vendors (>40 seed brands). A list of registered alfalfa cultivars and marketers that sell them are listed in an alfalfa variety list publication offered by the National Alfalfa & Forage Alliance (<http://www.alfalfa.org>). Although U.S. plant variety protection is available to cultivar developers, for the past 20 years, relatively few of the AOSCA registered conventional varieties were submitted by the developer for U.S. plant variety protection. Since 2005, approximately 30 Roundup Ready alfalfa cultivars have been registered within the AOSCA National Alfalfa and Miscellaneous Legume Variety Review Board process. In addition to registered public and proprietary varieties, numerous conventional unnamed brands and common seeds of alfalfa are available for planting.

### 3.2 Commercial planting seeds

The numerous seed alternatives differ in seed quality, adaptation, pest reaction, yield potential, forage quality, tolerance to grazing, degree of winter activity, and many other agronomic features. Alfalfa seed may be sold raw or more typically it is sold pre-inoculated with one or more strains of *Sinorhizobium meliloti* (the alfalfa-nodulating, nitrogen-fixing bacteria) and or coated with lime or clay that may contain a fungicide (e.g., metalaxyl), seed colorants and or micronutrients. Proprietary cultivars often are sold as treated or coated seeds. The retail price for alfalfa seed is related to its agronomic performance, value-added features, quality of the seeds (germination, purity), brand name/seed supplier reputation, annual supply and demand, etc.. The choice of seed is especially important because the decision is made only once in the life of each multi-year stand. The seed price is only two to three percent of the overall alfalfa stand establishment cost. Therefore, the use of high quality seed of superior varieties is a widely recommended practice by university and extension forage specialists. With respect to seed quality requirements and seed labeling laws, state and federal seed control agencies conduct seed lot inspections to ensure truth in labeling. Inadequately cleaned seed lots (purchased alfalfa, grower-saved or bin-run companion crop seeds) can be a potential source of weeds in newly seeded alfalfa.

Essentially all alfalfa hay growers purchase seeds for planting. Due to the unique climate required for successful commercial seed production on alfalfa, there are relatively few producers of alfalfa seed and, therefore, very few alfalfa growers have an opportunity to save seeds should they choose to do so. In most cases, an alfalfa seed producer grows seed of a specific named variety under terms of a seed company contract. Such contracts may require third-party inspection of production conditions and they may prohibit or restrict the practice of saving proprietary seeds grown under the contract. Commercial seed industry practices are discussed in section VII.B.5 and B.7 (pages 259 and 260) of the Petition and further addressed below.



### 3.3 Pollinators of alfalfa

In most alfalfa seed-growing areas, naturally occurring populations of those species of bees capable of tripping and producing cross-pollination are either nonexistent or in such low number that commercial production of seed alfalfa would be impossible without the deliberate production, introduction, and management of certain bee species to provide adequate pollination (Arnett, 2002). Professional alfalfa seed growers use at least one of three species of bees for pollination. They are the honey bee (*Apis mellifera*), the alfalfa leafcutting bee (*Megachile rotundata*), and in very small niche geographies with scattered alkali beds (e.g., Touchet, WA) the alkali bee (*Nomia melanderi*) is used often heavily augmented with cultured leafcutting bees. Feral and native bee species are present in low numbers and pollinate alfalfa. In addition to alkali, leafcutters and honeybees Hammon et al. (2006) identified nine native bee species visiting alfalfa flowers in Colorado.

#### 3.3.1 Distance of cultured and native pollinator travel and or foraging

Although maximum foraging radius for each of the three commercial bee species is dependent on the abundance (or dearth) of nectar and pollen resources, leafcutter bees are considered to have the shortest routine foraging distance (<1/4 mile) followed by the honey bee and alkali bee (ca. 1 to 3 miles) (Arnett, 2003; Hammon et al., 2006; Teuber et al., 2005). There is evidence that honey bees may infrequently transport alfalfa pollen and effect pollination up to 3 miles from the source (St. Amand et al. 2000; Teuber et al 2004; Hammon et al. 2006). Honey bees predominantly work to collect nectar not pollen from alfalfa flowers and they prefer other weed and crop species over alfalfa as nectar sources; therefore, they are less efficient commercial pollinators than leafcutter bees in many regions (Arnett, 2002; Crane, 2002). Cane (2002) determined that honey bees only pollinate (“trip”) only 22 percent of the flowers they visit; therefore, most of their foraging is for nectar, not pollen, and the nectar is obtained by “side feeding” without deposition of pollen or pollination.

In addition to these three cultured bee species, low density populations of bumble bees (*Bombus* spp.) other bee species occasionally visit alfalfa to collect nectar and pollen and may sometimes pollinate alfalfa flowers but their importance in alfalfa pollination is minor (Hammon et al., 2006; Arnett, 2002). Native bees, including *Bombus* spp, *Osmia* spp, and *Agapostomen* spp. and native *Megachile* spp. can be found visiting alfalfa in varying numbers. Non cultured honey bees are not native bees but may occur among the feral bees and although they prefer other plants, they sometimes pollinate alfalfa. Other insect pollinators have not shown to be effective pollinators of alfalfa. Hammon et al. (2006) found evidence to support that, “Most alkali foraging was within seed fields or local in nature,” and that, “Alkali bees were probably of minor importance in long distance pollen movement.” In the Hammon et al. pollinator collection survey (2006), in addition to commercial pollinating bee species, they collected low populations of nine native taxa of bees that may be short, mid and long-range pollinators of alfalfa. Most of the native bees are solitary in nature. A study of the native solitary bees of Germany by Gathmann and Tschardt (2002) found that, “solitary bees have a rather small foraging range so local habitat structure appears to be more important than large-scale landscape structure.” They also determined that, “maximum foraging distance between nesting site and food patch was 150-600 m for the 16 bee species examined,” and that, both foraging distance and mean foraging trip duration (6 to 28 min) were correlated positively with

body length. Therefore, large bees such as *Bombus* spp. may be likely to travel further distances but because they occur in very low numbers and forage on flowers of many other plant species, bumble bees pose a very small risk of significant long-distance gene flow among alfalfa populations.

It is possible that wind storms could blow bees carrying GM pollen long distances; however, due to factors of scale and dilution, the risk of resultant subsequent transgene flow to other alfalfa would be extremely small or zero. In all gene flow studies to date, in addition to the stocked pollinator, native and feral bees were present, so their potential contribution to gene flow under commercial conditions has been accounted for in the available data sets. A general recent review of principles of bee pollination may be found in *Crop Pollination by Bees* (Delaplane and Mayer, 2000). The risk of gene flow at various distances for each pollinator species is discussed in detail in other sections of this document.

### 3.3.2 Commercial pollinator species

The vast majority of certified alfalfa seed is grown under contract in the Pacific Northwest (PNW) and California where seed growers typically introduce and culture either leafcutter bees or honeybees, respectively. Certain seed growers use a blend of pollinator species to optimize seed yield and harvest date. Honey bees tend to tolerate higher temperatures than leafcutter bees. In unique, small geographies of the PNW, the ground-nesting alkali bee may be used to supplement leafcutter bee pollination of alfalfa seed fields or *visa versa*. Bees are introduced and provided with nesting sites (hives, domiciles, or permanent beds) near to or within the seed field. Each of the three commercial pollinator species has different attributes regarding their culture and behavior. When resource-limited, however, bees will scout and range to greater distances but their maximum possible flight distance has not been determined.

The bees are a necessary and costly input for professional seed growers. Growers time the bee introduction release date(s) to coincide with advanced bloom (> 50%) and as bloom resources gradually increase, bee stocking rates are proportionately increased to rapidly and efficiently set the seed crop. These are routine pollinator management adjustments that help ensure that a grower's valuable bees pollinate and remain largely near their home domicile. Approximate stocking rate for leafcutter bees and honeybees is approximately two gallons of loose cell pupae or two hives per acre, respectively; and more or less are applied depending on local bee prices, density of bloom, and seed contract settlement price.

FGI Best Practices for seed growers (<http://www.foragegenetics.com/News.asp>) and Roundup Ready seed grower contracts stipulate the predominant pollinator species to be used, field location and bee management restrictions to be used. If the grower stocks a blend of pollinators, the grower's isolation minimum is set based on the pollinator stocked with the longest foraging range. Once bees are placed in a Roundup Ready alfalfa seed field, the grower is prohibited from moving the bee colony/domicile to a conventional seed field for the rest of the growing season.

### 3.3.3 *Passive physical pollen transfer among bees leading to gene flow*

It is theoretically possible that within colony or when in physical contact, bee-to-bee passive surface transfer of pollen could occur which could lead, rarely, to a subsequent pollination event and gene flow (Mueller, 2005). According to Johansen (1970 Personal Communication as cited by V. Marble), "...bees clean themselves quite thoroughly back at the hive or nest, concluding that little pollen remained to contaminate a new area of [bee] forage when the bees do not return to the same area of a field on the subsequent trip." This suggests that there is near zero potential for gene flow that might result from passive pollen transfer among cohabitating bees and very little accumulation of viable pollen on the surface of bees that make repeated foraging trips to an alfalfa field or feral grouping of plants. There would be essentially no risk of within-nest transfer of pollen for most of the native bee species because they are solitary nesting bees.

### 3.4 Commercial Seed Production

In the U.S., alfalfa commercial seed production occurred on approximately 110,000 to 122,000 acres during 2002 and 2006, respectively. Alfalfa seed production occurs exclusively in the Western states where late-summer seed ripening may occur without damage from rain, heavy dew or high humidity (figure V-2). Alfalfa seed production is a distinct commercial practice from forage production (Hanson et al., 1988). Due primarily to the climate in the West, the U.S. is a major alfalfa seed-producing country. The value of the U.S. annual seed crop is estimated to be in excess of \$90 million. Approximately 70 percent of the seed crop is used domestically.

Key aspects of alfalfa seed production were discussed in Petition section VII B.5 (page 259) and VII.E.2 (pages 286-287). This document describes other practices and characteristics of the U.S. seed production industry with emphasis on stewardship strategies that will enable coexistence among diverse market sectors and preserve grower choice.

Although much alfalfa seed is imported to the U.S. (USDA-FAS, 2006) for planting, some of the imported seeds are reexported by U.S. seed companies. The U.S. is a net exporter of seed (tables V-2 and V-3). Approximately 30 percent of the U.S. seed crop is exported (tables V-2 and V-3).

Alfalfa cultivars are grouped into two main germplasm types: (1) the winter-active, day-length insensitive, "non-dormant" and "semi-dormant" varieties adapted to low deserts and very long growing seasons, or (2) the winter-inactive, day-length sensitive, dormant varieties adapted to the northern latitudes. In general, seeds of each variety type are grown in their respective area of adaptation: dormant varieties in the North and, non-and semi-dormant varieties in Southwest, especially California (table V-2 and table V-3). Seeds also are grouped according to whether they are Certified Seeds. Proprietary varieties are grown under company contract. Public variety and common seeds may be grown with or without a seed contract from a seed company.

The value of alfalfa seed varies widely between years, variety type (proprietary versus common; certified versus non-certified; value-added traits versus none) and quality specifications (germination, species purity, etc.). Official statistics on seed-grower settlement

prices are lacking, but on average, it may be approximately one-half to two-thirds of the wholesale price of seed. Domestic alfalfa seed prices (grower settlement, wholesale or retail) are not reported by USDA-NASS. The only official record of alfalfa seed selling price is for exported seed, not for domestically sold seed and was reported by USDA-ERS for the period 2000 to 2002 (USDA-ERS, 2002). For the period, the average (wholesale) price of Certified and Non-Certified exported seed was \$2.83 and \$2.50 per pound, respectively; these seeds were cleaned, conditioned, packaged for sale, and may be treated coated or raw. A seed value survey conducted by Hower et al. (1999) found that the average growers' raw-seed price was \$1.08 for the period 1988 to 1992, with the overall annual value in excess of \$89 million. In order to approximate an alfalfa seed market value, the recent seed grower settlement price will be estimated as \$1.30 per pound. It should be noted that the sale price that a seed grower receives varies widely (e.g., 0.75 to \$2.00 per pound). Highest prices are paid for contracted, high quality, proprietary production and the lowest for low quality, non-contracted common seeds.

According to USDA-NASS statistics for 2006, 122 thousand acres were harvested for alfalfa seed, total production was 72 million pounds, and the average yield was approximately 590 lbs per acre (weighted average) (table V-3). Using \$1.30 per pound to value the seed, the overall seed production market value was approximately \$94 million. As seen in figure V-2 within the seed producing states, seed production is localized to certain counties. In the most recent USDA-NASS Census of Agriculture (2002), during 1997 and 2002, 1,300 and 1,234 farmers grew alfalfa seed on 163.3 and 110.6 thousand acres, respectively. This is a small number of growers in comparison to those growing alfalfa for forage (i.e., 385 and 344 thousand alfalfa hay growers in 1997 and 2002, respectively). During 2002, 82 percent of the U.S. seed crop tonnage was grown by 314 seed growers operating farms with at least 100 acres of alfalfa seed (USDA-NASS, 2002). Therefore, most of the alfalfa seed production is managed by a relatively small number of large professional seed producers. Nearly all large growers have at least one proprietary seed production contract with one of the four national alfalfa seed production companies. Small acreage seed growers located mainly in the Plains primarily produce uncertified seeds (e.g., for the past several years, South Dakota Crop Improvement has not certified any alfalfa seed production although much alfalfa seed is produced). Overall, approximately 8 and 58 percent of the dormant and non-dormant seed crops are exported (table V-2). The states that export the most nondormant and dormant alfalfa variety seeds are California and Idaho (tables V-2 and V-3). No or virtually no certified organic production of alfalfa seeds occurs in the U.S.

Nearly all alfalfa seed is used for the establishment of hay fields, with a minor amount used as seed field stock seed (variety increase) or for sprouting purposes. Alfalfa seed is not consumed as a grain and therefore not used directly as a food or feed product. Essentially all alfalfa planting seed produced in the U.S. is grown using insecticides and or herbicides, the use of which precludes the seeds' use for food/sprouting purposes. The use of biologically contaminated canal or waste waters or livestock manures to fertilize alfalfa sprout seed fields also are prohibited by food safety regulations. Therefore seed products entering the planting and sprouting seed channels are kept as distinct. A small percentage of U.S. alfalfa seed may be used for sprouting seed. Bass et al. (1988) estimated that 7 percent of U.S. alfalfa seed is

used for sprouting, but this has not been confirmed. Acreage or production of sprout-destined seed is not reported, because field locations for such production are not recorded, they are not known officially. It is believed that most of the sprout seeds are imported because economic alfalfa seed production in the U.S. generally requires the use of some food-prohibited practices. Roundup Ready alfalfa was favorably reviewed by the U.S. Food and Drug Administration in 2004.

#### *3.4.1 Commercial seed production culture*

Alfalfa seed production requires a long growing season with very warm temperature, very low humidity during seed ripening and specialized equipment. Most professional seed producers use cultured bees and specialized equipment associated with bee culture. Therefore, professional seed production only occurs in niche areas of the western U.S. primarily under intensive management and irrigated field conditions (figure V-2).

Cultural practices used to produce seed are distinct from those used to produce forage. Professional seed growers usually grow seed under terms of a two or three year term seed company contract, by variety name. The contracting seed company supplies the stock seed (e.g., foundation seed) to the seed producer and genetic source variety of the seed is documented. In contrast, seed companies purchasing or growing “common seed” or “catch crop” seed typically use lower management and inputs, the genetic identity of the stock seed is often unspecified /unknown and the resultant product quality is highly variable and cannot be certified as to cultivar or variety identity.

Typically, seed fields are planted in the fall and clipped back in late spring so that bloom within the field is uniform, synchronous and optimally timed for the warm dry season and optimal pollinator activity. Weed and in-crop volunteer controls (herbicides and cultivation) are applied mainly prior to the start of pollination or after seed harvest. Flowering begins in approximately mid June. Insecticides (primarily for *Lygus* control) and other pesticides are applied prior to bee release to avoid insecticide damage to the bees. At approximately 50% flower (ca. early to mid July), cultured bees are gradually moved into the seed field for pollination with their domicile or hive for local shelter. The field is actively pollinated for approximately one month, allowed to ripen seed for approximately four more weeks, and then, chemically desiccated or swathed several days prior to combining the seed. At the end of the pollination period and just prior to desiccation, the pollinating generation of bees is either at the end of their lifecycle (i.e., leafcutter or alkali bees) or are transported by the honeybee keeper to a different location to forage on fall-flowering plant species. Seed is harvested in mid August to late September depending on geography. In long-growing season regions, the cool-season alfalfa forage growth between seed crops is sometimes mechanically harvested or grazed.

Usually, stands of alfalfa grown for seed production only are maintained an average of three production seasons. Seed production contracts and AOSCA variety certification standards generally predetermine the length of the seed stand. Because most seed production is planted in widely spaced rows and are not cut monthly, relative to forage stands, weeds in seed fields have more time and open area to proliferate and compete with the alfalfa. Therefore, weeds (and insect) pests are intensively managed in seed production systems. Weed seeds and weed

debris in grower seed lots directly reduce the purity and yield of alfalfa seed and drive up growers' costs to remove them. The presence of prohibited weeds, such as dodder (*Cuscuta* spp.) makes the alfalfa seed very costly to condition and or not saleable.

In 2002, alfalfa seed was grown only on 110,600 acres on 1,234 farms, whereas, the numbers for forage production were 23 million acres and 400,000 (USDA NASS, 2002)(Note: 2002 is the most recent year for which NASS alfalfa seed production full census data are available). In the past 10 years, the alfalfa seed production industry has consolidated and the number of alfalfa variety developers (breeding companies) is small relative to those for other U.S. field crops. Due to the specialized expertise, high-cost of perennial, tetraploid breeding programs and in-part due to a *conventional* alfalfa variety developer's limited ability to protect their proprietary variety from unauthorized increase and sale via common seed channels, there are a small number of alfalfa variety developers. One reason for the small number of variety developers is that, unlike most other crop breeding systems, in conventional alfalfa cultivars, there are no unique, true-breeding genetic markers to help ensure intellectual property, patent rights or plant variety protection rights are respected by unauthorized seed producers (i.e., alfalfa varieties cannot be "fingerprinted" like corn inbreds). Common, variety not stated and or "brown bag" seeds are seed market channels through which unauthorized producers sell improved germplasm of named proprietary varieties without variety developer authorization or knowledge. The unique, event-specific genetic sequence of transgenes will allow genetic fingerprinting of germplasm lines in alfalfa and thereby allow a means to certify cultivar origin, patent rights and trait stewardship. In 2006, there were only four major alfalfa seed companies that developed AOSCA registered varieties *and* produced seed: Forage Genetics International, Pioneer Hi-Bred International, Cal/West Seeds and Dairyland Seeds. In the past five years (2003-2007), in addition to these four companies, approximately three other seed companies and two public institutions have developed and registered new alfalfa varieties (<http://www.NAAIC.org> : NAMLVRB annual lists). In total, there are approximately 60 independent U.S. alfalfa seed companies/conditioners (primary processors) among which FGI is the largest company; approximately 29% of U.S. seed production acreage is produced under an FGI seed contract (Fitzpatrick et al., 2007b).

#### 3.4.2 Seed certification value and standards

Certified cultivar alfalfa seed commands a higher price than uncertified seed; the price of certified seed is also relatively more stable over years. During the 10-year period, 1996-2005, the average and range of retail prices paid by U.S. farmers for certified and uncertified alfalfa seeds were, respectively, \$2.82 (\$2.77-\$2.91) versus \$1.76 (\$1.57-\$2.05) (USDA-NASS, 2006). Hay producers buying certified seeds pay a 60 percent premium over non certified seeds because they understand the value of purchasing seeds of a known cultivar from a reputable supplier to establish a long-term crop. Seed price is approximately 2 to 3 percent of the forage stand establishment cost.

Gene flow between alfalfa populations is a natural occurrence and bee-mediated cross-pollination among plants within a cultivar is necessary for commercial seed production. Alfalfa seed producers use spatial isolation to separate cultivars and manage bee and pollen

flow between fields of different cultivars. The minimum isolation standard for foundation and certified seed fields more than 5 acres in size is 600 and 50 ft, and for fields 5 acres or less, the standard is 900 and 165 ft, respectively [Association of Official Seed Certifying Agencies (AOSCA), 2003]. State seed certifying organizations that are members of AOSCA may adopt the same or more stringent local standards for certified alfalfa seeds. For example, Idaho Crop Improvement Association (2007) requires a greater isolation distance (900 ft) than AOSCA between certified seed fields when one field is conventional and the other is of a genetically modified type (e.g., Roundup Ready). In addition to field isolation, certified seed production applies standards for field history, known genetic origin of the stockseed and in-crop volunteer control to maintain a variety true to type. Variety certification is distinct from organic certification of seeds: variety certification is a product-based certification wherein specified tolerances for off-types and impurities are recognized. USDA organic certification is a process-based certification only; organic seeds or products are not certified according to genetic purity. In a web search of organic seed suppliers, none were found that offered organically grown seeds of a certified variety (FGI: August 14, 2007).

### *3.4.3 Proprietary and public cultivar (variety) conventional alfalfa seed production*

High quality, high value and genetically pure alfalfa seed production requires specialized equipment, pollinators, isolation, climate and unique crop management practices that are not used for forage production. The majority of alfalfa seed tonnage is produced by large professional, specialized alfalfa seed growers using irrigation under multi-year seed company contracts primarily within seven western states (California, Idaho, Nevada, Oregon, Washington, Montana and Wyoming). For example, in 2002, 54 percent of the U.S. seed crop was grown by the 98 large-scale seed growers who harvested greater than 250 acres each (NASS, 2002). The smaller-scale seed growers (< 49 acres each), in total, produced only seven percent of the U.S. seed crop. For the past 20 years, most of the U.S. alfalfa seed crop was produced by registered variety name (known seed source), within official state field isolation inspection programs and under contract for a relatively small number of seed companies that develop or produce proprietary varieties. Due to the specialized expertise and seed conditioning infrastructure required, and in-part due to a conventional alfalfa variety developer's limited ability to protect their proprietary variety (intellectual property) from unauthorized increase and sale via common seed channels, there are a small number of alfalfa variety developers. (Note: Conventional alfalfa genetics preclude genetic fingerprinting of parent or commercial lines.) Less than ten alfalfa variety breeders (companies and public institutions) have officially registered >95% of the AOSCA registered proprietary alfalfa cultivars during the past 20 years (NAAIC-NAMLVRB, 2007). Of the more than 250 listed alfalfa cultivars, fewer than ten public varieties have been released in the past 20 years. The majority of the U.S. alfalfa seed crop is of AOSCA registered proprietary cultivars that are intensively managed by contracted seed growers, plantings are grown to optimize alfalfa seed yield and seed quality using sufficient field isolation, in-crop volunteer control and field history to minimize genetic off-types due to unintended gene flow between conventional cultivars (e.g., using AOSCA field isolation standards (AOSCA, 2003)). Seed of proprietary alfalfa varieties grown to meet official certification standards typically commands a 300% higher market price than common alfalfa seed (US Trade Office statistics for export, 2005). Alfalfa seed companies contracting seed production of a proprietary named variety require that the seed grower plant a company-supplied stockseed lot of the variety (e.g., foundation class

stockseed). Seed growers of certified seeds of public varieties must use foundation seed lots for the variety grown.

### 3.5 Common and organic seed production

Depending on the relative current prices of hay versus seed and amount of rainfall, a highly variable amount of “common” seed is intentionally produced on converted (un-harvested) forage fields or seed fields grown without variety identification, isolation requirement or official seed certification oversight. Common seed, including catch-crop seed and grower-saved seed, is not regulated. Common seed sold inter-state or internationally is subject to phytosanitary regulations (e.g., absence of prohibited weed seeds, diseases and insect, etc.) but cultivar genetic identity or genetic purity cannot be certified.

Organic seed is certified to have been organically produced, but very little if any organic-certified seed is available that is also variety-certified (most organic seed is of common or uncertified varieties sold under a brand name, not by registered variety name). Seed sold under brand name only without a variety name or of an unregistered variety name cannot be variety-certified.

Common seed production occurs mainly in marginal, dryland, hay/seed production geographies (e.g., portions of western South Dakota, North Dakota, western Kansas, western Nebraska, Oklahoma and the Imperial Valley of California, etc.) as a “catch crop” in years of seed shortage (higher seed price), low hay price and or drought sufficient to limit hay yield or feed quality. Most catch crop hay/seed growers are relatively low-input growers and they may or may not apply cultured pollinators to the field and consequently, seed yield and seed quality can be very, very low on catch crop seed. For example, mean seed yield in Nebraska and Kansas was 72 and 100 lbs per acre (1988-1992) versus greater than 500 lbs per acre for states in prime seed growing states (Hower et al., 1999).

Roundup Ready alfalfa seed may not be legally grown as common seed (appendix V-2). In locations of common seed production, Roundup Ready forage producers are obligated to cut their forage fields at or before 10% bloom as a means to mitigate gene flow to conventional common seed fields; see appendix V-2 and terms of Monsanto Technology/ Stewardship Agreement (Monsanto, 2007).

Although a small amount of organic alfalfa seed is purchased in the U.S. from U.S. seed distributors, little or none of the organic alfalfa seeds appear to have been originally grown in the U.S. (McCaslin, 2007 declaration). A National Organic Program Standards exception allows organic forage producers to establish their fields using non-organic (conventionally grown) seeds if their chosen cultivar or cultivar type is not available to them as organic, and after 3 years of adhering to an organic production plan, old hay fields previously managed/planted as conventional may be “converted” into the organic program for organic forage and or possibly for attempted organic seed production. Also, there is an exception for very small organic producers with gross annual revenue of less than \$5,000; no NOP certification is required for the small producer to garner official certification to label their hay



or seed product as organic. It is possible that a low number of economically small organic producers are supplying some organic alfalfa seed to U.S. organic hay producers and because no certification of any type is required, the organic seed and acres used to produce it are unaccounted for in USDA-AMS market census statistics (the volume of seed and the location of production is not officially known). Therefore, although approximately 0.9 percent of U.S. alfalfa acreage is certified as organic (USDA, 2005), only a small fraction of these acres were ever established using organic alfalfa planting seed; i.e., because it is not a requirement, there is little organic seed available. Organically certified and conventionally grown seed lots are routinely marketed to U.S. organic forage producers for the establishment of organic alfalfa forage fields (there are numerous examples on seed company web sites).

Across the western U.S., *Lygus* species bugs are a very serious insect pest on alfalfa seed production (Hower et al., 1999). In California and the Pacific Northwest, the principle U.S. alfalfa seed production regions, virtually every acre of alfalfa seed production is treated with insecticides one or more times each year to control *Lygus* bugs and other insects, and with herbicides to control weeds. In most years and in most fields in the West, complete alfalfa seed crop failure will result without chemical control of *Lygus*. For this reason, organic alfalfa seed production is not economically viable in the prime western U.S. seed growing region.

FGI is the largest producer of alfalfa seed in the world and has extensive first-hand experience in global trade of conventional and certified organic alfalfa seed. In 2006-07, FGI found no publicly available evidence to support that there are any certified organic alfalfa seed producers in the United States. (Disclaimer: It may be noted that due to competitive marketing positions, the external alfalfa seed company representatives polled by FGI and Monsanto may not have voluntarily divulged their company's actual sources of their organic alfalfa seed products.)

Organic alfalfa seed sold in the U.S. by U.S. seed companies is therefore most likely to have been wholly or largely imported from organic producers in Canada or elsewhere, where insect pests in alfalfa seed production are less catastrophic and base production costs for seed are much lower (McCaslin, 2007 declaration). After importation from the country of origin, the seeds may be packaged by a U.S. seed company prior to sale to U.S. organic forage growers; most of this seed is raw or treated only with NOP approved seed treatments and approved *Sinorhizobium* inoculant formulations.

## **4.0 Impacts of Roundup Ready Alfalfa Technology Adoption by U.S. Hay and Seed Producers**

The impact of adoption of the Roundup Ready alfalfa weed control system was discussed in detail in Petition section VII. This section addresses potential agronomic and market impacts as a result of technology adoption of Roundup Ready alfalfa by U.S. forage growers, alfalfa seed-selling companies, alfalfa variety developers and alfalfa seed growers.

### **4.1 Affected Environments**

Roundup Ready alfalfa may affect three primary environments in the United States:

- 1) Agricultural lands where alfalfa is cultivated for hay or seed production purposes;
- 2) Non-agricultural lands and lands adjacent to agricultural lands where alfalfa may be growing without cultivation as feral alfalfa; and
- 3) The human environment, wherein Roundup Ready alfalfa may have social and economic impacts for those choosing to adopt the technology and other impacts for non-adopting producers. Examples of likely non-adopters include conventional alfalfa hay, seed producers serving the organic, conventional as well as export market sectors, and the industries associated with these growers.

Aspects of the affected environments are addressed in detail in the Petition section II (The Alfalfa Family) and section VII (Agronomic Practices and Environmental Consequences). A summary of the affected environments as well as additional relevant information is provided below.

### **4.2 Regulatory Approval Status**

Roundup Ready alfalfa cultivars were initially sold for commercial planting in the U.S. in the fall of 2005. Successful introduction relied upon securing regulatory approvals in the U.S. and key export markets. Prior to market introduction, Roundup Ready alfalfa was deregulated by the U.S. Department of Agriculture, Animal and Plant Health Inspection Service (USDA, 2005) and a consultation was completed with the U.S. Food and Drug Administration (FDA) (FDA, 2004). Use of Roundup herbicide on Roundup Ready alfalfa was approved by the U.S. Environmental Protection Agency (EPA). To support import of Roundup Ready alfalfa hay or seed for food, feed and processing purposes, approvals were obtained from numerous international agencies including those in Japan, Korea, Canada, Mexico and the Philippines. Several countries are also signatories to the Cartagena Protocol on Biosafety (CBD, 2000); thus, regulatory reviews and approval fulfilled their obligation under the Protocol. A listing of key export markets and approvals obtained to date is presented in table V-7.

**Table V-7. Roundup Ready Alfalfa Regulatory Status**

| Country/Sub. | Type of Approval Sought | Approval/Submission Status                                                |
|--------------|-------------------------|---------------------------------------------------------------------------|
| U.S.         | Food/Feed               | FDA Consultation completed December 2004                                  |
|              | Environment             | Deregulation completed by USDA June 2005                                  |
|              | Roundup Label           | EPA approved herbicide labels June 2005                                   |
| Mexico       | Food/Feed               | Food approval completed February 2005                                     |
|              | Environment             | In country production trials in progress                                  |
| Argentina    | Food/Feed/Environment   | Submission planned for early 2008, in country studies underway            |
| Canada       | Food/Feed               | Approved (food and feed), July 2005                                       |
|              | Environment             | Approved, July 2005                                                       |
| Japan        | Food/Feed               | Approved October 2005 (Food); February 2006 (Feed)                        |
|              | Environment             | Approved February 2006                                                    |
| Korea        | Food                    | Approved October 2007 (no feed regulations)                               |
|              | Environment             | Submitted May 2005                                                        |
| Taiwan       | Food                    | Voluntary submission September 2004, only currently regulate corn and soy |
| Philippines  | Food                    | Approval for food, feed and processing, August 2006                       |
| Australia    | Food                    | Food approval February 2007                                               |

#### 4.3 Purpose and Need for a Roundup Ready Weed-Control System in Alfalfa

The benefits of the Roundup Ready alfalfa weed control system were described in the Petition (See section I, subsection C). A brief summary of expected benefits is discussed below. Alfalfa (*Medicago sativa* L.) is a widely adapted perennial species grown primarily for livestock forage in most regions of the United States. Over 20 million acres of alfalfa have been grown annually in the U.S. since 1950. Alfalfa represents the fifth major crop species following corn, soy, cotton, and canola to be improved through the use of biotechnology and is the first perennial to be developed for herbicide tolerance. An important component of alfalfa production in U.S. agriculture is the impact of weeds in alfalfa forage. Weeds consistently reduce the yield of pure alfalfa harvested and negatively affect forage nutritional quality (Peters and Linscott, 1988). Weed management in alfalfa is complicated by the large number of weed species that are of economic importance in the crop. In a U.S. survey, Hower et al. (1999) reported the occurrence of 81 weed species in spring-seeded alfalfa, 93 species in fall-seeded alfalfa and 98 species in established alfalfa. The differences in management required for spring seedings, fall seedings, established stands, pure stands and mixed species culture, in addition to the environmental and economic variables that exist between growing regions, make weed management a challenge in alfalfa. Forty percent of alfalfa forage acres are pure stand, 35 percent are planted with a cover (nurse) crop, and the remaining 25 percent are planted with a permanent companion crop, usually a grass.

Weeds can negatively impact stand establishment, stand density, crop yield, livestock feed value and safety, market price, harvest management timing, and stand longevity. Weeds are a serious stress on alfalfa stands, product quality, and producer profitability. Currently, weed management in conventional alfalfa forage and seed crops is accomplished using an integrated approach that combines cultural and or chemical methods. The normal crop harvest pattern (repeated removal of the hay) controls weeds by interrupting their growth and seed-production cycles. In addition,

field mowing, early harvest, spot burning, site avoidance/selection, planting date selection, co-seeding alfalfa with a cover-crop, crop rotation, and early stand renovation are examples of cultural practices used for weed control, and also negatively impact the alfalfa crop yield and disrupt the local environment to some degree. Numerous non-glyphosate herbicides are widely used in conventional alfalfa either alone or as tank mixtures, in pre-plant, after seedling emergence, and in established stands. These herbicides may be expensive, have a limited window for safe application, cause crop injury, and many times, weeds are not sufficiently controlled so as to warrant the cost or effort to apply. Certain of the herbicides may not be used in later years in the alfalfa crop cycle because they have soil residual activity that may injure a subsequent sensitive crop. Weed and non-native species seeds harvested with the alfalfa are transported with the infested hay mass and transported between farms and over long distances. Certain customers (e.g., those bringing hay into Bureau of Land Management controlled areas) must use hay that is Certified Weed Free. For these reasons, new weed control options are needed in alfalfa.

Herbicides provide considerable agronomic and economic benefits to alfalfa producers and they are essential to alfalfa management in many geographies. According to the 1988-1992 National Agricultural Pesticide Impact Assessment Program Survey (Hower et al., 1999), the majority of pure-stand alfalfa in the U.S. is established with herbicides. Alfalfa is a short-lived perennial species with approximately 20% of the total acres seeded on an annual basis. Of the acres planted each year, 1.49 million acres are pure alfalfa stands and established with herbicides. The overall economic benefit of herbicides used on alfalfa seed and hay acres is \$336 M (Hower et al., 1999). Gianessi et al. (2002) estimated that the value of alfalfa hay in California alone is reduced \$21 M per year because of weeds in harvested hay. Current herbicide programs for alfalfa have several limitations, including application timing restrictions, herbicide carryover and crop rotation concerns, incomplete weed control, and crop injury. While cultural and mechanical weed-management practices are used extensively in alfalfa, they are reported to be substantially less effective than herbicides (Peters and Linscott, 1988). Thus, improved weed control in alfalfa is needed.

Roundup Ready alfalfa will enable the use of Roundup agricultural herbicides to provide effective weed control during forage and seed production. Roundup agricultural herbicides are highly effective against the majority of annual and perennial weeds common to alfalfa seed and forage production. Roundup herbicides also have excellent environmental safety features, such as rapid soil binding (making them resistant to leaching), as well as low toxicity to mammals, birds and fish. In addition, glyphosate is one of the few herbicidal active ingredients classified as Category E by the Environmental Protection Agency (EPA) (evidence of noncarcinogenicity for humans) (57 FR 8739). The Roundup Ready Alfalfa technology offers several key advantages over conventional weed-control methods. Certain glyphosate-containing agricultural herbicides are labeled for use during alfalfa stand renovation (stand take-out), as a pre-plant burn down, and in-crop, during crop dormancy. Roundup agricultural herbicide over the top of Roundup Ready alfalfa will be used to augment integrated weed-control options in alfalfa systems and will offer a unique mode of action for in-crop integrated weed control.

To provide alfalfa producers with an improved weed-control system, Monsanto and Forage Genetics International (FGI) jointly developed cultivars of alfalfa that are tolerant to glyphosate, the active ingredient in Roundup agricultural herbicides. Roundup Ready alfalfa offers alfalfa (forage and seed) producers a new management tool to control weeds before, during and after alfalfa stand establishment, and provides a simpler and more effective weed-control system compared to current alfalfa weed-control practices. Thus, the Roundup Ready alfalfa weed control system simplifies and improves weed management during stand establishment, enhances the flexibility of weed control in established stands, and improves forage quality by reducing the weed content of harvested forage.

Roundup Ready alfalfa cultivars initially were sold for commercial planting in the U.S. in the fall of 2005. The demonstrated benefits of the Roundup Ready weed-control system in alfalfa and other crops and familiarity of the system by farmers resulted in much anticipation and demand for Roundup Ready alfalfa seed. Since 2005 and prior to March 30, 2007, more than 4,000 Monsanto-licensed alfalfa forage producers in 48 states have purchased more than 3.7 million pounds of Roundup Ready alfalfa seed, resulting in approximately 330,000 acres currently planted in the new alfalfa varieties. The supply of Roundup Ready alfalfa seed rapidly sold out in the spring and fall planting seasons. No herbicide-tolerant crop has experienced quicker grower acceptance than Roundup Ready alfalfa, and in California alone, an estimated 20 percent of the 1.1 million acres of alfalfa has been planted to Roundup Ready alfalfa. The benefits predicted for the Roundup Ready alfalfa weed control system met and exceeded the expectations of producers.

Roundup Ready alfalfa has helped forage producers reduce costs and increase income. University of Nebraska conducted studies with the Roundup Ready alfalfa system and showed a 0.2 to 1.0 ton per acre yield advantage in the establishment year over conventional alfalfa treated with standard herbicide programs. This equated to an average net income advantage of \$109 per acre in 2005 and \$91 per acre in 2006 for the Roundup Ready alfalfa system over conventional alfalfa and herbicide programs (Wilson, 2002 and 2006). Not only was more hay produced, but the hay was of better quality. A standard called relative feed value (RFV) often is used to compare nutritive values of hay and forage (University of Wisconsin, 2000; South Dakota State University, unpublished). In a University of Nebraska trial (Wilson, 2005) forage from Roundup Ready alfalfa had an RFV of 208 compared with an RFV of 171 for untreated conventional alfalfa. The cash hay value difference between these hays is approximately \$30 per ton, based on an estimated \$0.80 per RFV quality bonus (Rankin, 2007). This increased yield and quality of alfalfa hay translated into more milk from cows. Research done at the University of Minnesota predicted a dramatic difference in milk production. Based on yield and quality data, Roundup Ready alfalfa would produce an average of 8,204 pounds of milk per acre, compared with 7,568 pounds per acre for the conventional alfalfa— or nearly an eight percent increase (C. Sheaffer, unpublished). A large hay grower in Nevada who commercially used the technology measured a \$190 per acre per year net benefit of the technology over the conventional system (Phillips, 2007, Personal Communication). Testimonies submitted to the court by several growers are provided in Attachment 1 to this amendment. These declarations confirm the economic value provided to growers using the Roundup Ready alfalfa weed control system.

#### 4.4 Agronomic Impacts

Agronomic impacts due to the introduction of Roundup Ready alfalfa were reviewed in the Petition, section VII.

#### 4.5 Impact on Herbicide Practices

A thorough analysis of herbicide options available to alfalfa growers, and the characteristics and limitations of those herbicides were reviewed in the Petition (section VII, subsection D). Based on the adoption of other Roundup Ready crops, it is expected that Roundup Ready alfalfa will displace a significant portion of other alfalfa varieties, especially where alfalfa is highly managed (e.g., Western and Southwestern states). As Roundup Ready alfalfa is adopted, it is expected that Roundup herbicide will replace other forms of weed control currently used in alfalfa.

J101 and J163 are highly tolerant to glyphosate and show no yield loss or loss in forage quality when treated over multiple seasons over and above maximum glyphosate application rates (Pierson and Reyes, 2006). Recommended use rates are provided by Monsanto to growers in Regional Technical Bulletins (See appendix I of Document Number 04-AL-116U-1). In-season maximum application of glyphosate is up to 1.5 lbs a.e. per acre at a single application, and total per-year applications is 4.5 lbs a.e./acre. These application rates were used by Monsanto when conducting residue studies and for event selection purposes. In practice, these maximum rates will rarely be used since the vast majority of weeds are controlled using recommended rates and it would be uneconomical for growers to apply excess herbicide.

#### 4.6 Impact to Rotational Crops and Stand Life

Information provided in USDA Petition Number 04-110-01p section VII, subsection F.4, evaluated the impact of Roundup Ready alfalfa on rotational crop practices, including rotations with other Roundup Ready crops. With the exception of cotton, non-glyphosate-based herbicides are readily available for control of Roundup Ready alfalfa in common alfalfa rotations; therefore, it was concluded that there would be no impact on crop rotation practices. Cotton rotations with alfalfa may be managed using mechanical weed control and good stand termination practices.

There has been some speculation that weed-free stands may result in longer stand life requiring a change in land use. Extended stand life provides positive economic and environmental benefits because a significant amount of the total production costs over the life of the stand are associated with the establishment year. These costs include those associated with seed bed preparation, seed, fertilizer, herbicides and pesticides (Ward, 2007). After the stand is successfully established, costs diminish, and extending a healthy stand will increase profitability. Increased stand life would result in less tillage of agricultural lands and growth of a crop that introduces nitrogen credits, thus diminishing the generation of greenhouse gasses. The introduction of Roundup Ready alfalfa may provide growers the opportunity to extend the life of a stand because Roundup agricultural herbicides do not cause crop injury like some of

the other herbicides currently used on alfalfa. Thus, removal of weeds in the final years of the stand without crop injury provides the opportunity to maintain a healthy weed-free stand. The decision to terminate an alfalfa stand depends on stand productivity and planned crop-rotation practices. Weeds are certainly a factor in production of high quality alfalfa, but they are not the only factor leading to stand decline. Other factors impacting stand life include pest and disease pressure, abiotic stress (e.g., winter kill), harvest practices, rotational crop plans and natural plant senescence.

#### 4.7 Roundup Ready Alfalfa: Overview of Impact on Weed Potential

(Cross reference to Doc 04-AI-116-1)

#### 4.8 Other Roundup Ready Crops: Overview of Impact on the Weed Potential, Disease Susceptibility

(Cross reference to Doc 04-AI-116-1)

#### 4.9 Impacts to Nontarget Organisms

The CP4 EPSPS protein contained in Roundup Ready crops is similar to other members of the EPSPS family of proteins that are common in the environment. Therefore, there is no *a priori* reason to assume that the CP4 EPSPS protein will exhibit adverse biological activity towards non-mammalian organisms or soil microorganisms or associated biogeochemical processes. Further, the introduced CP4 EPSPS itself was derived from a common soil bacterium (*Agrobacterium* sp. strain CP4) and EPSPS proteins are commonly found in bacteria and fungi. Even though the likelihood of hazard is low for the CP4 protein, a number of researchers conducted laboratory and field investigations with different types of arthropods and other non-mammalian organisms exposed to Roundup Ready crops containing the CP4 EPSPS protein. Relevant information for arthropods will be discussed first, followed by soil microorganisms.

##### 4.9.1 *Impact of CP4 EPSPS expressing crops on non-mammalian organisms (arthropods)*

Representatives of pollinators, soil organisms, beneficial arthropods and pest species were exposed to tissues from Roundup Ready crops that contain the CP4 EPSPS protein. These studies vary in design; some for relatively short durations (pest species) and others for multiple generations (*Collembola*) (table V-8). Precise estimates of exposure of the test animals to the CP4 EPSPS protein in most of these test systems were not assessed. Importantly, no toxicity was observed in arthropods exposed to these Roundup Ready crops, reinforcing the conclusion of minimal hazard (table V-8).

The risk assessment for CP4 EPSPS protein in Roundup Ready crops reveals no evidence of unreasonable risk to nontarget animals because minimal hazard is predicted based on widespread occurrence of the EPSPS proteins and no plausible mechanism of toxicity. Although minimal ecological risk is predicted in the formal risk assessment process, several field-monitoring studies were conducted for Roundup Ready crops to reinforce the conclusion and address any potential uncertainties in the risk assessment process (table V-8). Plots were

monitored for arthropod abundance in Roundup Ready 2 Corn, Roundup Ready Soybeans, Roundup Ready Sugarbeet and Roundup Ready Canola. Results of these studies are consistent with the predictions of the ecological risk assessment in that there is no evidence of unreasonable risk demonstrated in these studies. In fact, some of the studies suggest that the Roundup Ready system, the combination of Roundup Ready crops with weed management programs that incorporate glyphosate applications, can promote the abundance of beneficial arthropods through increasing the amount of weed tissue present in Roundup Ready plots.

#### *4.9.2 Impact of CP4 EPSPS expressing crops on non-mammalian organisms (soil microbes)*

Soil microbial communities that mediate biogeochemical processes and directly impact soil quality are highly complex and are often characterized by high microbial diversity (Tiedje et al., 1989). While there is no direct evidence of any hazard to microbial systems from CP4 EPSPS, microbial processes are affected by biotic factors (community characteristics and dynamics, specific plant-microorganism interactions) and abiotic factors such as soil structure, hydration, pH and redox potential (Atlas and Bartha, 1997). In agricultural systems, changes in microbial communities have been observed in response to soil disturbance, history of soil amendment, irrigation, tillage, and plant community structure (Buckley and Schmidt, 2001). Consequently, significant variation in microbial populations is expected in agricultural fields. Furthermore, the individual components of a healthy microbial community within the soil have not been defined with sufficient precision to facilitate risk assessment using specific species as indicators. Although ecological risk predicted for the CP4 EPSPS protein is minimal, independent investigators have studied the potential effects of the purified CP4 EPSPS protein and the Roundup Ready production system containing CP4 EPSPS on soil microorganisms and processes. The distribution and abundance of soil microorganisms, microbial community composition, and microbially mediated processes have been analyzed in field plots containing Roundup Ready Canola (Dunfield and Germida, 2003; Siciliano and Germida, 1999). The results from these investigations confirm there are no meaningful immediate or long-term effects of the CP4 EPSPS-expressing crops on soil microbial communities.

#### **4.10 Impact on Forage Growers**

The Roundup Ready alfalfa technology will be adopted by forage growers seeking a new tool for weed control. It is known that weeds are a more serious economic problem in regions with long growing seasons. Forage growers in regions with higher yield and weed potentials currently have higher input costs into their weed control programs. For example, 50 versus 8 percent of the growers in the West and North Central Regions, respectively, apply non-glyphosate and glyphosate herbicides to alfalfa (Hower et al., 1999). Seeds of Roundup Ready alfalfa varieties will have a higher seed price per pound than conventional varieties but they will allow the added use of a crop-safe, flexible, broad-spectrum and less costly herbicide (glyphosate) for in-crop weed control.

Based on weed impacts, current herbicide use patterns, unmet weed control issues, use of proprietary seeds, prevalence of pure-stand planting, previous Roundup Ready alfalfa seed



sales (2005-2007), and the potential benefits for forage quality and yield per acre, it is anticipated that eventual adoption of Roundup Ready alfalfa will be highest in the Southwest, Plains States, Pacific Northwest (PNW), and Intermountain Regions, and lower in the Midwest, East, and Southeast. During the initial period of deregulation, there was a very strong demand for seeds of the Roundup Ready alfalfa varieties, and virtually all available seeds in the marketplace were rapidly sold and planted. Approximately 300 thousand acres (ca. 4 million pounds of seed) of Roundup Ready alfalfa were planted with some acres in each of the 48 contiguous states. In Monsanto customer feedback surveys, over 95 percent of the early adopters of the technology reported that they were either “very satisfied” or “satisfied” with the product and technology performance.

It is expected that adopters of the new technology will be mainly those growers who are currently higher input, progressive forage growers and those who now purchase higher quality and higher value seeds of alfalfa and of other crop species. Seeds are a small proportion of the cost to establish the multi-year alfalfa forage stand (e.g., two to three percent of the first year inputs). The decision to use improved seeds will be based on local conditions and grower attitudes.

In order to ensure that a sufficient number of alfalfa seedlings establish, the recommended planting rate (pounds per acre) for Roundup Ready alfalfa is the same as that recommended for conventional varieties. The recommended seeding rate varies among geographies, soil types and seeding methods, but it is approximately 12 to 15 lbs per acre in the eastern and northern regions and traditionally as high as 30 lbs per acre in the Desert Southwest. As a means to extend their higher-priced seeds over more acreage or a longer stand life, it is anticipated that some individual forage growers may experiment with planting their Roundup Ready alfalfa seeds at a slightly reduced seeding rate or they may try to maintain their stands one year longer than is customary for their conventional varieties. However, because there are many factors aside from weeds that determine optimal whole-farm profitability, crop rotation schedules (alfalfa stand length) and seedling establishment success, growers would not be expected to significantly alter crop rotation schedules or planting methods should they choose to adopt Roundup Ready alfalfa. It is possible that if growers are presented with any value-added opportunity for the crop or a new effective weed management tool, especially one like Roundup Ready alfalfa that is useful in stand establishment, the total number of acres planted to alfalfa might stop declining (stabilize) or it might slightly increase to some previous level. The number of acres planted to forage crops in total is closely tied to the number of local livestock, so it is unlikely that any large shift in the number or location of alfalfa acres overall would occur. Most producers who are not currently using any herbicides to grow alfalfa are less likely to adopt the technology; they are likely to continue to use companion or cover crops to suppress weeds. All forage producers adopting the technology will combine the use of glyphosate with their routine cultural methods that will act to suppress weeds. Glyphosate can be integrated with other alfalfa herbicides in Roundup Ready alfalfa forage (and seed) production.

**Table V-8. Summary of laboratory, green house and field studies investigating effects in pests and beneficial organisms exposed to the CP4 EPSPS protein and Roundup Ready crops containing the CP4 EPSPS protein compared to conventional varieties**

| <b>Product/<br/>Location</b>          | <b>Type of<br/>Organisms</b>      | <b>Study Description</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>Conclusion</b>                                                                                                                                                                                                                                                                                                                          | <b>Reference</b>               |
|---------------------------------------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|
| Roundup Ready Corn (NK 603)/ Thailand | Pollinator (Honey bee)            | Two greenhouse (with single and mixed test material within greenhouses) and a laboratory experiment were conducted to study honey bee foraging behavior, egg laying rate, and in-hive development. Test materials included RR corn, a conventional control and two conventional commercial hybrids. Two beehives were used per greenhouse experiment, and four replicates of 30 bees each per treatment were used in the laboratory experiment.                                                                            | No effects were observed on pollen harvest behavior of workers bees, or on survival and development of honey bee egg, larvae or pupa when exposed to RR corn pollen during and after pollination.                                                                                                                                          | <i>Boongird et al., 2003</i>   |
| Roundup Ready Corn (NK 603)/ Thailand | Aphids & lacewing                 | The experiment was a completely randomized design with 40 aphids and 20 lacewing larvae per treatment. Treatments included RR corn, a conventional control and two conventional commercial hybrids. Lacewings were exposed for 11-12 days to aphids fed on the treatments mentioned above. Measurements included aphid's days for growth development and progeny; and lacewing's days of development to pupa, number of aphids eaten per growth stage, number of eggs per female lacewing and number of eggs that hatched. | No effects were observed on growth or development of aphids feeding on RR corn or of lacewing feeding on the aphids reared on RR corn.                                                                                                                                                                                                     | <i>Jamornman et al., 2003</i>  |
| Roundup Ready Soybean/ U.S.           | Green cloverworm                  | The experiment was a complete randomized design with 30 replicates per treatment. Replicates consisted of individually housed green cloverworms. Treatments included four varieties of soybeans: two RR and two conventional varieties. Measurements included stadia for individual instars and stages, survivorships, and adult morphological measurements as indicators of reproductive fitness.                                                                                                                         | No differences were detected on development and survival of the green cloverworm between RR and the conventional soybean varieties.                                                                                                                                                                                                        | <i>Morjan and Pedigo, 2002</i> |
| Roundup Ready Soybean/ U.S.           | Beneficial species and soil mites | Twelve fields, six planted with RR and six planted with conventional soybeans, were monitored for abundance of 15 major groups of beneficial insects and soil mites. Weeds were managed with glyphosate in the RR soybean fields, and with commercial herbicides in the conventional soybean fields. Arthropods were sampled weekly using sweep nets and pitfall traps. Soil mites were sampled once before fall tillage.                                                                                                  | Results from pitfall traps and soil samples showed no differences in beneficial arthropods or soil mites between RR and conventional soybeans. Results from sweep net samples, however, revealed significantly more green lacewing adults in conventional soybean fields, only when the data from the six fields were pooled for analysis. | <i>Jasinski et al., 2003</i>   |

|                                |                          |                                                                                                                                                                                                                                                                       |                                                                                                                                                                                           |                                |
|--------------------------------|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|
| Roundup Ready Soybean/<br>U.S. | Pests and<br>beneficials | The experiment consisted in four replicate plots (16 rows x 15.2 m) planted with RR and conventional soybean varieties managed under different weed management regimes. Arthropods were monitored during one growing season using a d-vac.                            | No adverse effects on abundance of arthropods were noted relative to RR soybeans. No direct effect of glyphosate applications were observed on arthropod abundance.                       | <i>Jackson and Pitre, 2004</i> |
| Roundup Ready Soybean/<br>U.S. | Collembola               | Collembola abundance was monitored with pitfall traps in a three-year study consisting of eight replicate plots (6.1 x 7.3 m) per treatment. Treatments included RR and conventional soybean varieties under three weed management systems.                           | No differences in Collembola abundance were noted between RR and conventional soybeans under the same weed management system.                                                             | <i>Bitzer et al., 2002</i>     |
| Roundup Ready Soybean/<br>U.S. | Pests and<br>beneficials | Arthropods were monitored using sweep nets in a 1 year consisting of eight replicate plots (6.0 x 6.0 m) per treatment. Treatments included two RR and four conventional soybean varieties under three weed management systems. The study was conducted at two sites. | No adverse affects on abundance of arthropods were noted relative to RR soybeans. Insect abundance was correlated to weed density or plant height.                                        | <i>Buckelew et al., 2000</i>   |
| Roundup Ready Soybean/<br>U.S. | Pests                    | <i>Insect pests were monitored using sweep-nets in a two-year study consisting of four replicate plots (6-8 rows by 15.1 m) per treatment. Treatments included RR and conventional varieties under different weed management systems.</i>                             | <i>No differences on abundance of insect pests were attributed to the RR soybean variety. Differences noted in insect abundance were attributed to factors such as cultivar maturity.</i> | <i>McPherson et al., 2003</i>  |

**Table V-9. Summary of laboratory and field investigations on the potential adverse effects of CP4 EPSPS protein and Roundup Ready crops containing the CP4 EPSPS protein on soil microbial populations compared to conventional varieties**

|                                      |                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                             |                                                               |
|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|
| <b>Roundup Ready Canola/ Canada</b>  | Taxonomic diversity of bacteria associated with the roots of RR canola (Quest) and two conventional canola varieties were characterized using fatty acid methyl ester (FAME) analyses. Four randomly chosen plants were sampled from four replicate plots of each cultivar at two sites.                                                                                 | A subtle reduction was observed in the diversity of the bacterial root-endophytic community of a RR canola compared to that of two conventional cultivars. However, the authors concluded that the diversity of bacteria associated with the roots of canola differs between cultivars rather than the presence or absence of the RR trait. | <i>Siciliano and Germida 1999</i>                             |
| <b>Roundup Ready Canola/ Canada</b>  | Characterization of microbial communities associated with the roots of RR canola and conventional canola varieties were characterized using fatty acid methyl ester, community level physiological profiles and terminal rDNA restriction analysis. Plants were sampled over time during a two-year period from four replicate plots of each cultivar at multiple sites. | Principal component analysis showed variation in microbial community associated with canola variety and growth season. The authors concluded that the changes in the microbial community were temporary and did not persist into the next field season.                                                                                     | <i>Dunfield and Germida, 2003; Dunfield and Germida, 2004</i> |
| <b>Roundup Ready soybeans/ Korea</b> | The gene transfer from RR soybeans to soil bacteria <i>Rhizobium</i> was assessed by hybridization using DNA extracted from soil taken from pots. Soybeans were grown in pots for 6 months after which four soil cores (at different depths) were extracted and processed weekly three times.                                                                            | No foreign genes (35S promoter, T-nos or EPSPS) from the RR soybeans were detected in <i>Rhizobium</i> . The results showed no gene transfer between RR soybeans and soil microorganisms.                                                                                                                                                   | <i>Kim et al., 2004</i>                                       |
| <b>Roundup Ready soybean/ Korea</b>  | <i>Possible horizontal transfer between RR soybeans and certain bacteria and fungus common to fermented Korean food were assessed using PCR analysis and antibiotic resistant genes.</i>                                                                                                                                                                                 | <i>The authors did not detect horizontal gene transfer from RR soybeans to food microorganisms.</i>                                                                                                                                                                                                                                         | <i>Shin et al., 2004</i>                                      |

#### 4.11 Impact on Alfalfa Seed Companies and Seed Producers

During the initial period of deregulation, Roundup Ready alfalfa seeds were offered for sale by Monsanto licensed seed companies (i.e., seed brand names). The new Roundup Ready alfalfa seed products (varieties) offer a broad array of licensed seed dealers, distributors and retailers an opportunity to generate new revenues from selling a value-added, trait-differentiated product line.

As a step towards conventional, organic, export, and Roundup Ready alfalfa seed producer coexistence, trait stewardship and gene flow mitigation, the National Alfalfa & Forage Alliance (NAFA) sponsored a stakeholder coexistence workshop (Denver, CO, October 10, 2007). Three of the national seed companies, FGI, Pioneer and Cal/West Seeds, are members of this national alfalfa industry umbrella organization. Under the sponsorship of NAFA, these three seed companies coauthored and have agreed to implement a set of binding, stringent seed production best practices requirements: “NAFA Best Practices for Seed Production of Roundup Ready Alfalfa Varieties” (NAFA, 2007). In addition to these three seed companies, NAFA board members reviewed and accepted the NAFA best practices. Steering committee representatives of NAFA who reviewed and accepted the best practices document included industry stakeholder representatives from seed certification agencies, universities, farmers and companies engaged in the production of seeds and hay for conventional, organic and export market sectors.

There are only approximately 1,234 alfalfa seed growers in the United States (USDA-NASS, 2002 Census of Agriculture). One-quarter of these seed growers (about 300) grow at least 100 acres of alfalfa seed each year, and combined, this group produces about 82 percent of the U.S. alfalfa seed crop. FGI is the largest single alfalfa seed producer in the U.S. and it manages seed contracts for approximately 29 percent of the U.S. seed crop total (Fitzpatrick et al., 2007b).

Weeds directly reduce alfalfa seed yield even though they are heavily managed in alfalfa seed production systems using a combination of cultural practices and multiple herbicides (Hower et al., 1999). Roundup Ready alfalfa offers a new weed control tool and a unique value-added opportunity to U.S. seed growers. Many of them have demonstrated a willingness and capability to grow Roundup Ready alfalfa seeds (see court testimony and public comments to 2005 and 2008 Dockets). During the initial deregulated period (fall 2005 to early spring 2007, professional large-acreage alfalfa seed growers in ten western states produced approximately 4 million pounds of FGI proprietary Roundup Ready alfalfa seeds on approximately 18,000 acres (McCaslin declarations, 2007). Therefore, it may be inferred that among the 300 larger professional seed growers, about one-fourth of them already adopted the Roundup Ready alfalfa technology. Additional seed growers have expressed a strong interest in gaining seed production contracts for Roundup Ready alfalfa varieties from FGI or from Pioneer, the only FGI sublicensed seed producer to-date.

#### 4.12 Impact to Forage Export Markets

Regulatory approval for feed and or food use of Roundup Ready alfalfa hay was granted in Japan, The Republic of Korea, Philippines, Canada and Mexico (see table V-1) and regulatory approval for feed import purposes is not required for import of feeds into Taiwan. Combined, these export markets represent over 98 percent of U.S. hay exports (table V-2). Therefore, hay importer sensitivity to Roundup Ready alfalfa is overwhelmingly a buyer preference decision, not a regulatory issue per se. Insofar as food labeling requirements for biotech-derived foods, some countries, such as Japan, established a five percent GM-trait tolerance threshold for approved trait presence. It should be noted that hay is not a food per se and food labeling regulations are not applicable to feeds. For producers wishing to apply the food regulations as a guideline to their feed import contracts or tolerance limits, trait testing is available. Commercial hay test kits have been developed and independently validated for use in conventional hay testing for the Roundup Ready trait (Woodward et al., 2006). Feed grain and food markets in all of these countries have imported other approved trait GM crops (e.g., corn, soy, cotton, etc.). Therefore, although certain individual hay importers may for now opt to avoid Roundup Ready alfalfa, based on the widespread acceptance in these markets of other Roundup Ready feed crops, it is likely that Roundup Ready alfalfa eventually will be accepted by many foreign hay buyers and dairy producers (Woodward, 2006). Some exporters/importers are particularly averse to weeds in hay and may accept Roundup Ready alfalfa hay to avoid the weeds. However, most individual foreign hay buyers and the U.S. hay exporting companies that serve them are highly GM-sensitive (table V-3).

As stated above, hay export is a niche market but it is an important market in certain geographies of the Pacific Northwest and California where approximately 6 and 1.5 percent of the hay produced, respectively, is exported (Putnam, 2005; Shewmaker et al., 2006). Over 99 percent of exported hay is produced in irrigated acres of the West, primarily in Washington, Oregon, Idaho, Utah, Nevada and California (Putnam, 2005; Shewmaker et al., 2006). According to Woodward (2006) and Shewmaker et al. (2006) nearly 20 percent of Washington's alfalfa hay crop is exported to the Pacific Rim of Asia. Within these far Western states are small niches where sale into the export channel is more common than in others; for example, according to sources cited by Woodward (2006), 35 to 50 percent of Washington's exported hay is grown in the Columbia Basin within the four counties of Adams, Benton, Franklin and Grant. Woodward (2006) estimated that within the Columbia Basin, up to 80 percent of the growers may export at least one of their forage cuttings per year, but this is an estimate for all forage species hays and all growers of all forages, not alfalfa hay alone. According to sources cited by Putnam (2005) approximately 1.5 percent of California alfalfa hay is exported, but as in Washington, alfalfa growers only may sell one or two of their five to eleven cuttings per year into the export channel, so the number of acres harvested for export purposes is higher than 1.5 percent of the total and not known (Woodward, 2006).

A recent document specifically addressed the alfalfa hay export market in the context of gene flow, coexistence and trait mitigation into GM-sensitive hay export markets (Putnam et al., 2007). As described in this NAFA sponsored document, exported hay is sold as identity preserved lots; it is not fungible unless processed. Hay exporters may use hay trait testing, identity preservation of the hay lot, mitigation and avoidance measures to ensure that their hay or planting seeds do not contain the Roundup Ready trait (Putnam, 2006). If an individual lot

of hay were to test positive for the Roundup Ready trait and be rejected by its intended GM-sensitive importer/exporter, there are alternate customers (domestic and or non-GM-sensitive export) available to the U.S. hay producer. Based on export versus domestic market price data, there would be no significant negative price impact for the seller, although the cost of transportation could be affected (if it already were in transit) and buyer-seller delivery contract disruptions would occur if other acceptable conventional hay lots were unavailable as substitutes. Elsewhere in the U.S., little or no hay is exported (table V-3).

#### 4.13 Impacts to Organic Growers and Other GM-Sensitive Alfalfa Producers

A recently specifically addressed the organic alfalfa hay market in the context of gene flow, coexistence and trait mitigation into GM-sensitive organic hay markets (NAFA, 2007). As described in this National Alfalfa & Forage Alliance sponsored document, organic hay is sold as identity preserved lots; it is not fungible unless processed. Organic hay producers may use hay trait testing, identity preservation of the hay lot, mitigation and avoidance measures to ensure their hay or planting seeds do not contain the Roundup Ready trait (Putnam, 2006). If an individual lot of hay were to test positive for the Roundup Ready trait and be rejected by its intended GM-sensitive organic hay buyer, there are alternate customers (general-purpose domestic and or non-GM-sensitive export customers) available to the U.S. hay producer. Therefore, the potential impact on the organic hay producer only would be the difference in selling price (estimated as 18%) not the entire selling price of the hay. Although feedstuffs with detectable GM trait presence are not preferred by organic livestock producers, the presence of GM traits would not cause the lot of hay to lose its USDA National Organic Program (NOP) certified organic status and the lot would still qualify, according to NOP standards, as an appropriate feedstuff for organic livestock. However, the lot of organically produced hay with GM trait presence would not qualify as “GM-free.”

The impact or likelihood of gene flow into an existing GM-sensitive forage field resulting in adventitious presence (AP) of a genetically modified trait in conventional alfalfa is nil and easily mitigated. According to statements by D. Putnam (2007):

“... If an organic grower (or a grower otherwise ‘sensitive’ to the GM trait), plants non-GM seed for hay production near to Roundup Ready alfalfa hay fields, that grower should be nearly 100% ensured of continuing to harvest non-Roundup Ready forage for the life of the alfalfa stand, unless highly unusual circumstances prevail. These unusual circumstances can be prevented with a few simple management practices. [...] There is no evidence to date of any contamination of organic or conventional hay fields originating from Roundup Ready hay fields, and the available scientific evidence demonstrates that the risk of such contamination is almost zero. [...] All of the standard practices in alfalfa hay production work against gene flow. We cut early (usually before flowering) to achieve good quality, so that flowering is not maximized. We don’t deliberately add honeybees or leafcutter bees, which in any event prefer other species, so that

pollination and pollen movement is not maximized. We do not allow seed to develop under normal circumstances to any significant degree since we cut early. The rare seed that is developed is almost always and completely removed with the crop. The occasional rare seed that does develop, remain, and drop to the ground, does not readily germinate and grow in the vigorous canopy of an alfalfa field, as any grower who has tried to seed alfalfa into an existing stand will attest. [...] Thus, in this projection, the probability that pollen from a neighboring GM hay field will contaminate a neighboring organic or otherwise GM-sensitive hay field is 0.0000025%, or 2.5 out of 1 million AP.”

#### 4.14 Other GM-sensitive forage markets

In addition to export and organic hay markets, other hay buyers or conventional forage producers may be sensitive to GM-trait presence such as the Roundup Ready trait. Putnam (2005) estimated that in total approximately three to five percent of the U.S. hay market is now GM sensitive. Table V-3 presents estimates for the other conventional GM sensitive alfalfa producers, by state and by region. Data presented above indicated that 1.6 and 0.9 percent of the sensitive market is accounted for by export and organic markets, respectively. Therefore, approximately 0.5 to 2.5 percent of the remaining hay market may be sensitive to the Roundup Ready trait. This market is composed largely of a subset of horse, dairy goat, pleasure animal and non-organic GM-sensitive conventional livestock producers (Putnam, 2005). Horses are very sensitive to weeds in hay and pure alfalfa hay is not typically fed to horses and non ruminants as a primary feedstuff. It is likely that hay users in this category are sensitive to weeds in hay because many horse and pleasure animal owners purchase individual bales of hay at a feed store. These buyers personally may inspect the quality of the bale. Because of the low-weed or weed-free quality possible with Roundup Ready alfalfa, it is possible that many horse owners, etc., might opt to use weed-free (Roundup Ready) hays rather than avoid them.



## 5.0 Gene Flow: Extent, Impacts, Mitigation, Industry Stewardship and Coexistence Strategies in Cultivated and Noncultivated Settings

Gene flow will occur among and between various alfalfa populations growing in cultivated and noncultivated environments. Therefore, the discussion of alfalfa gene flow is presented between the cultivated and noncultivated environment sections of this document as it applies to both environments. Because of cropping scale and plant density, the opportunity for gene flow will be greater in cultivated settings than in noncultivated settings (Van Deynze et al., 2008).

An in-depth white paper review of gene flow potential and impacts in alfalfa was recently developed by Van Deynze et al. (2008) which was sponsored by The National Alfalfa & Forage Alliance (NAFA). The publication systematically addresses gene flow according to the population interface type, i.e., for gene flow to/from seed fields, to/from hay fields and to/from feral populations—in a total of nine possible combinations as shown in table V-10 (excerpted from Van Deynze et al., 2008). NAFA also sponsored the development of four additional topic papers that were written to assist the alfalfa industry in understanding and managing GM-trait coexistence. Within each topic paper, alfalfa gene flow is discussed with respect to impact and mitigation measures. The four topics are: (1) export hay, (2) export seed, (3) organic alfalfa, and, (4) Best Practices for Roundup Ready Seed Production (see above sections). These topic papers (in press) and the gene flow white paper (in press) will be available from the authors.

**Table V-10. Potential scenarios for pollen-mediated gene flow in alfalfa**

| ↓From To→    | Hay                 | Seed                 | <i>Feral</i>          |
|--------------|---------------------|----------------------|-----------------------|
| Hay          | Hay-to-Hay          | Hay-to-Seed          | <i>Hay-to-Feral</i>   |
| Seed         | Seed-to-Hay         | Seed-to-Seed         | <i>Seed-to-Feral</i>  |
| <i>Feral</i> | <i>Feral-to-Hay</i> | <i>Feral-to-Seed</i> | <i>Feral-to-Feral</i> |

Source: Ven Deynze et al., (2008)

### 5.1 Cultural Practices, Trait Stewardship Tools and Biology Influencing Gene Flow in Alfalfa Systems

As presented above, alfalfa is grown exclusively for livestock forage production purposes on over 22 million acres annually. Greater than 99.5% percent of alfalfa planted in the U.S. is used exclusively for alfalfa hay (forage) production (figure V-1). Approximately 110,000 acres or, 0.5% of the total U.S. alfalfa acres are harvested for seed production (figure V-2).

Alfalfa is a herbaceous, short-lived perennial forage crop species that is predominantly cross-pollinated and entirely dependent upon bees for cross-pollination. Wind cross-pollination in alfalfa does not occur (Teuber, 2007b; Viands et al., 1988). Insect (bee) pollinator activity is required to simultaneously deposit non-self pollen onto the stigma surface and rupture the protective stigmatic cuticle and effect pollination (Viands et al., 1988). Alfalfa flowers have an explosive tripping mechanism that may be triggered by bees visiting the flower to collect nectar or pollen. After it is tripped, the stigma of the flower becomes lodged into the groove of the standard petal of the flower. Because of the nonreversible tripping mechanism within the alfalfa flower, each alfalfa flower may be pollinated only a single time by a single pollinating

bee. While true embryos are found in developing alfalfa pods approximately five days after fertilization (Bass et al., 1988), it takes approximately four to six additional weeks for embryos to ripen to become physiologically mature seed under optimal seed production conditions. High winds and or drought stress may induce flowers to mechanically trip and auto-pollinate; however, it is known that the resulting self-pollination (inbreeding) most commonly results in no seed or few seed and progeny of inferior vigor (Viands et al., 1988).

Flower buds begin to form on stems approximately four to six weeks after field mowing during long-day photoperiods and warm weather. After flowering ensues, alfalfa flowers indeterminately. After pollination, alfalfa seed embryos require four to six additional weeks of adequate growing conditions to ripen. Rainfall or snow during the ripening time will cause decreased seed yield (seed shatters from the pod to the ground) and poor seed quality (e.g., reductions in seedling vigor and reduced percent germination because of fungal pathogen infection of the seed, or seed will sprout prematurely and die while it is still in the pod). Commercial production of the alfalfa seed crop, therefore, is exclusively confined to the western regions of the United States where late season (post-pollination) rain is unlikely, irrigation is carefully managed and specialized alfalfa seed growers, equipment and infrastructure is available (figure V-2). Mean seed yield per acre is greatest in the Pacific Northwest and California (approximately 500-750 lb/A) and very low in the Plains States (70-200 lb/A) (Hower et al., 1999).

The potential for gene flow between alfalfa populations is dependent upon many factors and it is closely tied to agronomic management practice (whether each of the populations or fields are managed for forage production, for seed production, or, if the population is without management, e.g., feral or neglected). Numerous environmental filters that mitigate the risk of gene flow between alfalfa populations growing in various alfalfa settings were extensively described by Daniel Putnam, University of California, Alfalfa and Forage Extension Agronomist (e.g., Putnam, 2006 and 2007), and, Larry Teuber, Ph.D., University of California, Professor of Plant Breeding and Agronomy, Director of the California Foundation Seed Program and Executive Director of the California Crop Improvement Association (Teuber, 2007b). These experts are authorities in alfalfa forage and seed production and breeding systems. In addition, superimposed over the environmental filters are agricultural filters to further mitigate the risk of gene flow. Agricultural filters include customary agronomic best management practices, such as crop rotation, field separation (isolation), equipment sanitation, planting certified variety seeds of known origin, or in some cases, contract-specified identity preservation, or trait stewardship practices (e.g., grower licensing requirements for use of seeds containing GM traits). Key factors affecting gene flow potential are:

- 1) Flowers: Presence or absence; synchrony between populations; duration; relative abundance of in-field (internal) and non-field (external) pollen sources
- 2) Pollinators: Presence or absence; predominant species of bee(s) present; density in relation to floral nectar and pollen resources; preference for alfalfa versus other flowering crops or weeds; temperature and or landscape barriers/incentives to

movement; bee cultivation practices if applicable; presence or absence of insecticide residues that would deter or imperil feral bees.

- 3) Proximity: Physical isolation that mitigates bee cross-foraging (pollen-mediated gene flow), wind-blown pollinators, or, animal, water, wind or agricultural transfer of seeds between populations
- 4) Post-pollination seed maturation conditions: Does the cross-pollinated embryo survive four or more weeks post-pollination to form physiologically mature seed? Does moisture during ripening phase cause nascent embryos to decay or wither in the pod prior to maturation or drop to the ground?
- 5) Seed germination and establishment: Does the cross-pollinated mature seed die soon after sprouting without establishment, or does it germinate, take root and survive despite inter-plant alfalfa autotoxicity and competition with existing vegetation?
- 6) Cultivar selection and cultural practice: Stand renovation and crop removal; crop rotation; timeliness of seed or hay harvest; equipment cleaning and planting seed selection; product handling and segregation; gene frequency in local cultivars; etc.

## 5.2 Pollen-Mediated Gene Flow Studies: Brief Summaries and Key Conclusions

Many studies were conducted which examined the incidence of pollen-mediated gene flow in alfalfa. The key studies were summarized by Van Deynze et al. (2008) and are shown in figures V-3 to V-7. In the 1970s and 1980s, alfalfa scientists used pest resistance and flower color genes to evaluate genetic purity of dissimilar cultivar types produced at various isolation distances between seed fields and along contiguous field edges (Brown et al. 1980; Brown et al. 1986; etc.). The Association of Official Seed Certifying Agencies (AOSCA) alfalfa crop standards committee adopted the recommendations of the North American Alfalfa Improvement Conference Committee on Alfalfa Field Isolation (Brown et al., 1986) to set isolation distances for certified and foundation seed classes (AOSCA, 2003). The AOSCA standards are consistent with established OECD seed certification standards with respect to isolation distance, field history requirements, and genetic purity tolerance for off-types, etc. In the 1990s, other naturally occurring genetic marker systems were used to study the risk of pollen-mediated gene flow between commercial hay, seed and feral plants (St. Amand et al., 2000) and since 2000, the Roundup Ready trait has been used to measure gene flow.

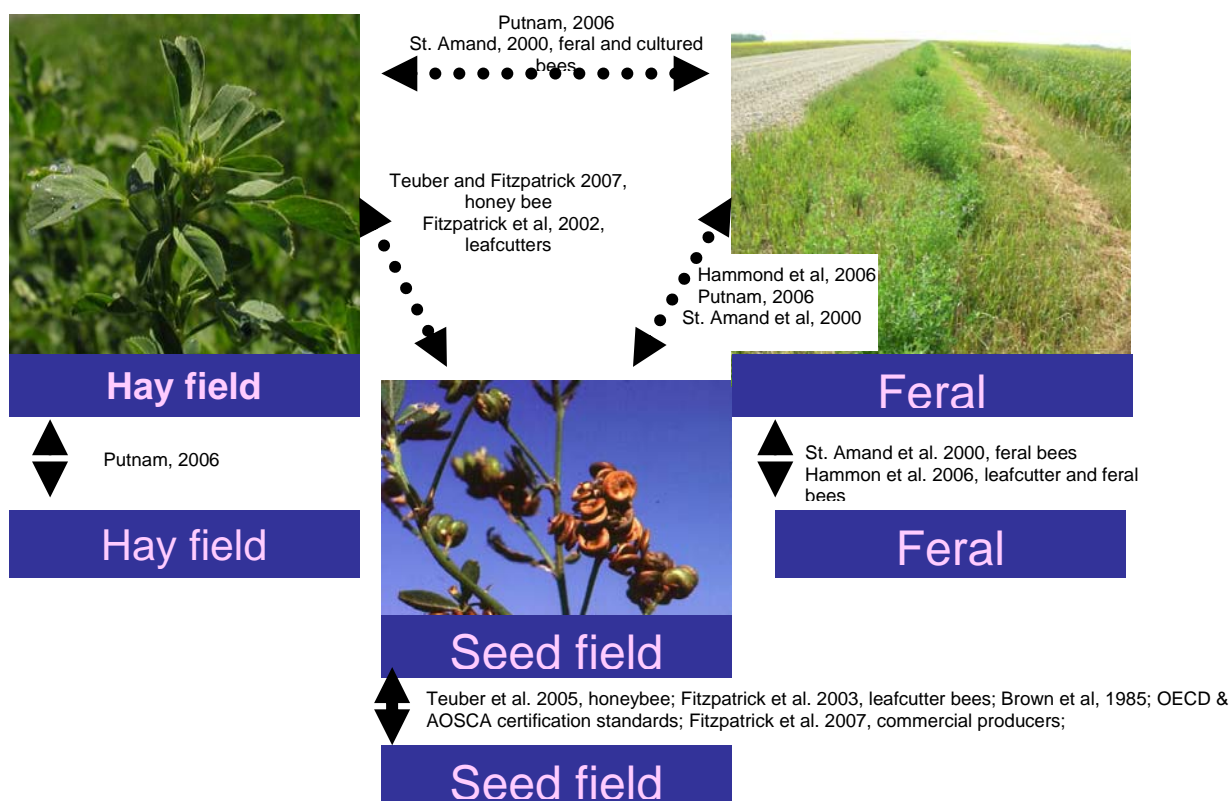
The most recent pollen-mediated gene flow studies (2000-2007) used the Roundup Ready gene as a high sensitivity pollen-marking tool under small, medium, and large field commercial seed and or hay production conditions. V-3 illustrates the various gene flow interface types (types of gene flow) where pollen movement can occur (also see table V-10). In order for true pollen-mediated gene flow to take place, an unbroken chain of six sequential events must occur as shown in figures V-4 and V-5 (Putnam, 2006; Van Deynze et al., 2008).

In addition to pollen-mediated gene flow, seed-mediated gene flow could occur by in-field volunteers (soil seed bank and escapes of stand take-out), seed admixtures during transportation or seed processing, seed transport by water or wind (short distances), seeds in overly mature hay, equipment and animals.

Figure V-3 highlights the key references wherein data have been developed to address the risk of gene flow between each type of pollen flow interface. Gene flow was reviewed in the 2004 Petition appendix 5 for data available prior to April 16, 2004. Since the Petition, Teuber et al. (2005b) have developed an extensive literature review on honeybee pollination and gene flow in alfalfa. The following sections will present the new information since 2004 in combination with previous study data and discussion. As an aid to this discussion, a consolidated gene flow versus distance data illustration by crop setting and pollinator species is presented as figure V-6. Details for each study are found in the original references and numerous key original references will be provided to APHIS with this technical report.

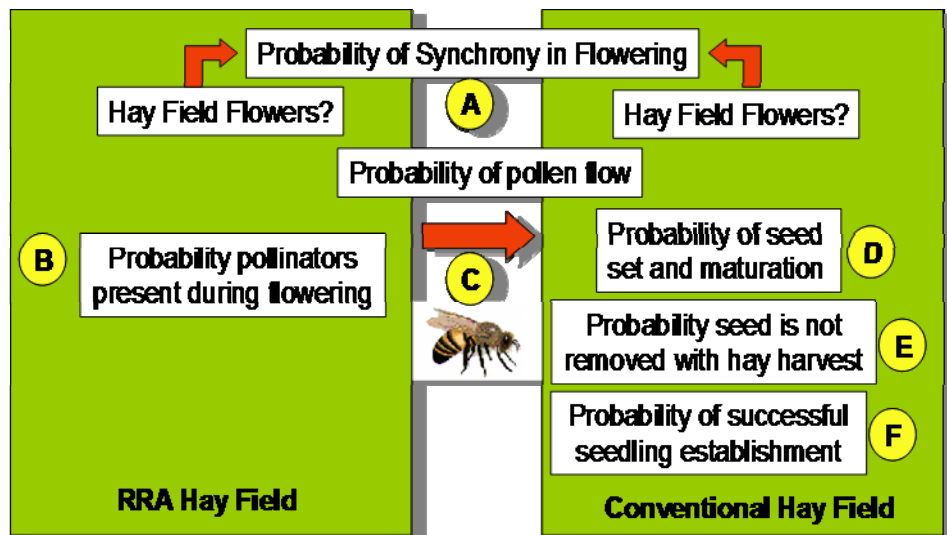
By experimental design, most these recent pollen-mediated gene flow studies estimated pollen-mediated gene flow under somewhat exaggerated and worst-case field conditions. From the standpoint of industry trait stewardship, gene flow mitigation and diverse market coexistence, worst-case studies are an important first-step in gaining an understanding of a novel trait production system. The results from these experiments were communicated to industry stakeholders and to the public. Through consultation with industry stakeholders, the data were used to design FGI's Best Practices Policies for Roundup Ready Trait Stewardship during Seed Production ("FGI Best Practices") in Fitzpatrick et al. (2007b). FGI Best Practices are a set of comprehensive process management requirements that encompass Roundup Ready trait stewardship requirements for licensees, mitigation of unintended gene flow and tools to foster peaceful market coexistence. FGI Best Practices were developed using identity preserved production models, foundation seed production standards and seed quality assurance principles. Data are presented in Fitzpatrick et al. (2007a and 2007b) and personal communication with Miller (2007) that supports the effectiveness of the Monsanto trait stewardship program in combination with the FGI Best Practices policies in attaining successful market coexistence for Roundup Ready alfalfa. Recently, NAFA sponsored a Roundup Ready seed producer Best Practices consensus protocol that was built upon the FGI Best Practices program foundation (2007).

As for other crops with GM trait choices, mitigation and coexistence strategies were developed to allow for the production of high quality alfalfa seed (and hay) to serve diverse market sectors (organic, export, common, conventional and Roundup Ready) and preserve a grower's choice to plant conventional or Roundup Ready seeds. Independent third parties have lead in the industry's development of a broad-based coexistence consensus; examples are the University of California-Davis Seed Biotechnology Center (2005) and the National Alfalfa and Forage Alliance (2007).



**Figure V-3: Cultural practices influence the risk of gene flow among alfalfa populations**

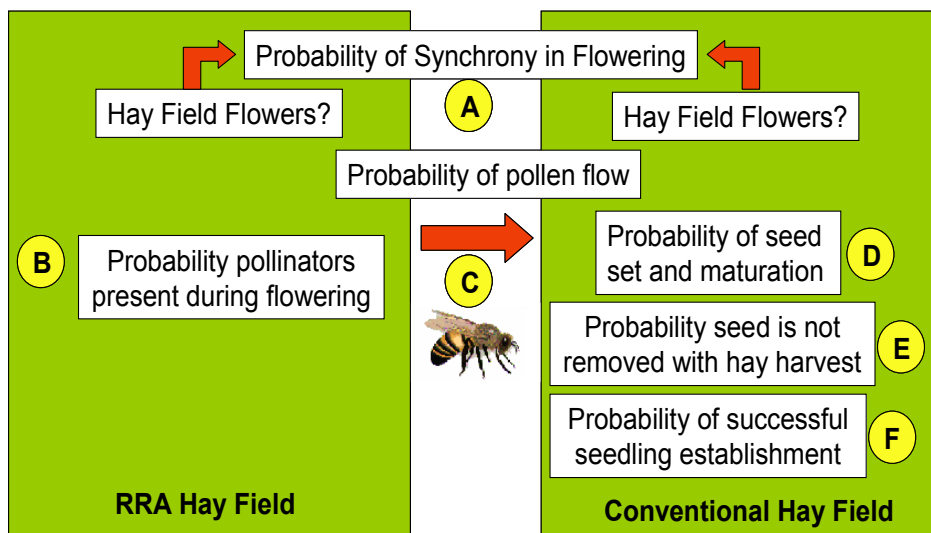
Each type of gene flow interface has been studied. Studies have been collectively reviewed and summarized by Van Deynze et al. (2008).



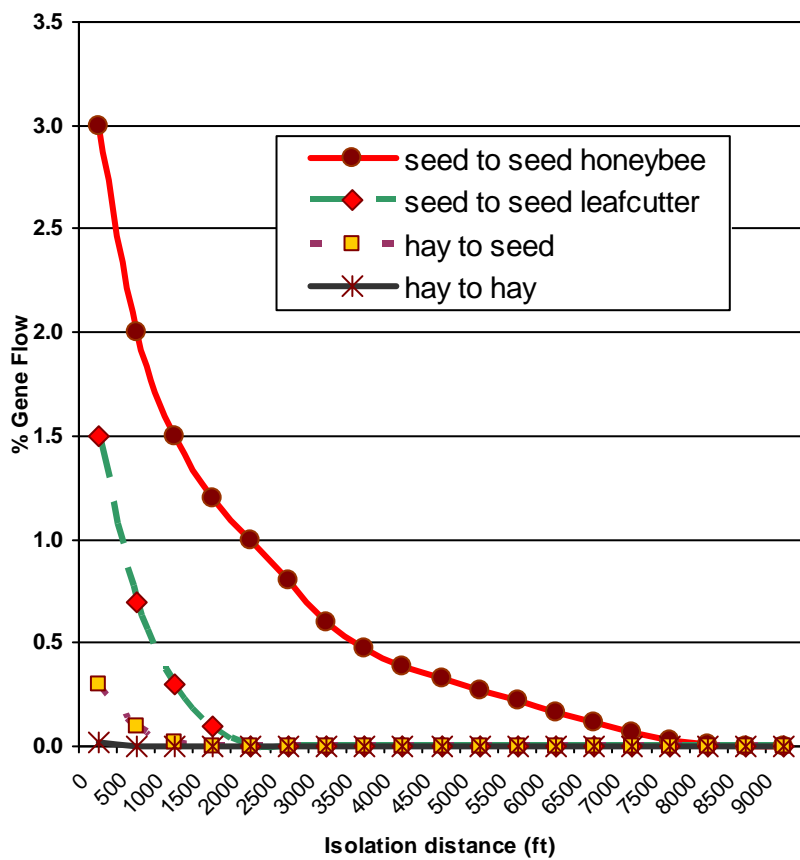
**Figure V-4: Probability of hay-to-hay field gene flow in alfalfa**

Excerpted from Putnam, 2006

Excerpted from Putnam, 2006



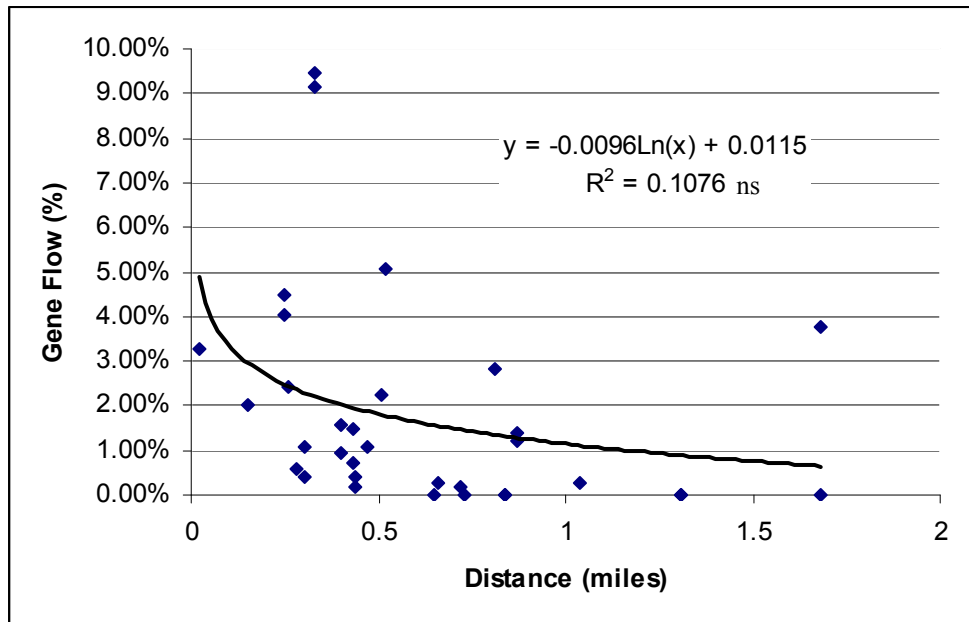
**Figure V-5: Probability of Hay-to-Seed field gene flow in alfalfa**



**Figure V-6: A comparison of the relative gene flow potential for various production systems in alfalfa**

Excerpted from Van Deynze et al., 2008

Gene flow declines with increasing distance from the source. The amount of gene flow is pollinator species and cultural practice specific. Pollen-mediated gene flow is plotted for four specific types of cultivated alfalfa interface types: 1) seed field-to-seed field under honey bee pollination (Teuber et al., 2004); 2) seed field-to-seed field under leafcutter bee pollination (Fitzpatrick et al., 2003); 3) mature (20-50% flower stage) hay field-to-seed field data sets combined for leafcutter and honey bee pollinators (Teuber and Fitzpatrick, 2007); and, 4) estimated hay field-to-hay field gene flow (Putnam, 2006).



**Figure V-7:** Pollen-mediated seed-to-feral gene flow observed from three-year-old commercial “Roundup Ready” seed fields (900 acres overall) to small feral and unmanaged alfalfa clusters

Gene flow was measured by evaluating 33 seed samples collected from 23 small clusters of feral or intentionally unmanaged alfalfa plants in western Colorado (raw data was excerpted from Hammon et al. 2006). The nearby Roundup Ready seed fields were commercially pollinated with cultured leafcutter bees, and, various species of native bees, alkali bees and honeybees were also intermittently present and pollinated the alfalfa. Median sampling distance and gene flow were 0.5 mile and 1%, respectively. There was no correlation (ns) between amount of gene flow and distance from the nearest field. The Roundup Ready seed production fields were in the third consecutive seed production year. Within the survey zone, virtually no sources of conventional pollen were present to cross-pollinate the feral plants except for that from other small, dispersed patches of feral/unmanaged or forage field plants and forage fields cut at early maturity.



Key conclusions from alfalfa pollen-mediated gene flow studies are discussed in the following three sections.

5.2.1 *Forage fields as the pollen-receiving environment, i.e. fields grown for hay, haylage, pasture or greenchop*

5.2.1.1 Hay-to-hay

“Hay into hay” pollen-mediated gene flow is essentially zero and can be reduced to zero with normal forage harvest management practices (Putnam, 2006 and 2007). Figure V-4 illustrates the environmental filters that act against effective gene flow between adjacent hay fields.

5.2.1.2 Seed-to-hay

“Seed into hay” pollen-mediated gene flow is likewise extremely improbable because the pollen receiving hay field would not be grown to produce any viable seed. Pollen and pollinators would be present because of the proximity of the seed field. If rare, viable cross-pollinated seed were to form on the forage field stems, it is highly unlikely that seeds in the forage mass still will contribute to gene flow because they rarely will establish new plants (Putnam, 2006; Cash, D., 2005, Personal Communication; and Cash, D., public comment 481 to USDA/APHIS Docket 04-085-1). The amount of pollen-mediated gene flow into a GM-sensitive conventional or organic forage field can be reduced to zero when the GM-sensitive forage field is harvested prior to seed maturation.

5.2.1.3 Feral-to-hay

“Feral into hay” pollen-mediated gene flow is also essentially zero and can be reduced to zero with normal forage cutting management practice on the GM-sensitive hay field (Putnam, 2006 and 2007). The amount of pollen-mediated gene flow into a GM-sensitive conventional or organic forage field from (likely infrequent) GM-feral plants can be reduced to zero when the conventional forage is harvested prior to seed maturation and or nearby feral plants are mowed prior to bloom or eliminated by herbicides and or cultural methods. Feral plants have not typically been targeted for control and in most situations, glyphosate would not be the herbicide of first choice to control it (see Petition, section VII.F.6. and Petition appendix 3). The paucity of feral plants coupled with the low frequency of the Roundup Ready gene in feral populations will constrain the amount of Roundup Ready feral pollen available to the hay field in the local environment. There would be little or no selection pressure on future feral alfalfa populations toward glyphosate-tolerant genotypes in plants or pollen. Even if feral alfalfa were left unmanaged, factors of scale, asynchrony, low pollinator density and other environmental and agricultural filters in the cultured fields would make it high improbable that gene flow to occur from feral plants into a hay field.

## 5.2.2 *Seed fields as the pollen-receiving environment*

### 5.2.2.1 Hay-to-seed

“Hay into seed” field pollen-mediated gene flow potential is zero to near zero with observance of routine AOSCA certified isolation distances (e.g., 165 ft) and or normal forage field cutting management practice ( $\leq 10\%$  bloom cutting) during the seed field pollination period. Figure V-5 illustrates the environmental filters that act against effective gene flow into seed fields from hay field sources. If because of weather factors or mechanical problems, a neighboring GM forage field is harvested at a later stage of maturity (e.g., 20 to 50% bloom) during the peak seed-pollination period, the potential for gene flow into a nearby small seed field is very low (e.g., 0.3% for distances less than 165 ft). With greater isolation, it is exceptionally rare (e.g., for 350-600 ft isolation, mean flow was 0.01%) (Teuber and Fitzpatrick, 2007). These values are at least ten-fold lower than predicted from worst-case seed-to-seed gene flow models. Therefore, current AOSCA isolation requirements for certified seed production (165 ft) are sufficient to mitigate gene flow from typical hay fields into conventional certified seed fields to low levels. Where feasible, highly GM-sensitive seed producers can lessen further the risk of pollen-mediated gene in-flow to their seed field from other/unknown varieties of hay by choosing to use larger size seed fields ( $>5$  acres), stocking pollinator species that range shorter distances (i.e., leafcutter bees vs. others), harvesting the seed field border as a separate lot (St. Amand et al., 2000; Fitzpatrick et al., 2007a) and working to coexist with their neighbors who grow alfalfa for forage (e.g., ask them to their cut their hay early during mid-summer or to use non-GM varieties). Organic, export, common, or foundation class seed producers who are highly GM-sensitive can opt to work with local crop improvement organizations and use wider isolation or buffer zones with identity preserved practices for their GM-sensitive seed fields (e.g., follow the most conservative AOSCA foundation seed class standards which require use of 900 ft or greater isolation to any different alfalfa variety whether grown for hay or seed purpose).

### 5.2.2.2 Seed-to-seed

“Seed into seed” field pollen-mediated gene flow is a common, measurable, natural occurrence for proximal seed fields of different cultivars. Conventional certified variety seed growers largely rely on physical isolation to minimize and mitigate pollen-mediated gene flow. The quantity of pollen-mediated gene flow between adjacent seed fields was extensively studied for the past three decades and the data used to develop current AOSCA and OECD seed isolation and production standards. The percentage of pollen-mediated gene flow into a seed field is dependent upon field isolation distance, bloom synchrony, cultural practices, in-crop volunteer management, gene frequency in the pollen, pollinator species present, density, available food resources, and shelter placement.

Under actual commercial conventional seed grower conditions, the use of pollinator-species specific isolation minimums and identity preserved production protocols have successfully mitigated GM gene flow to levels observed for other GM crop species and produced seeds of high genetic purity, i.e., seeds of greater than 99 percent genetic purity, and, AP level at zero to less than 0.2% (Fitzpatrick et al., 2007a and 2007b). The amount of actual gene flow under

commercial-scale (large field) conditions is several times less than is predicted by research models developed using smaller-fields (Fitzpatrick et al., 2007a and 2007b).

This most recent data set developed using the Roundup Ready trait supports the findings of previous gene-flow research studies wherein conventional traits were used as pollen markers in large and small fields. Small fields or feral patches have a higher relative percentage of pollen in-flow than larger fields (AOSCA, 2003; Brown et al., 1986; Fitzpatrick et al, 2007a and 2007b; Hammon et al., 2006; Marble, 1980 circa; St. Amand et al., 2000). Therefore, the predictive models developed using smaller field trap sizes (or isolated alfalfa feral trap patches) were very constructive in that they offer worst-case predictions for pollen-mediated gene flow, but they significantly overestimate pollen flow into larger more typical commercial fields. For small- to mid-scale seed-into-seed field settings, gene flow declines sharply with increasing distance from the source (see figure V-6 and supporting references).

As required by Roundup Ready seed production contracts and NAFA Best Practices for seed production (NAFA, 2007), Roundup Ready seed producers will continue to report the locations of all Roundup Ready seed fields to their local crop improvement organizations. These independent third-party agents will maintain Roundup Ready seed field location records and field histories. GM-sensitive seed producers, therefore, have an available mechanism to obtain GM alfalfa seed field location information and request professional services to assist them in seed field isolation planning. As stated above, where feasible, many GM-sensitive seed producers can lessen further the risk of pollen-mediated gene in-flow from other/unknown varieties of seed (or hay) by choosing to use larger size seed fields (e.g., >5 acres), stocking pollinator species that range shorter distances (i.e., leafcutter bees vs. others), harvesting the seed field border as a separate lot (St. Amand et al., 2000), and working to coexist with their neighbors who grow alfalfa for forage and seed. Organic, export, common or foundation class seed producers who are highly GM-sensitive can opt to use additional isolation or buffer zones and identity preserved practices for their GM-sensitive seed fields (e.g., follow the most conservative AOSCA foundation seed class standards which require use of 900 ft or greater isolation to any different alfalfa variety whether grown for hay or seed purpose, etc.). In addition, groups of local seed growers can use informal or formal conventional-only seed production zones. NAFA Best Practices stipulates that Roundup Ready seed producers will not contract for Roundup Ready seed production in such grower organized zones.

Commercial seed lot data validate that implementation of the Best Practices system is a very effective industry tool in the management of conventional seed lot genetic quality (Fitzpatrick et al., 2007a and 2007b). Adventitious presence of the Roundup Ready trait in conventional seed lots has been infrequent and in all cases well below the 0.5% industry consensus AP tolerance for domestic alfalfa and below values predicted using worst-case research models. The large-scale commercial validation also helps put in perspective the minimum incremental risk associated with potential real world concerns about pollination from wild pollinators, extraordinary pollen flow by wind-driven pollinator movement, and contamination through physical mixtures of seed in harvesting and/or seed processing.

The data of St. Amand et al. (2000) and Fitzpatrick et al. (2007a) supports that a conventional border (or buffer) area is a sound gene flow mitigation strategy for producers of highly GM-

sensitive seed crops (the border could be of the same conventional variety as in the field center). The outside edge could be harvested separately and tested, and if no GM-trait is detected in the border seed, it could be bulked with the main field lot. It should be noted, however, that if, as St. Amand et al. suggest, a conventional cultivar were used to border a GM-containing seed field or research plot, the genetically different variety border would violate seed certification isolation standards (i.e., the genetically dissimilar border would preclude variety certification of the main field seed crop). Moreover, even for non-certified seeds lots, especially small experimental lots, the encompassing conventional pollen would negatively affect GM seed crop's trait percentage and genetic purity.

During the development of field-isolation standards, AOSCA and other certifying agencies have considered data from fields and plots with little or no isolation (e.g., <100 ft.). Data sets developed using conventional traits indicated that although there is a very minor amount of gene flow between seed fields (Brown, et al., 1986) or within seed fields (St. Amand et al., 2000) bulking of seeds throughout the field help mitigate the percentage of whole-field off-types to industry and AOSCA accepted levels (<1% off-types).

Seed growers who are highly GM-sensitive may opt not to apply the 10% rule or any other exceptions to isolation in the production of their seed crop whether or not it is officially certified as to varietal purity. Specifically, the AOSCA certified class seed standards (2003) have a "10 percent rule exception" as follows:

- 1) "Minimum distance from a different variety or fields of the same variety that do not meet the varietal purity requirements for certification, shall be 600 and 300 feet for fields over 5 acres; and 900 and 450 feet for fields 5 acres or less that produce the Foundation and Registered seed classes, respectively.
- 2) "Isolation requirements for the certified class are based on the size of the certified field and the percentage of the field within 165 feet of another variety of alfalfa. If 10 percent or less of the certified field is within the 165-foot isolation zone, no isolation is required - only a definite separation. If more than 10 percent of the field is within the isolation zone, that part of the field must not be harvested as certified seed. The isolation zone is that area calculated by multiplying the length of the common border(s) with other varieties of alfalfa by the average width of the certified alfalfa field falling within the 165-foot isolation distance requirement.
- 3) "In those cases where a portion of the field meets isolation requirements, then a clear line of demarcation shall be established between the certified and non-certified portion of the field."

#### 5.2.2.3 Feral-to-seed

"Feral into seed" field pollen-mediated gene flow potential will be zero or very, very low and it can be reduced to zero or near zero when the GM-sensitive conventional seed producer mows feral alfalfa to prevent synchronous bloom or takes steps to eliminate feral alfalfa plants (see mitigation strategies discussed for seed-to-seed conditions, above). There is evidence that conventional seed producers already are managing against the presence of feral alfalfa in seed-growing counties of Idaho and California (Kendrick et al., 2005). Even if feral alfalfa were left

unmanaged, factors of gene frequency (feral plants may be genetically conventional or GM in type), factors of scale, asynchrony of bloom, low pollinator density in the feral areas and other environmental and agricultural filters in the cultured seed fields would make GM gene from feral plants into a seed field from feral plants extremely improbable or very low occurrence. As described in the previous section, the conventional seed field edge, if harvested separately as a border crop, may be used to further mitigate the potential for gene flow from feral alfalfa into seed fields. 2000).

### *5.2.3 Feral alfalfa plants as the pollen-receiving environment and feral plants as bridges for GM (Roundup Ready) gene flow*

Long-distance pollen and seed-mediated gene flow from GM (e.g., Roundup Ready) commercial-scale seed and blooming hay production settings into feral alfalfa populations will occur (Hammon et al., 2006; Kendrick et al., 2005; St. Amand et al., 2000). In locations where feral alfalfa is of concern to GM-sensitive seed or hay producers, it can be controlled or reduced so that the economic impacts will be negligible or nil (Kendrick et al., 2005; Petition appendix 3; Van Deynze et al., 2008). Large-scale feral or volunteer alfalfa patches can be a potential bridge for gene flow between managed seed or hay fields and within and among feral plant groups. It is important to note that many bee pollinators avoid collecting pollen or nectar from alfalfa flowers when other flowers (weeds or crops) are growing in the vicinity. Biogeographic survey data from six states indicates that for most agricultural areas feral alfalfa plants do not occur or they are sparse (Kendrick et al., 2005). Alfalfa is not considered invasive or weedy, so unless feral plants are actively humanly encouraged—as has occurred in the past (Petition page 375), it is unlikely that feral alfalfa populations or their role in pollinator or pollen-bridging would expand above current levels.

In California and Idaho, feral alfalfa was observed at fewer survey sites within counties where intensive alfalfa seed production occurs relative to those in counties where alfalfa is primarily grown for forage (Kendrick et al., 2005). This may indicate that professional, certified seed growers in California and Idaho are already controlling feral alfalfa as a means to ensure certified seed crop genetic quality or at a minimum, producers in these counties are not actively encouraging alfalfa to grow outside of cultivation (e.g., non-cultivated areas are not irrigated). Also, these seed growers would see a benefit from mitigating feral, escaped, unmanaged alfalfa patches because such unmanaged plant patches act as a reservoir of alfalfa seed insect pests (e.g., *Lugus*) which are detrimental to seed yield and physical quality.

According to Mueller (2005), in California, “feral or volunteer alfalfa grows rampant along roads and ditch banks, in fallow fields, and as a weed in cropland throughout the state, [and that,] it can provide a bridge for pollen movement from production fields to other fields. A good stewardship program [for biotech alfalfa] includes grower education concerning control of volunteer plants using mechanical or chemical alternatives and preventing viable seed set in volunteers.” To meet this objective, prior to the first commercial release of Roundup Ready alfalfa, FGI and Monsanto had incorporated feral and volunteer plant control education and seed field stand-take out requirements into the Roundup Ready alfalfa stewardship program.

Feral population densities are low. For example, in Colorado, Kansas and Washington when researchers conducted pollen-mediated gene flow into feral populations, the researchers opted to

simulate (cultivate) higher than locally occurring feral plant densities: i.e., the researchers either opted to transplant artificial pollen-trap plant populations along a roadside (St. Amand et al., 2000) or the augmented the number of available “feral” seed collection sites by intentionally leaving a network of hay field patches non-harvested so that they would simulate feral alfalfa and form cross-pollinated seeds (Hammon, et al., 2006). This indicates that even near intensive seed production locations, the researchers did not find a sufficient number of escaped feral plants to conduct their desired study design.

Until the recent advent of GM alfalfa, feral, roadside, escaped, relegated fields and volunteer alfalfa plants have been largely ignored by non certified seed growers or encouraged to proliferate (e.g., planted intentionally along roadsides with occasional harvest during drought seasons). Due to factors of alfalfa biology, bee biology, pests affecting feral alfalfa, relative population size, proximity, low likelihood of feral seed recruitment and establishment, and, a seed grower’s ability to control feral alfalfa through mowing during the pollination period or elimination by non glyphosate methods, future Roundup Ready feral plants will pose a very unlikely source of gene flow into GM-sensitive commercial seed (or hay) production. Seed production experts (e.g., Brown et al., 1986), gene flow data (St. Amand et al., 2000; Fitzpatrick et al., 2007a; Marble, 1980) and AOSCA foundation seed production standards (AOSCA, 2003) support that the potential risk of gene flow is scale-dependent. Therefore, the relative size, density and proximity of feral patches to one another and to nearby blooming cultivated alfalfa (i.e., the size of any competing pollen source) will affect both the frequency of GM traits in feral populations and the likelihood that feral plants will act as bridges for GM-trait gene flow. It is expected that over many sexual generations, the frequency of genotypes (conventional and or GM) in local feral populations will reach genetic equilibrium with locally grown commercial plantings if there is bloom synchrony and cross-pollination. The rate and extent for feral-to-feral population GM-trait gene flow will be affected by many environmental and agricultural filters (Putnam 2006). In the absence of glyphosate exposure, there is no adaptive benefit to feral plants containing the Roundup Ready gene versus their conventional counterparts. According to Van Deynze et al. (2008), “It is expected that only a minor portion of the seeds formed on the feral plants will result in true gene flow. Most seeds formed on feral plants will likely perish; as most would fail to successfully germinate, compete or establish outside of cultivation.”

Feral alfalfa occurs at very low density and scale relative to cultivated alfalfa grown for seed or hay. Gene flow into small fields has been studied extensively; however, the reverse—gene flow out of small fields or feral patches into large seed fields has not been. St. Amand et al. (2000) determined that gene flow is common between feral plants and that it likely occurs at short (0 to 4 m) and long distances (several miles). St. Amand et al. (2000) demonstrated that within an alfalfa seed field, pollen egress from a 1 meter diameter point source (similar in size to a patch of feral plants) could not be detected beyond 4 meters from the genetically marked pollen source plants. Dense patches of feral alfalfa, although not managed or protected from pests, could have similar bloom synchrony and comparable within patch gene flow dynamics to managed seed fields (but seed yield and quality would be much lower). St. Amand et al. found that, within seed fields:

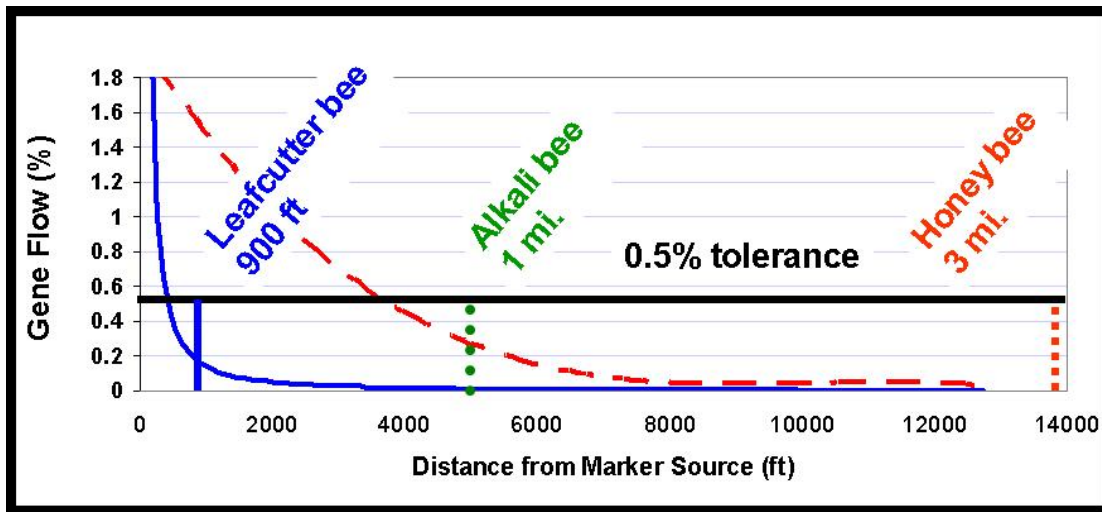
“Movement of the marker within the field occurred only over very short distances [and at low frequency]. Only 0.2% of the progeny 4-m away from the marker plants carried the marker gene and no progeny 6-m away were detected with the marker. Of those progeny carrying the GS marker, 97.4% occurred no more than 2-m from the source plants. Clearly, within-field gene movement only occurs over very short distances. It is likely that pollen is being cleansed [groomed] from the pollinators or is being covered with non-marker pollen after repeated visits to non-marker plants. This finding indicates that borders surrounding seed production fields may be useful in decreasing or limiting gene flow outside of a field.”

Pollen cleansing or occlusion would be expected to occur on bees traveling long and or short distances among feral plants. Bee behavior or pollen dilution of conventional with GM pollen would be expected to constrain the rate and extent of Roundup Ready gene flow into and among feral plant populations.

### 5.3 Gene flow mitigation via Roundup Ready Licensing: Trait Stewardship Overview

A comprehensive product licensing and stewardship program has been developed for Roundup Ready alfalfa. The program is a critical component to the successful long-term use of the technology for weed control in alfalfa. A summary of the commercial trait stewardship program is presented as appendix V-2 and key elements are highlighted in this document when they pertain to trait stewardship, mitigation of gene flow and or successful marketplace coexistence. All Roundup Ready forage producers are obligated to a core set of Monsanto trait stewardship license requirements and they are educated on the importance of their role in trait stewardship. Monsanto has an auditing program to ensure licensee compliance to the terms of the trait agreements.

Separate and in addition to the Monsanto requirements, all Roundup Ready seed producers are subject to an additional layer of licensing and contracting. Forage Genetics is the exclusive Monsanto licensee enabled to perform Roundup Ready Alfalfa seed production. Through sublicensing agreements, Forage Genetics will contract with a small number of qualified, professional seed growers or seed companies to increase commercial quantities of Roundup Ready alfalfa varieties (e.g., approximately 76 alfalfa seed growers were contracted during 2006-07, exclusively in the U.S.). In addition to the Monsanto license requirements, each FGI Roundup Ready seed producer is contractually obligated to adhere to the FGI Best Practices. FGI has an auditing program to ensure licensee compliance to the terms of the FGI Best Practice trait agreement for seed producers. The field isolation at planting for Roundup Ready seed producers is extraordinary in that the minimums are pollinator species specific and they are five to 95 times the current isolation requirement for conventional certified seed production. Extreme isolation at field planting (3 miles) is observed for fields in California where much seed is exported and honeybees are the preferred pollinator species. The FGI/NAFA Best Practices isolation distances are illustrated in figure V-8.



**Figure V-8: Roundup Ready alfalfa Best Practices for seed field isolation at planting**  
 (presented by Fitzpatrick)  
 (Fitzpatrick et al., 2007)

At planting the location of all Roundup Ready alfalfa seed fields is reported to local crop improvement and the isolation distance to the nearest conventional alfalfa field is inspected. GM-sensitive seed producers may use this information to plan their field locations.

#### 5.4 Gene Flow in Forage Crop Management Systems, Additional Comments and Background Information

As an animal feedstuff, alfalfa's optimum economic value per acre occurs just as the vegetative growth period is transitioning into the flowering phase (Sheaffer et al., 1988). Therefore, forage producers have a strong economic disincentive to allow mature seed set in hay production. Flowers and developing embryos—although briefly present in a hay field, are removed along with the vegetative growth before pollination or seed ripening. Therefore, because the fields have few flowers, most forage fields do not attract or support the nutritional needs of foraging bees. Livestock forage producers do not, therefore, introduce any bees into the forage fields.

Unlike seed or grain harvest, forage production periodically removes the entire plant canopy where flowers, pollen or seed might form (Sheaffer et al., 1988; Putnam, 2006; Putnam, 2007). After forage harvest, growth of the new vegetative canopy must be reinitiated from crown buds (as occurs in the spring) or from the elongation of lower stem axillary buds. Hence, some of the issues regarding uncontrolled proliferation of a trait will not biologically impact alfalfa managed for forage production because pollen is available to pollinators for a very limited duration and/or no ripened seed will be produced under typical cutting management (Putnam, 2007; Cash, D., personnel communication). In a forage field, in the unlikely event where viable physiologically



mature seeds are produced and dropped to the soil, the resultant germlings are unlikely to be successful in self-perpetuation because of intense inter-plant competition and effects of autotoxicity (Tesar and Marble, 1988; Putnam, 2006 and 2007; Undersander, 2005; Canevari et al., 2000; Cash, D., 2005, Personal Communication; and Cash, D., public comment 481 to USDA/APHIS Docket 04-085-1). There is strong evidence that even when alfalfa seeds are intentionally inter-seeded into an existing alfalfa field—a practice known as “over-seeding”, such introduced seed fail to establish (Canevari et al., 2000). Seed dropped near feral alfalfa plants have the same and additional barriers to successful establishment outside of cultivation (Cash, D., public comment 481 to USDA/APHIS Docket 04-085-1).

As in an alfalfa seed production field, a seed-bearing forage or feral alfalfa plant is more likely to have been pollinated by neighboring plants due to pollen-ovule proximity, local pollen abundance and within-field bloom synchrony. For example, St. Amand et al. (2000) measured no detectable cross-pollination within a (seed) field beyond 4 m from the pollen source plant. Moreover, when or if a rare cross-pollinated Roundup Ready seed forms in a conventional forage field the seed may fall from the pod or it may be subsequently transported out of the field by harvesting equipment, in the harvested forage mass or via water, wind, soil or animal defecation. Just like conventional alfalfa, the rare Roundup Ready cross-pollinated seeds will only very rarely result in the establishment of a successful new plant (Putnam 2006 and 2007). Gene flow into hay fields, whether from a neighboring seed field (Teuber, 2007b), hay field or feral population or grazing animal, etc. is very unlikely to result in any gene flow due to numerous biological, agricultural and environmental barriers discussed above. Alfalfa, whether of conventional or Roundup Ready derivation, is not a weedy plant *per se* although alfalfa may be targeted for control in certain crop rotations and non crop settings.

The impacts, mitigation and potential for gene flow between, into or out of alfalfa forage production fields has been recently extensively reviewed by Van Deynze et al. (2008) and previously by Daniel Putnam, Extension Agronomist, University of California (2006 and 2007), Larry Teuber, Professor, Plant Breeding and Agronomy and the Director of the California Foundation Seed Program (Teuber 2007b; Teuber and Fitzpatrick, 2007) and in the original Petition for Deregulation.

#### *5.4.1 Pollen-mediated gene flow into hay crops*

*Pollen-mediated gene flow* into hay crops is essentially zero (key references: Putnam 2006 and 2007; and, Teuber, 2007b). Experimentally, it is not possible to measure or detect pollen-mediated gene flow between adjacent hay fields because no seed is formed that may be evaluated (unless the forage field is intentionally neglected or mismanaged to the point of producing mature seed at which point it would technically be considered a seed-producing field *per se*). The best estimate of gene flow between neighboring forage fields is essentially zero.

In 2007, Putnam (2007) used probability estimates to calculate the risk of pollen-mediated gene flow between adjacent hay fields as follows: “...the probability that pollen from a neighboring GM hay field will contaminate a neighboring organic or otherwise GM-sensitive hay field is 0.0000025%, or 2.5 out of 1 million AP... these probabilities cannot be known with great certainty, and will be affected by individual environmental circumstances—however; this does

not change the validity of the argument. It would only change the probabilities from very, very, very, very low, to very, very, very low AP in hay crops.”

According to Putnam (2006), “Although gene transfer from one alfalfa hay field to another is theoretically possible, a range of environmental barriers make gene movement very unlikely,” (see figure 1 in Putnam 2006). Taking into account ordinary biological and cultural considerations, “the likelihood of AP occurring between hay fields becomes infinitely small, likely to be far less than 0.001% of field biomass even under high estimates of each of these probabilities. [...] The probabilities of gene transfer are estimated to be very low between alfalfa hay fields.”

Teuber (2007a) stated that, “Under hay production practices that prevail in California, I believe that both seed to hay and hay to hay transmission are highly unlikely.” California is always among the highest producers of hay and seed and it has a highly conducive climate for rapid seed development. Therefore, it may be construed that if the risk of gene flow into hay is highly unlikely in California, it is also highly unlikely elsewhere in the U.S.

#### *5.4.2 Seed admixtures*

Separate from pollen-mediated gene flow, there exists the potential for an AP-sensitive hay (or seed) grower to inadvertently plant conventional seed containing low levels of biotech traits to establish their AP-sensitive forage field. As in other organic and AP-sensitive crop production settings, trait-sensitive producers can choose to purchase seed that is of known genetic origin (e.g., certified varieties) and or purchase seed that has been pre-planting tested for the presence of GM trait(s). Seed sellers representing their product as organic or claiming other specialty qualities (e.g., “GM-free or GM-free”) should produce and source their products from identity preserved seed companies or growers. There are numerous producers and suppliers of organic and conventional alfalfa seed products so it is certain that conventional seed choices will remain available in the future. In order to produce high quality conventional and organic seeds, FGI and other U.S. seed companies contract with conventional or organic certified seed producers in the U.S. and globally. In addition, in adherence to the FGI Best Practices, FGI will produce and process all Roundup Ready alfalfa seeds under stringent seed handling procedures effective in mitigating the risk of seed admixtures.

#### *5.4.3 Volunteers*

Seedling recruitment from previous alfalfa seed or forage crops is also a possible source of rare seed-mediated gene flow into subsequent hay (or seed) fields. The following text was excerpted from Van Deynze et al. (2008):

##### ***“Volunteer seedlings”***

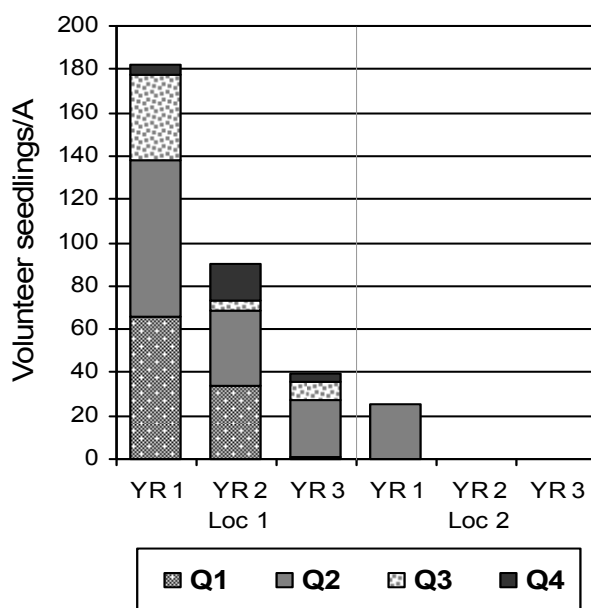
“Volunteer alfalfa can germinate from viable, hard remnant seeds left in or on the soil by a previous alfalfa crop cycle. Alfalfa grown for hay represents more than 99 percent of

U.S. alfalfa acreage so the potential for volunteer seed-mediated gene flow within hay fields will be considered first.

The potential for seedling volunteers to arise from a previous hay crop is exceptionally small or non-existent as it is determined by the same parameters as Hay-to-Hay gene flow, i.e. a viable seed must fall to the ground and germinate in the new stand.. The potential for gene flow via remnant seed volunteers to a subsequent alfalfa hay crop planted in the same field is even more remote because the remnant planting seeds would be three to six years old by the time the stand is terminated (see “Hard Seed” and “Autotoxicity”) Both are further circumvented by crop rotation. Most hay ground is rotated to a different species for two or more years before replanting alfalfa for hay. Therefore, hard remnant seeds will decompose during approximately seven years of seed aging, cropping activities and continuous exposure to the biota in the soil.

Hard seeds in alfalfa are defined as the seeds with a hard seed coat that do not imbibe water in a standard 72 hour laboratory germination test. Hard seed content for different seed lots of a single variety can be as high as 69% and as low as 14%, depending on where the seed was produced and the weather conditions during seed maturation (Bass et al., 1988). Undersander et al. (1993) planted various seed lots of the same variety wherein hard seed varied from 11% to 44%. At three locations in the Midwest, emergence was measured on a regular basis for 120 days. This data showed that differences in hard seed content in commercial seed lots did not significantly delay germination, and that, independent of hard seed percentage, virtually all of the viable seed germinated within the first 90 days. All viable hard seed germinated in the seeding year with no seed germinating the next year, even in the absence of any competition.

Alfalfa grown for seed production occurs on approximately 0.5% of the total acreage planted to alfalfa. The acreage is small compared to that for hay; however, the likelihood of volunteer seedling-mediated gene flow is somewhat greater. Virtually all of the commercial alfalfa seed is produced under irrigation in the western US. Although there is no directly comparable data from the West looking at seed germination rate and hard seed content, some recent data monitoring the number of volunteers after alfalfa seed production in the field is useful. Reisen (unpublished) monitored volunteer seedlings following non-chemical fall termination of a dozen alfalfa seed production fields in Idaho. These fields were either fallowed or rotated to one of six rotational crops wherein alfalfa volunteer seedlings could be counted and controlled. The number of volunteer seedlings per acre were counted several times each year, and summarized by quarter, over the 3-year period (figure V-9). Arias (unpublished), likewise monitored volunteer seedling emergence in three Texas seed fields that had been fall-terminated using herbicide and cultivation. These three fields were rotated to corn for the next three years. Arias observed an average of 25 volunteers per acre during the first summer and zero thereafter (figure V-9). More aggressive stand take-out of seed fields and prudent management strategies for broadleaf plants in the subsequent crops was demonstrated to be very effective in mitigating nearly all alfalfa seed production volunteers in subsequent crops.



**Figure V-9: Volunteer emergence by quarter in Idaho (Loc 1) and Texas (Loc 2) for three years after seed field take-out (mean count/A)**

Figure excerpted from Van Deynze et al., 2008

## 5.5 Coexistence and mitigation strategies for conventional, organic, export and other GM-sensitive conventional forage producers

Seed and hay industry methods exist for successful coexistence of conventional, organic, and Roundup Ready forage (and seed) market segments. Coexistence of conventional and Roundup Ready alfalfa is desirable and possible (Bradford, 2007; Putnam, 2006; Van Deynze, et al., 2008; NAFA, 2007). Roundup Ready seed producers are required to take mitigation and stewardship steps to preserve conventional seed and hay markets. Similarly, Roundup Ready forage producers are obligated to follow trait stewardship and coexistence programs required by their Monsanto licensure (see section E.6., below). The following section describes GM (and conventional) trait avoidance measures that GM-trait adverse forage growers can use to produce conventional forage to meet specifications for organic, export or other specialty market sectors.

### 5.5.1 Field establishment using conventional varieties

According to Putnam (2006), “The most important steps to ensure hay trait purity are selecting non-GM varieties using certified seed from reputable companies, testing this seed for adventitious presence before planting, and maintaining product identity.” It may be noted that in alfalfa, because it is a perennial crop, the seed choice decision is made only once during the multi-year life of the stand; therefore, as in all alfalfa production, selecting the appropriate variety and seed source is a long-lasting decision. Similar to other crops using the Roundup Ready trait, there are simple to use seed, leaf and hay trait testing kits for alfalfa (e.g., Strategic Diagnostics, Inc. and Envirologix, Inc.) and trait test service laboratories commercially available to the GM-sensitive buyers and sellers who wish to test for the presence of the Roundup Ready

trait (e.g., BioDiagnostics, Inc., GeneScan, Inc. Mid-West Seed Services, Inc., and, various state's seed certification programs). The Roundup Ready seed test kits and protocols have been validated by the manufactures and by an independent third-party tester using field-grown seed samples (Teuber et al., 2007b). AP sensitive hay (or seed) growers should use seeds of planting stockseed grown under certification as well as an identity preserved system for additional assurance of high seed purity. Identity preserved production services are available from independent local third-party certifiers such as those accredited by the National Organic Program, Association of Official Seed Certification Agencies (AOSCA) and or OECD programs.

### 5.5.2 *Management of pollinators and neighboring cultivated or feral alfalfa*

Pollinators serve no purpose for the production of forage, and, well-managed forage fields with few open blooms do not attract or support the nutritional needs of pollinating bees. GM-sensitive conventional or organic forage producers can mitigate the small potential for GM-trait cross-pollination by not placing or allowing others to place bee domiciles (hives) in or near their GM-sensitive conventional forage field and harvesting the forage prior to seed formation. This is the routine forage management practice so no special management will be needed by the GM-sensitive forage producer.

In certain low-input forage production settings (e.g., southeast U.S. or northern Plains States), a very low number of conventional or organic hay producers allow honey producers to place hive boxes in their alfalfa forage fields. In general, honeybees demonstrate a strong behavioral preference *against* foraging for nectar in alfalfa (seed or hay fields) therefore flowering weeds or other crop species are more important sources of honeybee nectar and pollen (Arnett, 2002; Pitts-Singer, 2007; Teuber, et al., 2005). Overall, honey production on alfalfa is a very uncommon forage grower practice in the U.S. and it results in very mature forage with very low forage quality or in some cases, the conventional field is grazed or is not harvested. Under the terms of the Monsanto Trait Stewardship License Agreement, forage producers are prohibited from placing bees in their Roundup Ready forage fields. A low frequency of *feral* solitary bee species may visit blooming alfalfa fields to collect pollen or nectar, but they would contribute to a very minor amount of pollen flow between forage, seed or feral alfalfa populations (Hammon et al. 2006).

Another exception within the conventional forage producer group is a small number of diversified farmers who, based on seasonal drought or immediate market prices (hay versus seed price), they may sometimes opt not to cut forage but instead produce a summer “catch crop” of seed on the “forage” field. In this way, their alfalfa field is converted to a temporary, non-certified or “common” conventional seed production field. Catch crop seed producers were previously discussed in the Petition (section VII, subsection B.). The potential for gene flow in non-certified conventional or organic seed production is discussed as a part of the seed production system, below. Under the terms of the Monsanto Trait Stewardship License Agreement, Roundup Ready forage producers are prohibited from harvesting any seed in their Roundup Ready forage fields and in geographies where common conventional alfalfa seed production occurs, as a precaution to mitigate pollen availability and facilitate peaceful coexistence, the Monsanto licensee must harvest the Roundup Ready field for forage not later than 10% bloom.

Because feral alfalfa may act as a potential bridge (conduit) for pollinators between non-isolated fields or into feral populations of alfalfa (St. Amand, et al. 2000), Putnam (2006) recommends that, “Prudent steps to prevent excess flowering or seed production during hay production will be beneficial to maintain coexistence of GM and non-GM alfalfa. [...] Controlling feral alfalfa is a prudent measure to prevent movement of genes between hay fields.” As discussed in the Petition, Feral alfalfa is not common in most forage-growing geographies and where it is present and in close proximity, flowering can be controlled through clipping or feral plants eliminated by identity preserved forage producers, (appendix V-4, letters from Weed Control Experts).

### *5.5.3 Harvest management*

Optimal forage harvest management involves cutting at or before 10% bloom, typically occurring approximately one week after first flower. This harvest schedule greatly reduces the potential time in which there can be synchronous flowering of the conventional hay field and any neighboring Roundup Ready hay or seed production field. By managing their forage harvest dates and crop maturity, the GM-sensitive conventional or organic forage producers can eliminate the potential for any seeds to form within their conventional forage field; whether the pollinations may have resulted from in-field or out-of-field pollen sources.

Sometimes forage producers struggle to cut their hay in a timely fashion due to rain, saturated soils, equipment breakdown, etc., or a forage field rapidly progresses to advanced maturity due to high temperature or drought stress. In delayed maturity harvest situations, viable seed may form within the hay canopy. For reasons explained in depth by Putnam (2006 and 2007), the risk of cross-pollination and dropped seed establishment in the AP-sensitive conventional hay field is “very very very low” (projected to be less than 2.5 seed per million).

### *5.5.4 Crop rotation/field history*

Alfalfa producers practice crop rotation between terminated alfalfa plantings to avoid a build up of pests and maximize soil nitrogen credits to non-legume rotational crops. Conventional forage producers wishing to avoid GM-traits may select fields without a prior history of GM variety use and or use pre-planting cultural and chemical controls and rotational crop choices appropriate to the elimination all alfalfa volunteers prior to planting the conventional alfalfa stand. Although “hard” alfalfa seeds may be viable for many years under dry laboratory conditions, in the field where moisture is present, extremely few or no hard seeds survive or successfully establish as volunteers within or outside of cultivation due to limited germling vigor, field biotic and abiotic decay processes (Undersander, 2005; Bass et al., 1988). Even when abundant mature seeds have been grown and dropped in the field (e.g., within or adjacent to a seed production field or its area of water drainage), two or four growing seasons without alfalfa are sufficient to mitigate remaining hard seed volunteers for the production of certified or foundation class alfalfa seeds, respectively (AOSCA, 2003). Therefore, GM-sensitive forage (or seed) producers can utilize traditional, reasonable crop rotation cycles and volunteer controls to mitigate the small potential for in-field volunteers from a previous alfalfa planting or mitigation of seeds that may have been moved by natural or irrigation water, wind or animals, etc.

#### *5.5.5 Identity preservation of conventional, organic or GM-sensitive hay lots*

Post-harvest mechanical co-mixing of forage lots is a separate, potential source of determinate (non viable) gene (detectable trait) flow between harvested hay lots, i.e., trait flow that is independent from seeds or living plant material. Identity preserved hay growers such as those producing conventional, export, weed-free, GM-free, and or organic hays can adapt their existing market-required hay lot identification processes to segregate, label, test and sell hay lots by cutting date, field and farm identification number. The available Roundup Ready trait hay test kits and hay lot sampling protocols have been validated by third-party testers using harvested hay field samples (Putnam, 2007; Woodward, 2006; Woodward, et al., 2006). As stated by Daniel Putnam (2006), “Organic growers already have a process by which they identify and document organic hay, so no greater paperwork burden would be generally required to deal with this situation”. For conventional hays, quality tested hay lots are likewise routinely identified and segregated (Putnam, 2004). According to Putnam (2006), prior to the advent of GM alfalfa, “Export and organic markets already require paperwork that identifies the lot, seller, and origin of hay, so a GM or non-GM label may be relatively simple for these marketers.”

#### *5.5.6 Equipment sanitation*

Contaminated equipment can be a source of physical co-mixing between dissimilar hay products (e.g., organic, conventional or GM-trait), cross-contamination between planting seed lots or it might transfer soil/stems that contains weed and or alfalfa seeds. Equipment sanitation is an effective, simple precaution that is highly effective and recognized as critical in all identity preserved production systems. Planters, cultivators and forage harvesters, processors, etc. may be cleaned before or after use to avoid unwanted residual debris or seed. In some situations, it is possible to designate that a piece of equipment may only be used in preplanned sequence or for certain types of products (e.g., organic fields only), so that the need for cleaning between product types is reduced or eliminated. It should be noted that equipment sanitation is useful to prevent the unintended dissemination of weeds, foreign materials and pests between fields so equipment sanitation is recommended and will remain important to product integrity irrespective of GM-trait sensitivity.

#### *5.5.7 Mitigation of negative impacts through prudent record keeping, planning and contractual agreements*

Complete and correct field and harvest records and advanced planning are recognized as critical to producing crops with consistent and predictable attributes. Producers of organic crops must maintain records and develop an organic crop production plan that satisfies National Organic Program Standards. Certifiers are available to document that minimum production standards were fulfilled. Similar use of records, planning and independent certification will assist those forage (or seed) growers who wish to avoid Roundup Ready or other GM-traits in fields, seeds or equipment.

*Contract stipulations regarding tolerance limits to GM traits:* To manage potential economic negative impacts of unwanted traits in hay, GM-sensitive, organic or other conventional hay

producers may use the effective gene/trait mitigation and avoidance practices discussed above which are based on sound science and successful co-existence models adopted in previous GM crop market channels and in use for specialty market alfalfa hays such as organic, certified weed-free or forage quality tested hay lots [see USDA-AMS Livestock and Seed Program (<http://www.ams.usda.gov/lsmnnpubs/hsum.htm>) web site for examples of by-feature hay lot identification strategies]. In addition, some of the potential negative impacts to sensitive producers may be avoided by careful consideration of voluntary contract specifications prior to signature on the agreement. Buyers and sellers alike, must read, understand and manage the GM-specific language that is offered to/by them in voluntary buyer-seller contracts. As in other crops where GM traits are in commercial use, forage (or seed) producers who agree to absolute zero-presence GM contracts could individually experience more negative impacts than producers using contracts with verifiable testing standards for GM trait presence/absence. During the initial deregulation period for Roundup Ready alfalfa (June 14, 2005 to May 12, 2007), several conventional alfalfa seed and hay producers implemented contracts that stated a greater-than-zero tolerance level (low-level presence threshold) for conventional alfalfa products [e.g., less than 0.5-1 percent trait threshold in conventional seed (McCaslin, 2007)]. Contract verbiage recommendations for GM-sensitive alfalfa forage contracts have been published by William Woodward, Extension Faculty, Washington State University (Woodward, 2006a and 2006b). Woodward has provided examples of recommended contract statements to adopt and statements to be avoided in conventional (specifically export) hay contracts. Woodward's hay industry guidance recommendations, are congruent with statements regarding the adventitious presence contract and labeling guidance positions of American Seed Trade Association (ASTA), Council for Agriculture Science and Technology (CAST) and the USDA National Organic Standards Program. Testing tools and statistical interpretation for GM trait tolerances are available on-line to help guide and inform members of the GM-sensitive hay (and seed) industries (e.g., see Woodward, 2006, CAST and ISTA web sites).

## 5.6 Coexistence strategies for producers of Roundup Ready alfalfa forage

All purchasers of Monsanto's Roundup Ready traited alfalfa seed are obligated to adhere to all terms of the Monsanto Trait Stewardship Agreement (MTA) which is a limited use license for the patented seeds. These important coexistence and trait stewardship program obligations and limitations are presented in the 2008 Monsanto Technology Use Guide (TUG) (Monsanto, 2007).

Alfalfa hay is planted in every state in the U.S. Intermingled alfalfa hay and alfalfa seed production only occurs in portions of a few western states which have the specific climate required for successful commercial production (figure V-1 and figure V-2, compare areas of overlap). Certified alfalfa seed production requires minimum isolation from alfalfa (hay/seed/feral) of any other variety (AOSCA, 2003). The isolation is inspected and verified by state seed certification organizations or, if organic, the planned buffer zone is verified by an accredited organic certifier. Although non-certified seed is not officially regulated or inspected, in areas where "common" seed production is intermingled with Roundup Ready forage production fields, the Roundup Ready alfalfa forage producer is required to harvest at or before 10% bloom (Monsanto Technology Use Guide and Monsanto Technology/Stewardship Agreement, 2008). This requirement is very effective in mitigating the pollen and pollinators in



Roundup Ready forage fields that might possibly travel to neighboring common alfalfa seed fields (e.g., Putnam, 2006).

## 5.7 Overview of Roundup Ready Alfalfa Seed Crop Management and Seed Industry Systems

All Roundup Ready alfalfa varieties are patent protected, AOSCA registered proprietary cultivars that are phenotypically and genetically identifiable due to the presence of the Roundup Ready gene. Trait licensing requirements and the presence of the unique gene insertion will offer previously unavailable tools for intellectual property protection (e.g., genetic fingerprinting of parent lines) and marketplace stewardship opportunities in alfalfa.

Forage Genetics is the exclusive Monsanto seed-producer-licensee for Roundup Ready alfalfa cultivars. Seed increase on any Roundup Ready alfalfa cultivar requires a special seed grower contract issued through Forage Genetics or one of its sub-licensees (to-date, December 16, 2007, there is only one sub licensee and the number is expected to remain small due to the small number of candidates).

All Roundup Ready seeds must be grown and sold by variety name (no common seed production is authorized). Each FGI Roundup Ready alfalfa seed grower and seed company is obligated to the terms of the Monsanto Trait Stewardship Agreement and Forage Genetics seed producer contract terms that require implementation of FGI Best Practices for Roundup Ready Trait Stewardship.

To maintain variety type, FGI Best Practices and official variety registration descriptions require seed growers to apply one application of Roundup agricultural herbicide per growing season and in accordance with State and Federal product registrations. There are separate labels for Roundup agricultural herbicides in forage versus seed production settings: one or more Roundup agricultural herbicide formulation is labeled in 50 or 13 states, for forage or seed, respectively. Roundup Ready cultivar seed production may only be legally grown in states where a Roundup agricultural herbicide label has been approved for seed crop production. As a part of the seed trait stewardship program and as a means to mitigate gene flow to occasional common conventional or potential organic seed producers, FGI and Monsanto have chosen not to contract for or to enable legal seed production of Roundup Ready alfalfa in some states where common seed production is most typical and or certified alfalfa variety production is very atypical (e.g., Kansas, South Dakota, North Dakota, Minnesota, and Nebraska). An outcome of the NAFA Coexistence workshop was that the steering committee agreed to facilitate the development of a binding Best Practices for Roundup Ready seed production document which was supported by all three of the genetic supplier member companies (Peaceful Coexistence: Creating a Strategy for Harmony Among GM, Organic and Conventional Alfalfa Producers, October 10, 2007, Denver, CO). These three current NAFA members represent approximately 90 percent of the U.S. proprietary cultivar conventional genetic supply capacity and 100 percent of the Roundup Ready seed producer companies. Terms of the Best Practices document will be publicly available information and it will be available from Forage Genetics and or the other Roundup Ready Seed Producers. Along with the genetic suppliers, state seed certification organizations will play a key role in coexistence monitoring and management. This agreement will help ensure mechanisms for peaceful coexistence among conventional, organic and GM alfalfa seed

producers and choice for growers to use organic, conventional and GM varieties. The Best Practices also stipulates that all Roundup Ready seed producers will respect local “conventional only” seed zones should they develop.

## 5.8 Overview of Alfalfa Industry Coexistence Systems Development

During 2000-2005, APHIS regulated studies were conducted using either introduced leafcutter bees as the primary pollinators (McCaslin et al., 2001), 2001 (Fitzpatrick et al., 2002; Fitzpatrick et al., 2003; Teuber and Fitzpatrick, 2007) or, introduced honeybees (Teuber et al., 2004 and 2005b). In all gene flow studies to date, in addition to the stocked pollinator, native and feral non-native bees were present at ambient levels so their potential contribution to gene flow under commercial conditions has been accounted for in the available data sets. In the 2006 growing season while Roundup Ready alfalfa was not APHIS regulated, FGI and public scientists conducted additional gene flow research studies (Teuber and Fitzpatrick, 2007; Hammon et al., 2006; Fitzpatrick et al., 2007b; Teuber et al., 2005a and 2007).

During 2006, FGI continued to implement and evaluate efficacy of its Best Practices for Trait Stewardship in Seed Production. Over 120 conventional FGI commercial seed lot samples were evaluated to ascertain the actual amount of gene flow between commercial-scale, Roundup Ready and conventional seed fields under leafcutter bee, honeybee or typical mixed-species pollination systems throughout key regions of the western U.S. These commercial seed lot data validated that the FGI Best Practices are effective in mitigating adventitious presence of Roundup Ready alfalfa pollen-flow to very low or non-detectable amounts: AP percentages were, in all lots, not detected or at levels less than would have been projected using the worst-case research trial study predictions (Fitzpatrick et al., 2007a and 2007b), thereby validating that the commercial seed trait stewardship program was achieving a key objective—mitigation of gene flow to conventional and organic seed producers.

There is a strong body of evidence to support that the comprehensive and collective Roundup Ready alfalfa trait licensing and stewardship programs implemented by Monsanto and FGI plus implementation of reasonable trait-avoidance quality control measures by GM-trait sensitive conventional producers are and will be effective in preserving market choices and allowing successful coexistence between Roundup Ready and conventional hay and forage producers; this includes those conventional producers growing seed or hay for export, organic or other GM-trait sensitive market niches. Over the past decade, the U.S. domestic and international agricultural seed and grain industries have a proven track record of developing and adopting coexistence mechanisms in the production and marketing of several other agricultural crops where GM-varieties are available.

The U.S. alfalfa industry has taken key steps toward coexistence and product differentiation. Some examples are:

- *AP tolerance, greater than zero*: During 2005-2007 growing seasons, certain alfalfa seed companies with GM-trait production sensitivities began to issue seed grower contracts with stated AP tolerances, e.g., “<1% GM trait” (McCaslin, 2007), thereby,

demonstrating that mainstream conventional seed companies are (were) shifting toward market coexistence and GM-trait tolerance in conventional seeds. Roundup Ready trait detection methods and commercial test services are readily available to help seed and hay producers, buyers and sellers support their company's quality assurance programs. A stated position of the American Seed Trade Association (ASTA, 2007) is that zero tolerance to gene flow of a commercially adopted trait (e.g., Roundup Ready alfalfa 2005-2007) is not an attainable or realistic goal for most producers in large scale U.S. production agriculture. There is an alfalfa industry consensus that a tolerance value greater than zero for GM traits should be developed and implemented (e.g., NAFA, 2007). A 0.5% AP tolerance for domestic use, non GM-sensitive seed, has been proposed by several NAFA members to be an attainable and effective tolerance goal (NAFA, Denver, CO, October 10, 2007).

- *Offering sale of GM-trait alfalfa varieties:* Although not necessarily producing the Roundup Ready seeds or breeding the varieties themselves, all four of the major U.S. seed genetic suppliers and seed production companies (Forage Genetics, Pioneer Hi-Bred, Dairyland Seeds and Cal/West Seeds) were Monsanto licensed and sold one or more Roundup Ready alfalfa varieties alongside of their own conventional and or organic seed product offerings. Roundup Ready alfalfa was sold by more than 20 seed brands all of which continued to offer conventional cultivar products.
- *Rapid market penetration:* During the 2005-2007 period of deregulation, approximately 300,000 and 18,000 acres of Roundup Ready alfalfa forage and seed, respectively, were grown with no substantiated cases of conventional forage or seed market disruption (McCaslin, 2007).
- *Value-added trait opportunity for domestic seed growers:* Roundup Ready alfalfa seed is only produced (and consumed) in the U.S. Therefore, U.S. seed producers of Roundup Ready alfalfa seed have had an exclusive value-added market opportunity wherein there is no foreign competition by lower-cost seed producers.
- *Seed industry cooperation towards peaceful coexistence:* The FGI Best Practices are effective in mitigating gene flow to conventional seed production to a very, very low level (Fitzpatrick et al., 2007b). Monsanto, FGI and Roundup Ready alfalfa licensees have implemented comprehensive trait stewardship policies and have worked proactively with state seed certification organizations to develop industry tools for coexistence and mitigate GM-trait gene flow to very, very low levels. Two examples of such industry cooperation are the California Alfalfa Industry Stakeholders Meeting hosted by the University of California-Davis Seed Biotechnology Center, on January 27, 2005 (UCDSBC, 2005) and the National Alfalfa and Forage Alliance's workshop on peaceful coexistence strategies held on October 10, 2007 in Denver, CO (NAFA, 2007). The NAFA coexistence workshop resulted in the joint authorship and development of five alfalfa industry consensus documents that will be available from the authors or from NAFA (<http://www.alfalfa.org>) with the following topics

1. Gene flow in Alfalfa: Biology, Mitigation and Potential Impact upon Production for GM-sensitive Markets (White Paper); Authors: A. Van Deynze, S. Fitzpatrick, B. Hammond, M. McCaslin, L. Teuber, D. Undersander and D. Putnam
2. Best Practices for Roundup Ready Alfalfa Seed Production; a binding consensus for all commercial producers of Roundup Ready alfalfa seed

3. Export hay market coexistence, risks and mitigation of gene flow
  4. Export seed market coexistence, risks and mitigation of gene flow
  5. Organic market coexistence, risks and mitigation of gene flow \
- *Independent monitoring and oversight of FGI seed stewardship practices:* FGI has used third-party inspection services to document its compliance with its Best Practices seed field isolation distance policies (e.g., Lowry, 2007). Crop Improvement Organizations have used this GM seed field location information to assist GM-sensitive seed producers in seed field isolation planning and their identity preserved process inspections.
  - *Validation of best practices for seed production:* FGI and NAFA Best Practices isolation requirements and stewardship during seed production have been evaluated and validated. Use of the Best Practices resulted in zero to very low levels of the Roundup Ready trait in conventional seed lots, e.g., 0.00 to 0.18 percent AP (Fitzpatrick et al., 2007a and 2007b; Miller, 2007).
  - *Seed company communication and low level AP:* In specific conventional seed lots, when detectable AP has been publicly claimed to have occurred outside of FGI contracted conventional seed lots (e.g., informal comments quoted from a 2006 Idaho Eastern Oregon Alfalfa Seed Grower meeting), if a percentage AP has been publicly claimed it has been at a very low level, i.e., “trace to 0.9 percent”—levels below the 1% contract tolerance in all relevant cases (McCaslin, 2007 declaration) and not in conflict with the up to 1% off-types allowed by varietal purity standards. FGI has worked cooperatively with other seed companies on a case-by-case basis to successfully resolve seed field proximity challenges (McCaslin, 2007).
  - *Growth of organic market sector:* For the past several years, the number of alfalfa forage acres certified as organic has increased (2005-2007) and likely flourished in-part due to the publicity surrounding the commercial use of the first GM-trait in alfalfa (Putnam, 2006; Putnam, 2007). Organic and identity preserved GM-free forage and seed products are new premium-priced, differentiated, and specialty market opportunities available to U.S. alfalfa producers. Demand for organic alfalfa is expected to grow for the next several years so that supply is sufficient to meet the growing market size of organic dairy and livestock producers.
  - *Increased awareness and education regarding seed quality issues and seed certification:* Especially for GM-sensitive market sectors like organic and export, there has been increased education and discussion about the importance of and value in using identity preserved production methods, planting certified variety seeds and benefits of enhanced quality control. It is anticipated that during 2008, AOSCA member agencies will begin to offer new inspection and certification services that exceed traditional seed certification standards and that are customized specifically for the identity preserved conventional, organic, export and GM alfalfa seed markets. The gene flow information has and is being used by state, national and international seed certification programs to review and if needed update certified seed production standards. Individual seed companies are also using the information to review current company policies. Information to support coexistence of diverse market sectors has been made available in numerous public, government, court, scientific society, seed grower, hay grower, industry stakeholder and

industry-wide presentations and much information is readily accessible to the public on searchable internet web sites or by contacting a state forage extension specialist.

## 5.9 Coexistence and mitigation strategies for conventional, organic and other GM-sensitive alfalfa seed producers

Key references are the in-press NAFA and CAST documents (2008) describing coexistence and mitigation of gene flow for organic and export producers.

### 5.9.1 *Isolation from unknown or dissimilar alfalfa varieties and field history (physical and temporal separation)*

GM-sensitive conventional and organic alfalfa seed producers wishing to produce a genetically pure seed crop may utilize AOSCA (2003), state seed certification program rules, and/or National Organic Program standards to physically and/or temporally genetically isolate their GM-trait sensitive production field. AOSCA programs stipulate standards for an appropriate physical isolation distance from other alfalfa pollen sources and NOP standards require that a buffer zone should be observed. Seed certification rules require a minimum crop rotation period and in-crop volunteer control (e.g., two or more years of field history without alfalfa cultivation). Typically, when genetic purity is desired, in-crop volunteers are controlled to ensure seed quality. Where a GM-trait sensitive conventional alfalfa seed field is grown in proximity to any other alfalfa, at a minimum, the AOSCA isolation requirements for certified seed production should be observed. The requirements are designed to ensure high genetic purity and minimize off-types (AOSCA, 2003). The seed producer may wish to utilize seed or organic certification inspection services to document that the grower's desired isolation and other available crop identity preserved protocols have been observed. The certified seed program rules, the Federal Seed Act and National Organic Program Standards all allow for a low frequency of genetic off-types in certified seeds; zero tolerance is not required. Individual conventional GM-trait sensitive seed producers may follow isolation or other protocols more stringent than program certification requirements so that unintended traits may be further avoided. Some state seed certification programs offer inspection services for enhanced, grower-defined identity-preserved programs intended to produce seeds of specialty quality (e.g., foundation generation or certified stockseed, low linoleic acid soy grains, certified organic, certified low-level GM products). Recently (July 24, 2007), the AOSCA alfalfa crop committee proposed a new identity preserved certification program designed specifically to enhance market coexistence opportunities and facilitate the segregated production of Roundup Ready and certified low/no-AP conventional alfalfa seeds lots (Larry Teuber, AOSCA Alfalfa Committee Chair).

In conformance with the NAFA and the FGI Best Practices for Seed Production Stewardship, Roundup Ready alfalfa seed production is currently planted with a minimum isolation distance of 900 ft, 1 mile and 3 miles from existing conventional seed production, for leafcutter bee, alkali bee and honey bee pollination, respectively (figure V-8). Field location and field size are reported to local state seed certifying agencies that inspect to determine that the minimum isolation requirement is met. This extraordinary isolation requirement is 5-95 times the current isolation requirement for conventional certified seed production. These science-based and highly precautionary FGI isolation guidelines for Roundup Ready alfalfa seed production were

established through open discussion among stakeholders, in forums organized by state crop improvement organizations (UCDSBC, 2005; Lowry, 2007; NAFA, 2007).

### *5.9.2 Stockseed genetic purity*

Conventional (and organic) alfalfa seed producers wishing to avoid GM-traits, inferior seed germination or vigor, weed seeds or organic program prohibited methods should plant high quality seeds of a known variety sourced from a reputable seed supplier. Prior to planting, the GM-sensitive conventional seed producer can require that an identity preserved seed lot sample be tested for the presence of the Roundup Ready (or other GM) trait. Similar to other crops using the Roundup Ready trait, there are simple to use seed, leaf and hay trait testing kits for alfalfa (e.g., Strategic Diagnostics, Inc. and Envirologix, Inc.), and trait test service laboratories commercially available to the GM-sensitive buyers and sellers who wish to test for the presence of the Roundup Ready trait (e.g., GeneScan, Inc.; Mid-West Seed Services, Inc., and, various state's seed certification programs). The Roundup Ready seed test kits and protocols have been validated by the manufactures and or by a third-party tester using field seed samples (Teuber et al., 2007b). Most of the U.S. seed crop is grown by variety name under contract with an alfalfa seed company who provides and defines the genetic quality of the planting stockseed. Therefore, because most alfalfa seed growers produce seed under a contract, most individual alfalfa seed growers do not self-determine which seed lot to use; the variety developer or seed company provides the grower with the seedstock. Seed companies that contract and provide stockseed to seed growers by variety name routinely test the stockseed for germination, purity, and key variety characteristics and GM-sensitive conventional producers have and will test seed lot samples for the presence of GM traits. The commercial issues associated with adventitious presence of GM-traits in seed have been extensively discussed with the global seed industry for more than a decade; the alfalfa seed industry has and will build coexistence and trait stewardship models using the experience gained in other crops enhanced using modern breeding methods (e.g., UCDSBC, 2005; NAFA, 2007).

Professional plant breeders and seed certification inspectors routinely monitor foundation seed stocks for off-types (e.g. flower color, plant stature, etc.) that are not characteristic for the described variety and breeders use simple conventional breeding approaches to proactively eliminate and manage against undesired off-types. These routine procedures for seedstock maintenance and quality control can effectively manage the rare occurrence low levels of biotech traits in conventional seedstock. In the event that conventional seedstock or breeder germplasm lines were suspected of containing adventitious presence of a biotech trait, the contamination can be excluded in parental lines using simple Roundup Ready trait/protein detection screening methods prior to pollination of the breeder generation. Tissues from candidate parent plants can be pooled or individually tested using the lateral flow strips designed specifically for fresh leaf tissues available from Strategic Diagnostics, Inc. and Envirologix, Inc. Any individual plants found to be trait positive would be excluded from the conventional parents prior to pollination of the breeder seed. Breeder seeds would then be grown using foundation or greater isolation to produce foundation seeds. Foundation seeds would be planted to produce commercial certified class seeds using certified class or greater isolation.

### 5.9.3 *Management of cultured pollinators*

Most conventional seed producers control the bee species, bee domicile field placement, bee stocking date(s) and bee stocking rate(s). Seed producers can mitigate (reduce) the potential for cross-pollination with outside fields through prudent cultured bee management, and, where summer temperature is not too high, they can opt for the use of leafcutter bees instead of other bee species because leafcutter bees tend to forage at shorter distance from their domicile. The majority of alfalfa seed producers add either leafcutter bees or honeybees to the seed field to synchronously and efficiently pollinate the crop. Conventional alfalfa seed has historically been grown using either cultured honeybees or leafcutter bees, in the Desert Southwest and Pacific Northwest, respectively. In the northern, central and southern Plains where a small proportion of the alfalfa seed is produced (and seed yield per acre is very low), the type of pollinators used is more variable: typically seed producers in these marginal production areas rely on feral and native bees. In certain niche geographies where suitable soil beds exist (e.g., southern Washington), permanent colonies of the ground-nesting alkali bee may contribute significantly to commercial alfalfa pollination (estimated to contribute 20% pollination for alfalfa fields proximal to an alkali bee bed); alkali bee pollination is often augmented by adding cultured leafcutter bees. GM-sensitive conventional seed producers can take further steps to mitigate cross-pollination with unknown alfalfa pollen by stocking the field with bees (to synchronously and quickly pollinate the field and make it less attractive to feral bees). They should stock freshly emerged young leafcutter bees and maintain them in the same field for the full pollination cycle (i.e., to keep them oriented to forage near the home hive).

### 5.10 Coexistence strategies for Roundup Ready alfalfa seed producers

Roundup Ready alfalfa seed growers and seed producing companies (“producers”) must be licensed by Forage Genetics and by Monsanto. The Roundup Ready seed producers, therefore, are obligated to follow all of the trait stewardship terms in their contracts and license agreements. Key features of the licensing agreements that will be important to seed marketplace coexistence are the requirements for implementation of all of the following:

- Seed field location and planting date; inspected by crop improvement
- Extraordinary, pollinator species-specific seed field isolation at planting (extraordinary pollinator-specific isolation will be 900 ft, 1 mile or 3 miles minimum for leafcutter, alkali or honeybees, respectively); inspected by crop improvement
- Seed field stand termination date; inspected by crop improvement
- Education and compliance auditing: FGI and Monsanto have implemented grower education and third-party auditing procedures to help insure awareness and compliance with license agreements.
- Authorized seed transfers only: All Roundup Ready seeds transferred only to the contracting company (no saved seeds, no transfer or sale to third parties). Any seed transfer requires licensure and associated stewardship.
- Product labeling/differentiation: Roundup Ready seed may not be legally sold without its variety name or into unlicensed or common seed channels. Processed Roundup Ready alfalfa seeds will be differentiated from conventional or

common alfalfa in that they will be coated with a distinct purple colorant and transferred in packages labeled “Roundup Ready Alfalfa”.

- Best Practices policies: Rigorous policies are science-based and market stakeholder-driven, and as such, the company (and or NAFA) may revise its Best Practices as new information is developed or as new coexistence consensus agreements or strategies are developed by the alfalfa industry (e.g., NAFA, 2007).

### 5.11 “GM-sensitive” alfalfa markets

The Roundup Ready technology would offer the technology-adopting alfalfa producers a new tool for broad-spectrum weed control throughout the life of the alfalfa stand. However, because the Roundup Ready varieties have been developed using a process of biotechnology, that is, they are genetically modified (“GM”) or genetically engineered (“GE”) certain market sectors (e.g., organic) and individual producers who object to GM traits *per se* will not want to use them and they will take steps to strictly avoid any detectable levels of GM in their products or on their farms. This has occurred in other crops. The stated GM-sensitivity of individual customers or markets varies from those having “zero tolerance”, “none detected”, “not more than X percent GM”, etc., and it varies among individual contracts and by importing country tolerance limits, if applicable. For purposes of the Roundup Ready market impacts analysis, “GM sensitive” is defined hereafter as the producers/customers that require that less than 0.5 % GM trait is present. Although certain buyer-seller agreements require it, zero presence is not statistically provable, it is not required to meet USDA National Organic Program (NOP) Standards, and it is unlikely to be feasible after large-scale commercialization of GM varieties (ASTA, 2007; see statements made by Mike Gumina in NASDA-PEW, 2006).

The organic and a portion of the U.S. agricultural export market channels are now averse and categorically closed (or nearly so) to essentially all traces of GM products, regardless of the crop, the commodity type, the trait or its regulatory approval status. In most of these markets there is no stated tolerance to GM trait presence, but international trade has continued in these crops. There have been GM AP tolerances—with conditions, established for food products in Australia (1%), Brazil (1%), the European Union (E.U.) (0.9%), Japan (5%) and Korea (3%) [see statements by M. Zumwinkle (NASDA-PEW, 2006)]. Various tolerance levels may be agreed to in buyer-seller contracts.

The development of identity preservation systems where growers produce a crop to meet certain market segments (i.e organic, conventional) is not specific to the Roundup Ready trait. The alfalfa market GM-sensitivity is highly subjective as is the case for certain other sales attributes in some cases (Putnam, 2005). In other crop species—and in alfalfa following the June, 2005, deregulation action for Roundup Ready Alfalfa, market segmentation has occurred to differentiate organic, conventional and GM-free products. Identity preserved market segments have grown even within conventional crop markets. U.S. market coexistence has also developed so as to serve the economic, trade, environmental and social interests of diverse alfalfa market sectors (NASDA-PEW, 2006; UCDSBC, 2005; NAFA, 2007).



Organic forage and other specialty crop markets are demonstrating an increasingly rapid growth rate (e.g., 17 percent per year) despite, or perhaps in-part, because of increased organic food consumer awareness of biotechnology use in crops (Putnam, 2006). Based on the development of coexistence strategies and overall strong organic market trends, although individual organic hay producers may need to take new steps to avoid the unwanted presence/detection of Roundup Ready or other future GM alfalfa varieties, the introduction of Roundup Ready alfalfa and the likely public discussion surrounding it, may result in increased organic market demand and expanded opportunities for existing and new organic hay growers.

## 5.12 Details of key pollen-mediated gene flow studies

In studies using the Roundup Ready gene, the pollen source plot was planted to Roundup Ready alfalfa that contained a *cp4-epsps* transgene marker, the pollen trap (“sink”) plots were planted to conventional alfalfa over a range of isolation distances. Cultured bees were introduced to the test site following typical seed grower practice for each region. Studies were conducted in the Pacific Northwest and in California where leafcutter bees or honeybees, respectively, were introduced. Gene flow from source to trap plots was measured by evaluating the trap plot seed or seedlings for the presence/absence of the source plot pollen marker in a bioassay (i.e., % trap seed expressing glyphosate herbicide tolerance). Observed means were used to calculate pollen-mediated gene flow decay curve equations. Additional pollinator and gene flow studies are in progress to help validate Best Practices and add new information to that already available.

These data demonstrate that pollen-mediated gene flow diminishes significantly with increasing distance from the source, cultured bee species differ in their potential to mediate gene flow at a given isolation distance (figure V-8) and that smaller fields tend to have higher rates of gene inflow compared to larger fields. The data has been used as part of the scientific foundation in the development of the Best Practices for Seed Production.

Van Deynze et al. (2008) have reviewed the studies available to date for alfalfa gene flow between hay, seed and feral settings.

### 5.12.1 Quantity of seed-to-seed field gene flow under leafcutter bee pollination; key reference Fitzpatrick, et al., 2003

Gene flow data for leafcutter bees is presented in figure V-6 and has been summarized (Fitzpatrick et al., 2003). No gene flow (0.0000%) was detected at 2000 ft in 2000, and in 2002, only 1/30,000 seed was found to carry the pollen marker when isolation was ½ mile (2640 ft). Gene flow was not detected at ¾ or 1 mile isolation distances in this study. Observed gene flow for leafcutter bees ( $Y_{obs}$ ) is described by the equation,  $Y_{obs} = (1 \times 10^{10}) (X^{-3.6262})$ ,  $R^2 = 0.9391$ ; and, the upper bound of the 99.9% confidence interval for gene flow,  $Y_{CI}$  is calculated as,  $Y_{CI} = (4 \times 10^6)(X^{-2.3673})$ ,  $R^2 = 0.9728$ .

It is interesting to note that the amount of pollen-mediated gene flow in alfalfa (an insect-pollinated crop), as observed 2000-2002, approximates that observed for corn (a wind-pollinated crop). For instance, in a study conducted by Haskell and Dow (1951), out-crossing in corn was 2.33, 0.48 and 0.20% for plants located 125, 300 and 500 m from source plants, respectively.

*5.12.2 Quantity of seed-to-seed field gene flow under honey bee pollination; key references Teuber et al., 2004, 2005a, 2005b and 2007b*

In 2003, at 900 ft, honey bee-mediated gene flow was 1.49% and it decreased linearly to 0.20% near 5,000 ft [ $Y_{\text{obs}} = -0.0003x + 1.8529$  ( $R^2=0.98$ )]. Gene flow continued to decline out to 2.53 miles where it was detected at a very low but detectable frequency ( $<0.06\%$ ). Gene flow from 900 ft to 2.53 miles with honey bees was described by the decay equation  $Y_{\text{obs}} = -1E-12x^3 + 5E-08x^2 - 0.0005x + 1.9908$  ( $R^2=0.98$ ). Gene flow to the west and the east trap plots was not significantly different.

Honeybee pollination dynamics in alfalfa are the subject of an in-progress project (Teuber, et al., 2005a and 2007b) which has been cooperatively funded by USDA-CSREES, University of California and FGI. Preliminary data was reported in 2007 (Teuber et al., 2007b). Preliminary data from the 2006 crop year were similar to those generated in 2003 (previous paragraph). Traps at 1 mile with bridged isolation had similar gene flow to those at 1 mile with true isolation.

At 1 mile, gene flow between the large commercial fields was approximately 0.1% overall. At 3 miles it was approximately 0.03% and it was not detected at 5 miles (Teuber et al., 2007b)

*5.12.3 Quantity of seed-to-seed field gene flow between commercial seed grower fields and validation of the FGI Best Practices; key reference Fitzpatrick et al., 2007a and b*

In 2006-07, Forage Genetics International (FGI) implemented an internal seed quality assurance program to monitor and validate efficacy of the FGI Best Practices for Roundup Ready Trait Stewardship during Seed Production (“FGI Best Practices”). This was the first year of widespread commercial Roundup Ready alfalfa seed production in the United States.

Conventional alfalfa seed lots grown and/or processed in proximity of Roundup Ready alfalfa seed in 2006 and 2007 were tested for adventitious presence (AP) of the Roundup Ready trait. The data showed that AP of the Roundup Ready trait in FGI conventional seed lots occurred infrequently and, in all cases if detected, was at a very low level—0.004 to 0.180%. This level was well within the company’s goal of  $<0.5\%$  AP and below values predicted based on “worst-case” research models developed using smaller field sizes. This large-scale commercial validation of FGI Best Practices helps support research-based isolation standards and demonstrates the effective implementation of FGI quality control programs at both the grower and processor level. FGI believes this also demonstrates that reasonable tools are available and are being used by seed producers to allow successful coexistence within and between diverse alfalfa seed market sectors and preserve conventional seed and hay market choices.

The large-scale commercial validation also helps put in perspective the minimum incremental risk associated with potential “real world” concerns about pollination from wild pollinators, extraordinary pollen flow *via* wind-driven pollinator movement, and contamination through physical mixtures of seed in harvesting and/or seed processing.

#### *5.12.4 Quantity of hay-to-seed field gene flow under leafcutter and honeybee pollination of the seed field; key reference Teuber and Fitzpatrick, 2007*

Hay-to-seed field pollen-mediated gene flow measurements have been conducted in field studies in which effective gene flow was measured from a Roundup Ready hay field gene source to conventional seed production field pollen-traps plots. The two studies used the Roundup Ready trait as a sensitive pollen marker tool. Teuber and Fitzpatrick (2007) summarized both of the hay-to-seed gene flow data wherein overly mature hay fields were intentionally grown near to alfalfa seed field plots pollinated using bees. Data from the first study conducted in 2000 used trap seed production plots pollinated by leafcutter bees growing near to a hay plot not harvested until 50% bloom (i.e., five times the recommended forage harvest stage of 10% bloom); this study was described within Petition appendix 5. Additional hay-to-seed study data from the University of California were generated in 2006 using honeybees as pollinators on the seed plots and the hay field gene source reached the 20% bloom stage twice during the seed pollination period; again simulating sub-optimal harvest timing (Teuber and Fitzpatrick, 2007). The combined data are presented in figure V-6.

Bees were applied to pollinate the seed fields in these studies and during the midsummer pollination period the hay field plots were intentionally allowed to flower more extensively than is typical for forage. Therefore, the hay field gene sources were representative of delayed-stage cutting or poorly managed hay fields growing close to a seed field. Under these conditions, gene flow into the seed field was very low (0.2-0.3%) at 150-300 ft and, it was rarely detected (0.00 to 0.05%) at distances greater than 350 ft. The pollen-mediated gene flow decay curve from mature standing hay to nearby seed fields for the two combined study sets is:  $y = -0.1844 \ln(x) + 1.1778$ ,  $R^2=0.72$ .

#### *5.12.5 Feral alfalfa gene flow to/from commercial seed fields*

In geographies where alfalfa is cultivated, feral and neglected cultivated alfalfa populations exist. In some geographic areas feral alfalfa plants have resulted from intentional plantings in roadsides, rangelands or wildlife areas; in other cases feral populations were likely initiated from dropped alfalfa seeds (Petition section VII. E.). Potential for long-distance gene flow into unmanaged, seed-bearing feral alfalfa plants was studied using several marker gene systems described in the sub sections below.

##### *5.12.5.1 Quantity of gene flow from concentrated commercial scale seed fields to feral alfalfa plants; key reference Hammon, et al. (2006)*

Hammon et al. (2006) conducted a survey of the pollinator species present and the gene flow potential into feral and intentionally neglected (non-harvested) alfalfa plants growing amongst and nearby a cluster of commercial-scale seed fields producing Roundup Ready alfalfa varieties under contract in western Colorado. In 2006, when the trap (sentinel) plant seed samples were collected, the Roundup Ready gene source fields were in their third seed production year and were approximately 900 acres cumulatively. The seed fields were predominately pollinated using cultured leafcutter bees with some additional pollination mediated by local populations of honeybees, alkali bees and nine other non-cultured bee species documented in site survey collections. Conventional and Roundup Ready alfalfa forage fields growing in the vicinity were

cut at early flower and were not a source of pollen for the trap plants. There were no known conventional alfalfa seed fields growing elsewhere within western Colorado (> 50 miles isolation, minimum); therefore, other than the pollen from small groups of neighboring conventional trap plants or brief episodes of forage field flowering, the Roundup Ready seed fields were the sole source of alfalfa pollen for the past three years. In mid summer (July-August), seed collections were made at 23 trap plant sites; ten of the sites were sampled a second time in September for a total of 33 samples. Trap plants were separated 0 to 1.7 mile distance from the nearest Roundup Ready field edge (median sampling distance 0.51 miles). Seed was evaluated in a greenhouse seedling glyphosate tolerance bioassay. Under these sustained, commercial (extremely isolated) seed production conditions that conformed to the FGI Best Practices for the Roundup Ready seed production, the percentage of gene flow to the small clusters of feral/uncut plants ranged from 0 to 9.5 with the median and mean, 1.06 and 1.68 percent, respectively. The raw data from this study have been graphically presented as figure V-9. The researchers determined that honeybees and bumble bees were more likely than alkali bees to have effected pollination at distances greater than 1 mile from the seed fields. Due to proportion, scale, pollen competition and proximity effects—and a professional seed grower's ability to control feral alfalfa in many situations, it is very unlikely that the scattered, feral, cross-pollinated seeds would result in a detectable trait flow into subsequent years' conventional seed crops. Conventional seed growers sensitive to off-types or low levels of GM traits can actively clip or eliminate most nearby hay and feral alfalfa plants during the pollination period. Even if a low to moderate level of a GM trait is present in feral alfalfa populations, the amount of pollen available from the feral plants for bee transport into a conventional seed field will be extremely little relative to the vast amount of pollen produced within the commercial seed field.

#### 5.12.5.2 Risk of gene flow from commercial scale mature hay and seed fields to simulated feral alfalfa plants; key reference St. Amand et al., 2000

In the 1990's St. Amand et al. (2000) used a rare, naturally occurring genetic marker trait to estimate the maximum distance of pollen-mediated gene flow from late maturity-stage hay or seed production fields to simulated and natural feral alfalfa pollen trap plants. They utilized two different native marker gene techniques with three study objectives, specifically, the measurement of pollen-mediated gene flow: 1) from large commercial fields to sparsely planted roadside alfalfa, 2) within seed fields; and, 3) among feral alfalfa plants.

The pollen traps (1 m<sup>2</sup> each) contained a single genetic clone planted along a roadside vector. The small plots were left unclipped so as to simulate feral, non-isolated, incrementally spaced plants and allowed to ripen seed. There was evidence of cross-pollination of the clonal plants at 1000 meters and gene flow declined with increasing distance from the commercial fields. Assuming the clone genotype used was representative of alfalfa, all of the trap plants were self-incompatible (they would not successfully self pollinate or pollinate with other members of the same clone). This situation would have acted to artificially select against local pollen sources and select toward pollen carried from only the large fields, thereby, creating a setting to measure worst-case gene flow. St. Amand et al. (2000) determined that within-seed-field pollen-mediated gene flow could not be detected more than 4 meters from the pollen source plants, demonstrating that pollen from rarer genotypes is diluted by or possibly occluded by pollen subsequently

collected from surrounding plants in natural (heterogeneous) alfalfa populations. Therefore, in part, the potential amount or rate of realized long-distance gene flow into isolated feral populations will be mitigated by the local abundance of compatible genotypes at shorter distances if they occur.

#### 5.12.5.3 Isolation and field size

For the second and third study objectives, St. Amand et al. (2000) used two marker systems, the GS marker and a RAPD marker, to measure gene flow to unclipped ramets of a single, marker-free, genetic clone planted as twelve  $1\text{ m}^2$  pollen traps along a roadside at each of four locations. Small plots have a higher percentage of out-crossing versus larger fields (AOSCA, 2003) so the  $1\text{ m}^2$  plots would likely demonstrate extreme, worst-case gene flow potential. The pollen traps, intended to simulate dispersed feral alfalfa, were distributed along a single vector at each location at increasing intervals from each of the pollen sources (i.e., 0, 20, 40, 60, 80, 100, 200, 300, 400, 500, 750 and 1000 m distance). Source fields were managed either for seed or for hay production and were considered either commercial-scale (ca. 0.13 ha or 1.74 ha, for seed or hay, respectively) or research-scale ( $2\text{ m}^2$  for both seed and hay). The RAPD or GS markers were used as the pollen-tracking system for the commercial- or research-scale plots, respectively. Plots were located in the states of Washington and Kansas. The small and large seed-production plots in Washington were stocked with leafcutter bees, while all other plots relied on natural populations of native and or feral bees for pollination.

Data indicated that pollen flow from research plots was minimal, with 1% to 2% flow at 0 to 100 m and no flow was detected at distances greater than 200 m. These data would support the conclusion that 200 m (640 ft) isolation zone without border crop would mitigate pollen outflow from small plots and or into larger fields from small groups of neighboring feral alfalfa potentially containing a GM trait.

Gene flow from the four large fields to the very small ( $1\text{ m}^2$ ) pollen traps was notably higher, with 25% to 35% out-crossing measured at 1000 m. Data are presented for percent out-crossing, but the gross number of seed produced on each trap or trap plant (the sample size) was not reported. In other words, if few seeds were produced a very low number of outcrosses would equal 25% (e.g., 10/40), whereas, if normal seed set occurred, numerous outcrosses and multiple bee visits would have been necessary for 25% out-crossing (e.g., 100/400). The number of seed produced on the trap plants would be important for direct comparison of the clone of artificial feral plants to naturally occurring feral plants. Plants within and among small traps were of the same genotype (genetic clone), which was likely, self-incompatible to some degree. Therefore, the plants within a trap were unlikely to form seed with any plant *except* one whose pollen was carried from the source field. Therefore, interpretation of this data is not straightforward. While use of the clonal-trap is an appropriate technique to measure the maximum distance of potential pollen flow, it may result in artificially high estimates for gene inflow to natural (non-clonal) feral alfalfa populations. It should be assumed that the naturally occurring out-crossing mechanism prevalent in cultivated alfalfa is also prevalent in feral alfalfa populations. Therefore, the potential for self-incompatibility among the trap clone ramets (nearest neighbors) may have acted to select for pollen carried from non-genetically related individuals. Thus, the use of the clones may have artificially skewed the out-crossing frequency toward long-distance pollen sources relative to what may have been found if the trap plants had been cross-compatible

with each other (nearer sources) as is found in nature. In a diverse, heterogeneous, natural, feral population, there would be no bias for or against any source of non-self pollen and proportionately more progeny would trace to pollen carried shorter distances.

Other factors that may have enhanced flow to the very small clonal trap plots include the relative attractiveness of the plants with respect to other plants along the roadsides, small plot size and the close proximity of the traps. First, the close proximity and unidirectional, regular placement of the twelve trap plots may have influenced bee movement by forming a highly attractive, pollinator-conduit or bridge from one trap to the next. It is important to note that the relatively high frequency of out-crossing reported at 1000 m took place at the distal end of the regularly spaced, unidirectional trap plots. Although the findings may be relevant to gene flow bridging potential among (self incompatible) high-density feral populations, it would be inappropriate to apply the findings to long-distance flow with 1000 m of true isolation from the nearest alfalfa pollen source (e.g., between 1000 m isolated seed fields and or feral patches). Secondly, the trap plants were not clipped or managed in any way that would have made the twelve 1 m<sup>2</sup> areas less attractive to bees and this would simulate feral alfalfa only if it were growing in completely unmanaged or unmanageable roadsides or wild areas in proximity to GM-sensitive seed producers. In many conventional seed production situations, alfalfa seed growers can and do take effective steps and precautions to mitigate feral alfalfa and feral alfalfa pollen (Kendrick et al., 2005). It is also likely that after they transplanted the trap ramets, St. Amand et al. took steps to irrigate them, control weed competition within the trap plots, and may have otherwise encouraged the growth of the trap plants, making them cultivated rather than feral (entirely unmanaged) *per se*.

#### 5.12.5.4 Effects of borders and potential for short-distance or within-field seed field gene flow

St. Amand et al. used a naturally occurring variant of the alfalfa glutamine synthase (GS) gene as a marker to monitor within seed field gene flow from marked source plants to surrounding plants not containing the variant gene. Minor gene flow (0.2%) was detected 4 m or less from the 1 m<sup>2</sup> (non-replicated) source plot and zero gene flow was detected greater than 4 m from the source plants. The authors discuss that these results would indicate that pollen traps or borders might be effective to mitigate alfalfa pollen flow. It should be noted that in this study, the area covered by the pollen trap plants from which +GS seed was harvested (i.e., the non-marked alfalfa border plants located  $\leq$  6 m from the edge of the 1 m<sup>2</sup> gene source plot) was 134 times greater than the area occupied by the single block of gene source plants—a ratio that would be unmanageable for commercial alfalfa seed or forage production. Same-species border crops would be problematic for regulated and/or commercial alfalfa seed fields where genetic purity of the target seed product is of central concern, i.e., the use of a non-transgenic synthetic alfalfa variety to surround a Roundup Ready seed field would reduce trait purity, reduce varietal purity and preclude varietal certification because spatial isolation standards would not be met. Non-alfalfa borders may have incompatible agronomic management and/or irrigation requirements when grown in the same field with alfalfa seed production which would impact the crop's potential efficacy as a pollen trap. Additionally, because alfalfa is not a preferred source of pollen for pollen-collecting bees (Arnett, 2002) a non-alfalfa border species might be counter-productive in reducing gene

flow, because that crop may be more attractive to bees than the alfalfa which it surrounds. This could reduce pollinator activity on the alfalfa and/or unintentionally attract more rove or scout bees from distant colonies than the non-bordered alfalfa alone would attract and inadvertently result in longer-distance pollen-mediated gene flow. Another challenge would be managing species purity during seed harvest and cleaning. If seed from the border species commingled with the alfalfa seed product, seed cleaning costs would increase or, if the border crop seeds were very difficult to segregate from the alfalfa seed, even a slight decrease in species purity would significantly impair the alfalfa seed's value or marketability. For example, the presence of other small-seeded legume seeds, such as birdsfoot trefoil or red clover, negatively impacts alfalfa seed lot species purity. In significant quantities, it will prevent alfalfa seed lot certification and decrease the alfalfa seed lot's value.

## **6.0 Alfalfa in Non-Cultivated Lands (Existing Environmental Setting): Non-Agricultural lands where alfalfa may be present**

Alfalfa is a widely adapted plant that has been introduced and grown extensively throughout the U.S. and occasionally, plants may be established outside of cultivation. It is known that feral alfalfa populations exist sparsely throughout the United States. In the Petition data were presented to APHIS documenting that alfalfa survives to a small extent outside of cultivation, and providing an estimate of the extent of feral populations in the U.S. (see Petition sections VII.E., VII.F. and appendix V-4).

Recently, feral alfalfa is discussed by Van Deynze et al. (2008):

“Feral plants are crop plants that grow and reproduce outside of cultivation. Feral alfalfa plants can sometimes be found on road edges, in fence lines and in abandoned fields. In the US, feral alfalfa populations have occurred through unintentional plantings of cultivated varieties (“escapes” from cultivation) or, in some cases, they originated from intentional planting of the abandoned fields, roadsides or marginal lands. Feral alfalfa occurs at very low density and scale relative to cultivated alfalfa grown for seed or hay. Biogeographic survey data from six states indicates that for most agricultural areas feral alfalfa plants do not occur or they are sparse (Kendrick et al., 2005). In a 2001/2002 multi-state survey, feral plants were found as dispersed plants or patches within 1.25 miles (2 km) of cultivated alfalfa at only 22% of the survey sites (Kendrick et al., 2005). Feral alfalfa plants are sometimes managed on roadsides by clipping, either with hay being harvested or simply left on the ground along with the other roadside vegetation. Feral plants are sometimes completely unmanaged and given adequate moisture and timely presence of pollinators, can flower and set seed. Feral plants are susceptible to the environmental (e.g. drought in the irrigated West) and insect (e.g. Lygus bugs in the West and potato leafhopper in the East) stresses common to the local area. Although alfalfa was introduced to North America more than 200 years ago, it is not considered weedy, noxious or invasive in cultivated or feral settings.”

This statement, that alfalfa “is not considered weedy, noxious or invasive in cultivated or feral settings” is additionally supported statements submitted by several experts during the 2005

USDA public comment period [e.g., USDA docket 04-085-1, comments by Undersander #519 (Wisconsin), Doll #505 (Wisconsin), Murray #485 (Oklahoma), Beuselinck #501 (USDA-ARS Missouri), Whitesides # (Utah), Miller #502 (Wyoming), Howatt #510 (North Dakota), et al.].

The biogeographical survey data of Kendrick, et al. (2005) were used to assess the potential for gene flow from cultivated to feral alfalfa populations. In the survey, six states were selected representing major alfalfa production states in the U.S. The states surveyed were California, Idaho, Pennsylvania, South Dakota, Washington and Wisconsin. A total of 940 roadside sites were surveyed (500 M<sup>2</sup>/site). At approximately 22% of the sites, feral populations were located within 2000 meters of cultivated alfalfa. On average, alfalfa occupied <3% of the area surveyed. The results from this survey likely are representative of other states in the U.S. where alfalfa is produced for seed or forage. It is reasonable to assume that feral alfalfa populations also exist to a minor extent in other locations where alfalfa hay or seed is produced, or seeds are spilled during transportation or processing. The occurrence of feral alfalfa near seed-production sites was less than those observed where forage was produced; this may be because of the importance that seed producers place on maintaining isolation during seed production to ensure genetic purity of alfalfa varieties. Frequently, alfalfa exists outside of cultivation in abandoned and relegated fields or sown rangelands: i.e., the founder seeds for these populations were not recruited from feral or natural sowing and they were not transported by wildlife, but rather were initiated by human intentions and not since targeted for control.



## Appendix V-1.       References

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## **Appendix V-2. Stewardship Program for Gene Flow Management in Roundup Ready® Alfalfa Production**

Monsanto and Forage Genetics International (FGI) have jointly developed Roundup Ready® alfalfa for commercial forage production in the United States. Prior to and after the introduction of Roundup Ready alfalfa (RRA) to U.S. alfalfa producers, Monsanto and FGI developed a stewardship plan that included securing regulatory approvals in key U.S. alfalfa hay export markets, implementation of hay and seed production practices designed to facilitate co-existence of both Roundup Ready and conventional alfalfa hay and seed<sup>1,2,3</sup> and a commitment to continued dialogue with alfalfa forage and seed producers.

### **1.0 Key Elements of Traits Stewardship**

#### **1.1 Licensing, contracting and pesticide registration**

Under terms of the Monsanto Technology/Stewardship Agreement (MTA) RRA may only be used to produce forage for feed uses. Seed production of RRA requires a specific contract from FGI or an FGI authorized FGI seed contractor. FGI is the sole Monsanto licensed seed producer. Although Roundup herbicide is broadly registered for RRA forage production purposes in the U.S., Roundup herbicide is labeled for seed production purposes in only certain states. Unregistered pesticide use and unlicensed commercial harvest, sale or uses of patent protected seed are violations of state and federal laws.

#### **1.2 Seed channel management**

All RRA seed is packaged with a unique purple seed coating and “Roundup Ready alfalfa” seed-bag labeling. RRA seed will only be sold by variety name. All seed purchasers, dealers, distributors, producers and processors of Roundup Ready seed must be licensed by Monsanto and agree to trait stewardship appropriate to their activities.

#### **1.3 Industry tools**

To support buyer-seller agreements that may stipulate conditions for biotech trait status, simple to use trait detection strips are available for alfalfa seed and hay product use (e.g., Strategic Diagnostics, Inc., Envirologix, Inc.).

#### **1.4 Mitigation of Pollen-Mediation GMNE Flow**

Gene flow between populations is a natural occurrence in all crops. Alfalfa requires cross-pollination by certain bee species; it is not wind pollinated. In alfalfa, the potential for Roundup Ready gene flow between fields is significantly constrained (limited) by crop and pollinator biology, typical alfalfa grower

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practices, and numerous additional grower practices required in the Monsanto license for forage growers and Forage Genetics best practices for contracted RRA seed growers as follows.

#### *1.4.1 Hay-to-hay field gene flow*

In alfalfa, forage producers cut hay at regular intervals prior to or near early bloom for optimum forage quality and yield. Pollinators are not attracted to non-flowering, vegetative alfalfa fields. The potential for pollen-mediated hay-to-hay field gene flow has been thoroughly discussed in a recent University of California publication<sup>4</sup> wherein it is stated that, "...the likelihood of AP [adventitious presence] occurring between hay fields becomes infinitely small, likely to be far less than 0.001% of field biomass even under high estimates. ...The combination of frequent harvests, lack of significant flowering, lack of significant seed production, and the highly competitive and allelopathic nature of alfalfa that prevents ready germination of alfalfa seeds in existing fields should prevent most if not all gene transfer".

#### *1.4.2 Hay-to-seed field gene flow*

Certified alfalfa seed must be produced using production methods and isolation defined and inspected by state seed certification organizations or an accredited organic certifier. Non-certified seed is not officially regulated. Seed producers and regulators recognize that genetic purity of the seed is related to physical isolation between the seed field and outside sources of pollen. For reasons explained above, due to sparse and short-term flowering, Roundup Ready forage fields are an unlikely source of pollen or pollinators. Hay-to-seed gene flow research has been conducted and data is publicly available<sup>1,2</sup>. Bees were applied to pollinate the seed fields in these studies, and, during the midsummer pollination period, the hay field plots were intentionally allowed to flower more extensively than is typical for forage: i.e., 50% bloom in 2000<sup>1,2</sup> and 20% bloom in 2006. Therefore, the hay field gene sources were representative of delayed or poorly managed hay fields growing close to a seed field. Under these conditions, gene flow into the seed field was very low (0.2%) at 150-300 ft and, it was rarely detected (0.00 to 0.05%) at distances greater than 350 ft. In contrast, forage producers who plant Roundup Ready Alfalfa seed will cut hay aggressively to manage for optimum forage quality and minimize the number of open flowers on the standing hay. In the western U.S. where hay and seed are both produced, licensees must identify the exact field location where Roundup Ready alfalfa seed will be planted. RRA forage growers will be monitored for compliance to license terms. Conventional seed producers can use reasonable seed field isolation distances from neighboring alfalfa fields and certified identity preserved best management practices (such as organic certification) to produce seed with little or no adventitious presence of traits from hay fields.

#### *1.4.3 Seed-to-seed field gene flow*

Certified alfalfa seed must be produced using production methods and isolation defined and inspected by state seed certification organizations or an accredited organic certifier. Non-certified seed is not officially regulated. Forage Genetics requires that all contracted RRA seed growers and conditioners follow FGI best practices policies for Roundup Ready trait stewardship. These best practices have been implemented to maintain high seed quality in FGI seeds; are based on industry experience and gene flow research data; and, they are effective strategies for assuring seed and hay industry market coexistence. It is well documented that isolation is one of the effective measures to mitigate pollen flow to very low levels<sup>1,2,5,6</sup> and that bee species differ in their potential to effect gene flow<sup>1,2,5,6,7</sup>. FGI and its contractors use process-based best practices that are modeled on the principles of AOSCA Foundation Class alfalfa seed production standards and crop identity preservation. Likewise, other producers of conventional and or specialty quality alfalfa seeds independently implement various production strategies to ensure their company's product quality claims. Research data is available to the industry so that other seed producers can use the information to manage seed quality<sup>2,5,6</sup>.

FGI Best Practices for RRA seed producers include: (1) All RRA seed is produced exclusively the U.S. using AOSCA and/or OECD certification standards. (2) At planting, all RRA seed fields respect a foundation isolation distance (or greater) to existing conventional seed fields: RRA eligible fields have 900 ft, 1 mile or 3 miles isolation for leafcutter bees, alkali bees or honeybees, respectively. (3) Seed growers must follow FGI's strict equipment sanitation, pollinator management and seed handling requirements. And, (4) the planting date, location, field size, variety name and termination date for all RRA seed production fields are reported to and inspected by the state's certifying organizations to facilitate the industry's management of field history and seed field isolation information.

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**Appendix W. Plant Pest Risk Assessment for  
Glyphosate-Tolerant Alfalfa Events  
J101 and J163**

## **Plant Pest Risk Assessment for Glyphosate-Tolerant Alfalfa Events J101 and J163**

This plant pest risk assessment is to determine whether glyphosate-tolerant (GT) alfalfa events J101 and J163 are unlikely to pose a plant pest risk. If APHIS determines that a genetically engineered (GE) organism is not a plant pest, APHIS then has no regulatory authority over that organism.

APHIS' authority to regulate genetically engineered organisms under the Plant Protection Act (PPA) (7 U.S.C. Sec 7701 *et seq.*) is limited to those GE organisms that are plant pests as defined under Section 14 of the PPA.

“Plant Pest - The term “plant pest” means any living stage of any of the following that can directly or indirectly injure, cause damage to, or cause disease in any plant or plant product:

- (A) A protozoan.
- (B) A nonhuman animal.
- (C) A parasitic plant.
- (D) A bacterium.
- (E) A fungus.
- (F) A virus or viroid.
- (G) An infectious agent or other pathogen
- (H) Any article similar to or allied with any of the articles specified in the preceding subparagraphs.”

Of the information requested by APHIS for submission of a petition for nonregulated status (§ 340.6(c)(4)), APHIS will use information submitted by the applicant related to plant pest risk characteristics, disease and pest susceptibilities, expression of the gene product, new enzymes, or changes to plant metabolism, weediness of the regulated article, any impacts on the weediness of any other plant with which it can interbreed, and the transfer of genetic information to organisms with which it cannot interbreed. Issues related to agricultural or cultivation practices will be considered in the Environmental Impact Statement for alfalfa events J101 and J163. These two events are not genetically engineered to produce a toxin or pesticide, thus Events J101 and J163 alfalfa are not targeted for use against pests in alfalfa agriculture. Thus, APHIS did not examine the effects of the regulated article on nontarget organisms. However, APHIS does examine the effects of alfalfa events J101 and J163, and potential use of glyphosate on animals, plants, and Threatened and Endangered Species (TES) in the Environmental Impact Statement. APHIS has not identified any issues related to indirect plant pest effects on agricultural production caused by alfalfa events J101 and J163.

Potential impacts to be addressed in this risk assessment are those that pertain to the use of alfalfa events J101 and J163 and their progeny in the absence of confinement. The genetically engineered construct inserted in alfalfa events J101 and J163 was evaluated to determine if those sequences in J101 and J163 cause plant disease. Morphological characteristics of alfalfa events



J101 and J163 were analyzed to determine if these alfalfa varieties would become weedy or invasive. The potential for gene flow to, and introgression of the genetically engineered construct into, other alfalfa varieties or wild relatives of alfalfa were also evaluated to determine the potential of increased weedy or invasive characteristics in other plant species. APHIS also analyzed the propensity of alfalfa events J101 and J163 to become greater reservoirs of plant pests (insects or pathogens) compared to conventional alfalfa varieties, and potential for horizontal gene transfer between alfalfa events J101 and J163 and bacteria.

### **Development of Glyphosate-Tolerant Alfalfa Events J101 and J163**

Alfalfa events J101 and J163 were engineered to be glyphosate-tolerant by inserting a gene into the alfalfa genome that codes for the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (CP4-EPSPS) that continues to function in the presence of glyphosate. The gene is from the common soil bacterium *Agrobacterium* sp. strain CP4 and was introduced into alfalfa via a disarmed *Agrobacterium*-mediated transformation protocol. The management of weeds in alfalfa fields can be an expensive, labor intensive, and sometimes complicated operation. Often farmers use pre-emergent herbicides that will stop some weed seeds from germinating and post-emergent herbicides that will control some weeds after germination. Typically, pre-emergent herbicide use is applied throughout the field because of the assumption that weeds will always be a problem in all parts of the field. Additionally, although these herbicides reduce weeds, most of these herbicides cause temporary damage to the desired alfalfa plants which results in reduced yields. With J101 and J163 and progeny, farmers will have the option of applying herbicide after weeds have germinated to only in the areas of the field where there are weeds, and also apply glyphosate herbicide without substantial damage to the alfalfa plants.

Glyphosate, a broad spectrum systemic herbicide, is one of the most environmentally friendly herbicides commercially available. The glyphosate herbicide (N-phosphonomethyl-glycine) is registered for non-selective weed control on both non-food use and food use plants.

Glyphosate works by interfering with normal plant metabolism by competing with the naturally present enzyme, 5-enolpyruvyl-3-phosphoshikimate acid synthase (EPSPS). EPSPS is involved in the biosynthesis of the aromatic amino acids, phenylalanine, tryptophan, and tyrosine (as well as some secondary metabolites) through the shikimate pathway. These aromatic amino acids are essential building blocks of proteins in all species. As a consequence of interfering with aromatic amino acid biosynthesis, plant cells cannot complete the synthesis of proteins and the plant dies (Kishore and Shah 1988). EPSPS is found naturally in all plants, fungi and some bacteria but is not present in animals (including humans). For animals, aromatic amino acids must be obtained through the diet (Steinrucken and Amrhein 1980). Consequently, all animals are naturally exposed to sources of EPSPS through their normal diets.

### **1. Description of inserted genetic material and potential of the material to cause plant disease.**

Data supplied in the petition and reviewed by APHIS (Section V.A., pp. 38-68) support the conclusion that events J101 and J163 contain the following sequences: (1) a 35S promoter from a modified figwort mosaic virus (P-FMV), (2) coding sequence for a chloroplast transit peptide from *Arabidopsis thaliana*, (3) the 5-enolpyruvylshikimate-3-phosphate synthase gene (*epsps*) from *Agrobacterium* sp. strain CP4, and (4) DNA containing polyadenylation sequences from the

3' non-translated region of the *Pisum sativum* (pea) *rbcS* E9 gene. The non-coding 35S promoter is from the plant pathogen figwort mosaic virus. This sequence, however, cannot cause plant disease and serves a purely regulatory function for the *epsps* gene. The *epsps* gene is from the soil-inhabiting bacterial plant pathogen, *Agrobacterium* sp. strain CP4. It encodes the CP4-EPSPS protein which functions to impart tolerance to the broad spectrum herbicide glyphosate. It does not cause disease and has a history of safe use in a number of deregulated genetically engineered plants (e.g., corn, cotton, soybean, rapeseed, and sugar beet varieties).

The plant material used for development of events J101 and J163 was Forage Genetics International (FGI) proprietary alfalfa clone R2336 from a high yielding, fall dormant breeding population. The initial plants, selected for tolerance to glyphosate, were designated J101 and J163, and various populations were developed from these events to provide the data presented in the petition. Events J101 and J163 were developed using a disarmed (i.e. pathogenicity genes removed) *Agrobacterium*-mediated transformation system of sterile alfalfa seedling cotyledons. Post-transformation, *Agrobacterium* were eliminated from tissues by a 7-week culture on antibiotic-containing medium. Glyphosate was used to select for transformed tissues containing the *epsps* gene construct. This technique using disarmed *Agrobacterium* followed by selection has a 20-year history of safe use and has been used for transformation of a variety of plant species and tissues (Howard *et al.*, 1990).

Data were provided and reviewed by APHIS that demonstrate stable integration and inheritance of the *epsps* gene and its associated regulatory sequences over several breeding generations. Statistical analyses show that glyphosate tolerance is inherited as a dominant trait in a typical Mendelian manner (petition Table V-1, p. 71).

## **2. Potential impacts based on the relative weediness and/or invasiveness of alfalfa events J101 and J163**

APHIS assessed whether alfalfa events J101 and J163 are any more likely to become weeds than the non-transgenic control populations, or other currently cultivated alfalfa. The assessment encompasses a thorough consideration of the basic biology of alfalfa and an evaluation of unique characteristics of alfalfa events J101 and J163.

Almost all definitions of weediness stress as core attributes the undesirable nature of weeds from the point of view of humans; from this core, individual definitions differ in approach and emphasis (Baker, 1965; de Wet and Harlan, 1975; Muenscher, 1980; Booth *et al.*, 2003). The parent plant in this petition, *Medicago sativa* L., is not listed as a serious weed in A *Geographical Atlas of World Weeds* (Holms *et al.*, 1991) or as a weed in *World Weeds: Natural Histories and Distribution* (Holms *et al.*, 1997), *Weeds of the North Central States* ([http://www.aces.uiuc.edu/vista/html\\_pubs/WEEDS/list.html](http://www.aces.uiuc.edu/vista/html_pubs/WEEDS/list.html)), *Weeds of the Northeast* (Uva *et al.*, 1997), or *Weeds of the West* (Whitson *et al.*, 1992). Alfalfa is not listed as a noxious weed species by the U.S. Federal Government (7 CFR Part 360), is not listed as a weed in the major weed references (Crockett 1977; Holm, Pancho *et al.* 1979; Muenscher 1980), nor is it on other weed lists such as: Washington State Weed Lists ([http://www.nwcb.wa.gov/weed\\_list/weed\\_list.htm](http://www.nwcb.wa.gov/weed_list/weed_list.htm)), California Weed Species Lists (<http://www.extendinc.com/weedfreefeed/list-b.htm>), Montana County Noxious Weed

List(<http://agr.mt.gov/weedpest/noxiousweeds.asp> ), and North Dakota Noxious Weeds (<http://www.ext.nodak.edu/extpubs/plantsci/weeds/w1103w.htm> ).

Alfalfa is not considered a serious weed, a noxious weed or an invasive species in the United States, even though feral (free-living) populations are fairly common and volunteers may occur in succeeding crops.

The updated Southern Weed Science Society (SWSS), in collaboration with the North Central Weed Science Society, Interactive Encyclopedia of North American Weeds Version 3.0 (447 entries), includes alfalfa (NCWSS 2005). This is an updated version of the 1998 version cited above. The documentation provided by this list does not indicate why alfalfa is considered a weed. It is possible that it is included because it can be an unwanted volunteer in agricultural settings.

The author of the alfalfa segment of the SWSS Weed Identification guide has stated that alfalfa is not “an invasive weed” nor does it “displace native species,” but alfalfa does colonize disturbed areas (Brett Serviss, Docket No. 04-085-1 #480).

Generally feral populations, many of which are along roadsides, are not a problem, and generally no attempts are made to control these populations. In some instances, these feral populations are considered advantageous and are encouraged (petition Appendix 3, p. 375, 12/31/02 Letter from South Dakota State University). These volunteer plants can be controlled by mechanical means or several other registered herbicides besides glyphosate. Alfalfa possesses few of the characteristics of plants that are notable of successful weeds (Baker, 1965; Keeler, 1989; Booth et al., 2003).

APHIS reviewed various data sets comparing J101 and J163 populations and non-transgenic control populations (petition Section VI pages 99-254) to aid in determining whether the J101 and J163 populations were changed in any manner that might affect the plants ability to persist or compete as a weed and as a method of determining the presence of unintended effects. Data were reviewed on seed dormancy, seed germination, seedling emergence, seedling vigor, spring stand, spring vigor, seed yield, vegetative growth or plant vigor, plant dormancy, growth habit, flowering properties, effect on symbiotic organisms, all characteristics that might relate to or have an effect on increased weediness.

Seed Dormancy: Seed dormancy, which includes hard seed (a water impermeable seed coat (AOSA, 2002)) as found in alfalfa, has a potential effect on weediness by affecting the soil seed bank (the total quantity of viable seeds of various species in the soil at any one time) and allowing the seed to remain viable over various seasons and potentially over several years. The percentage of hard seed in alfalfa can vary in a particular seed lot, depending on genetic factors, environmental conditions during and after seed maturation, and harvesting methods (Bass et al., 1988). The data found in the petition for hard seed (Section VI pages 114-135) is also quite variable. In the first year, seed of J101 and J163 populations had a significantly higher level of hard seed than the control populations. In the second year, the seed in J101 and J163 populations had a significantly lower level of hard seed than the control populations. In the third year, the seed of J101 and J163 populations were both higher and lower levels of hard seed than the

control populations with the mean of the J101 and J163 populations being essentially equal to the control populations. In addition, during the public comment period in late 2004 and early 2005 after notifying the public of the availability of the petition 04-110-01p for deregulation and the corresponding environmental assessment, six scientists from four different states each with more than 20 years experience working with alfalfa and or seed physiology commented that there was no evidence linking the increased levels of hard seed with glyphosate tolerance. They also generally noted that hard seed in the case of alfalfa was not linked to dormancy since their observations and studies in the past showed that hard seed almost always germinated within a few weeks of seeding and the seedlings that developed were generally too weak and noncompetitive to survive. From the data submitted in the petition and from the comments from these scientists, APHIS concludes that glyphosate tolerance does not cause increased seed dormancy.

Seed Germination: The level of alfalfa seed germination as determined under laboratory conditions is generally negatively correlated to the level of hard seed since both are determined in the same seed test (AOSA 2002). If the percentage of hard seed is determined to be high in the seed test, then the percentage of seed germination is generally lower. If the percentage of hard seed is low, then the percentage of seed germination is generally higher. Increased levels of seed germination may have an effect on weediness by allowing more plants to establish in the environment by outnumbering plants with lower levels of germination. The data in the petition for seed germination (Section VI pages 114-135) are best explained by the levels of hard seed in the various samples of seed tested for each of the populations of J101, J163, control and representative varieties. From the data submitted in the petition, APHIS concludes that glyphosate tolerance does not cause increased seed germination.

Seedling Emergence: Increased seedling emergence may have an effect on weediness by allowing more plants to establish in the environment by outnumbering plants with lower levels of seedling emergence. Seedling emergence is a combination of seed germination rate, seed dormancy which may decrease the number of seeds germinating, and the effect of various environmental conditions on the germinating process such as cold soils, level of available water, insect predation, and level of disease pressure on the germinating seeds. Therefore seedling emergence is an overall score for the level of plant survival between seeds planted and surviving seedlings. The data in the petition for seedling emergence (Section VI pages 135-157) indicate that J101 and J163 populations were essentially the same as the control populations or reference varieties. From the data submitted in the petition, APHIS concludes that glyphosate tolerance does not cause increased seedling emergence,

Seedling Vigor: Increased seedling vigor may have an effect on weediness by allowing more seedling plants to establish in the environment by outnumbering and outcompeting plants with lower levels of seedling vigor. Increased seedling vigor is a combination of early seedling establishment, increased vigorous seedling growth, and tolerance to seedling diseases. The data in the petition for seedling vigor (Section VI pages 135-157) indicate that J101 and J163 populations were essentially the same as the control populations or reference varieties. From the data submitted in the petition, APHIS concludes that glyphosate tolerance does not cause increased seedling vigor.

Spring Stand: This is a rating for winter survival or winter hardiness. Higher ratings for spring stand would indicate better winter survival. Increased spring stand may have an effect on weediness by outcompeting other more desirable plants allowing more plants to survive and compete in the environment to the detriment of other plants. The data in the petition for spring stand (Section VI pages 135-157) indicate that J101 and J163 populations were essentially the same as the control populations or reference varieties. From the data submitted in the petition, APHIS concludes that glyphosate tolerance does not cause increased spring stand.

Spring Vigor: This trait could be considered a combination of spring stand and the rate of plant growth in the spring. A dense spring stand along with rapid spring plant growth would be very detrimental for the growth of other plant species. Dense alfalfa stands are known to be very competitive against weeds. On the other hand the argument could be made that an alfalfa variety that has an increased ability to provide a denser spring stand along with excellent spring vigor could be considered more weedy if allowed to grow in an area where it is not wanted. The data in the petition for spring vigor (Section VI pages 135-157) indicate that J101 and J163 populations were essentially the same as the control populations or reference varieties. From the data submitted in the petition, APHIS concludes that glyphosate tolerance does not cause increased spring vigor.

Seed Yield: High seed yield is a desirable characteristic of a successful commercial alfalfa variety since seed yield is a major component in the final selling price. Higher seed yields (weight per acre) generally translate into lower selling prices if all other factors are held constant. On the other hand, the argument could be made that an alfalfa variety that has a higher seed yield could be considered more weedy if allowed to grow in an area where it is not wanted. Higher seed yield would mean more seeds and or bigger seeds would be produced that could give it a selective advantage. The seed yield data in the petition provided information on seed weight per 1000 pollinations, seed weight per plant, weight per seed, and the number of seeds per flower (Section VI pages 209-217) for the J101 and J163 populations and the control populations or reference varieties. From the data submitted in the petition, APHIS concludes that glyphosate tolerance does not cause increased seed yield.

Vegetative Growth or Plant Vigor: High forage yield is a desirable characteristic of a successful alfalfa variety since a high yield of highly nutritious forage is the goal of forage production for animal consumption. Good plant vigor is also necessary for minimizing weed competition in a forage field. More vegetative growth or more plant vigor could also be considered a characteristic that could lead to more weediness. The petition provided information on vegetative growth or plant vigor in the form of forage yield (fresh weight per acre or weight per plant), crop growth stage (Mean Stage by Count), regrowth after cutting, and growth and or vigor scores (Section VI pages 135-137, 167-170, 175-182) , for the J101 and J163 populations and the control populations or reference varieties. A significantly higher forage yield for one or more cuttings or total weight for the year could possibly indicate a faster growing or larger plant that in the right environment could indicate more weediness. A significantly higher crop stage growth rating would indicate that more plants could be producing seeds more rapidly which also could mean more weediness. A significantly higher rating for regrowth after cutting could possibly indicate that the plants are more vigorous after cutting or grazing, possibly making these plants more competitive against other plants. Growth and or vigor scores that are consistently

and significantly higher over dates within a year, over years and over locations could also possibly provide information on the potential competitiveness of a plant which may make it more weedy. From the data submitted in the petition, no significant consistent pattern was noted for higher forage yield, for higher crop stage growth rating, for higher regrowth rating, or for higher growth and vigor scores. Thus APHIS concludes that glyphosate tolerance does not cause increased vegetative growth or plant vigor.

Plant Dormancy: This characteristic and its relationship to possible weediness is highly dependent on the climate in which the plant is grown. More plant dormancy is critical for the perennial plant's survival in climates with freezing winter temperatures. A plant that is actively growing when freezing temperatures occur will generally die. On the other hand, if the plant has a high level of dormancy going into the fall of the year (the plant slows or stops active growth and the various physiological properties are conditioning the plant for withstanding freezing temperatures) and the plant is growing in a climate with no freezing winter temperatures, the plant is at a competitive disadvantage to those plants that are actively growing. Alfalfa varieties vary widely in dormancy from no hardiness to high levels of dormancy. In the petition, fall dormancy was determined by plant height measured in the fall after the last cutting of the season or as a visual rating. Greater fall plant height and higher visual ratings would indicate greater fall dormancy. From the data submitted in the petition (Section VI pages 135-157, 175-182), no significant differences were noted for fall plant height or visual fall dormancy ratings. Thus, APHIS concludes that glyphosate tolerance does not change fall dormancy.

Growth Habit: A prostrate growth habit or an upright growth habit is not necessarily weediness characteristics in themselves but more a relationship to the plant community in which they are growing. A rapidly growing plant with a prostrate growth habit would be more competitive against plants that are slow to germinate or slow to regrow in the spring or after grazing. A rapidly growing plant with an upright growth habit would be more competitive in a more dense stand of plants slow to germinate or slow to regrow in the spring or after grazing. From the data submitted in the petition (Section VI pages 135-137, 158, 175-182), no significant differences were noted for fall growth habit. Therefore, APHIS concludes that glyphosate tolerance does not change fall growth habit.

Survival: For a perennial crop, survival is an important characteristic since it helps determine the economically viable time length of commercial fields. If the alfalfa forage fields can survive longer, the significant costs involved with establishing and destroying fields can be avoided for longer periods of time and prorated over more harvests. It is a measure of a variety's tolerance of various biotic and abiotic stress, such as frequent mowing/grazing, freezing temperatures, diseases, insects, traffic from vehicles and animals, etc. The possibility exists that if an alfalfa plant can survive longer when stressed by the same biotic and abiotic factors, then it may have a greater potential to become weedy in some circumstances. From the data submitted in the petition (Section VI pages 175-182), no significant differences were noted for survival, and APHIS concludes that glyphosate tolerance does not change survival.

Flower and Pollen Morphology: For alfalfa that is dependent on bees for cross pollination and seed production, changes in flower morphology may have an effect on bee visitation. Exactly

how changes in flower morphology may affect weediness are not understood, so if any changes are noted then it needs to be examined more closely. Data submitted in the petition (Section VI pages 183-209) provided measurements on number of flowers per raceme, length of the standard petal, length of the keel petal, diameter of the calyx tube, length of the sexual column, number of pollen grains per flower, percent pollen germination, percent pollen viability, pollen diameter, and visual observation of the following: flower color, general flower morphology, rachis attachment to the stem, flower attachment to the rachis, flower ripening pattern of the raceme, general observation of the pollen load per flower, self fertility of flowers whether tripped without any assistance or mechanically tripped by the researcher, and general seed morphology. From these data submitted in the petition, no significant differences were noted for any of these flower and pollen characteristics. Therefore, APHIS concludes that glyphosate tolerance does not change flower and pollen characteristics and therefore cannot have an effect on weediness.

Symbiotic Organisms: Since nitrogen-fixing bacteria (*Sinorhizobium meliloti*, formerly known as *Rhizobium meliloti*) are known to have a symbiotic relationship with legumes, observations were taken on nodule formation (Section VI pages 248-251) as well as phenotypic observations that would be affected by modification of the nitrogen fixing process, such as seedling growth (Section VI pages 248-251), levels of total protein, asparagine, and aspartate (Section VI pages 223-247), and forage yield (Section VI pages 135-137, 167-170, 175-182). From these data submitted in the petition, no significant differences were noted for any of these symbiotic nitrogen fixing relationships. Thus, APHIS concludes that the glyphosate tolerance trait does not effect symbiotic relationships and therefore cannot have an effect on weediness.

No unusual characteristics were noted that would suggest increased weediness of J101 and J163 plants. Additionally, no characteristics relating to disease or insect resistance that might affect weediness were noted. These characteristics were consistent over all field trial locations (petition Tables VI-16, VI-18, VI-19, VI-20 pages 159-175). J101 and J163 alfalfa plants are still susceptible to the typical insect and disease pests of alfalfa. Therefore, there is no selective advantage to alfalfa containing CP4-EPSPS compared to conventional alfalfa, and there is no increased potential for weediness or invasiveness from alfalfa events J101 and J163.

### **3. Potential impacts from gene flow and gene introgression from alfalfa events J101 and J163 into its sexually-compatible relatives.**

APHIS evaluated the potential for hybridization and gene introgression to occur from alfalfa events J101 and J163 to sexually compatible wild (free-living) relatives, and considered whether such introgression would result in increased weediness. Alfalfa is sexually compatible with several subspecies within the *M. sativa* complex (Small and Jomphe, 1989). The center of origin for the genus *Medicago* is generally believed to be in the Caucasus, northwestern Iran and northeastern Turkey; the genus is not native in North America. An additional 18 *Medicago* species are known to be naturalized (free-living) or possibly so within the United States, of which only *M. lupulina* (black medic) is widely naturalized throughout the United States. None of these species are native to the United States, and none are sexually compatible with *M. sativa*. The *M. sativa* complex, which was introduced into North America early by Europeans for forage and includes all the commercial alfalfa varieties, is a group of closely related subspecies, including the cultivated *M. sativa* ssp. *sativa* and *M. sativa* ssp. *falcata* (synonym *M. falcata*) (Small and Jomphe, 1989).

In addition to the *M. sativa* complex within which all of the subspecies are sexually compatible to some degree, an additional 17 and possibly 18 *Medicago* species have been recognized as being naturalized (free-living) or possibly so in the United States (USDA-NRCS, 2004; Kartesz, 2004). All of these 18 species are annual species, except for the species *M. hybrida* (in *Medicago* section *Medicago*) hybrids of which have only been produced experimentally by embryo culture. No annual species are known to hybridize with *M. sativa* (Quiros and Bauchan, 1988; McCoy and Bingham, 1988; and the petition's Appendix 4).

*Medicago lupulina* (black medic) is the species that might be of most concern within this list of 18 species. It is considered a weed in lawns and waste places and in forages since its seeds frequently contaminate forage legume seed crops. Black medic is an annual (possibly sometimes short-lived perennial) self-pollinating species and is known to occur throughout the United States. Successful hybridizations between *M. sativa* and *M. lupulina* have been reported (Southworth, 1928; Fryer, 1930; Shrock, 1943). However, because of the lack of hybrids after many subsequent experiments, there is general agreement that these putative "hybrids" were most likely not hybrids but due to self-fertilization (Lesins and Gillies, 1972; Fridriksson and Bolton, 1963; Valizadeh et al., 1996). For more details on this topic, see Section E.1 (p. 284) and Appendix 4 of the petition. Based on all the recent data available on this subject, APHIS' opinion is that hybridization between *Medicago sativa* and *M. lupulina* has an extremely low to non-existent probability of occurring in a non-experimental or even in an experimental setting.

APHIS concludes that the potential of the glyphosate tolerance trait moving from J101 and J163 to other sexually compatible *Medicago* species in the United States is essentially non-existent.

#### **4. Potential of alfalfa events J101 and J163 to harbor plant pests (insects and disease)**

The data submitted by Monsanto and FGI indicated no significant differences between alfalfa events J101 and J163 and the non-transgenic counterparts for disease observations (as measured by seedling damping-off (e.g., fungal genera such as *Pythium*, *Phytophthora*, *Aphanomyces*); foliar diseases (e.g., fungal genera such as *Leptosphaerulina*, *Colletotrichum*, *Peronospora*, *Phoma*, *Stemphylium*, *Cercospora*, and stem nematodes like *Ditylenchus*); and root rots, vascular wilts and crown diseases (e.g., fungal genera such as *Phytophthora*, *Verticillium*, *Fusarium*, *Phoma*, and bacterial wilt caused by *Clavibacter*) and pest susceptibility (as measured by potato leafhoppers (*Empoasca fabae*), aphids [pea (*Acyrtosiphon pisum*), blue (*A. kondoi*) and spotted alfalfa aphids (*Therioaphis maculata*)], alfalfa weevil (*Hypera postica*), lygus bugs (*Lygus* species), other plant bug species (family *Miridae*) and alfalfa caterpillars (various lepidopteran species)) (Tables VI-16, VI-18 to VI-20 of petition pages 159-175). The data presented in the petition indicates no difference in compositional and nutritional quality of alfalfa events J101 and J163 compared to conventional alfalfa, apart from the presence of CP4-EPSPS. Although some of the variables measured by the applicant showed statistically significant differences between alfalfa events J101 and J163 and the nontransgenic control population (Tables VI-34 and VI-35 of the petition, pages 226-244), none of the values for the forage composition characteristics were outside the range of natural variability of conventional alfalfa as found in the literature (Table VI-36 of the petition, page 245). Therefore, the composition of alfalfa events



J101 and J163 is not biologically different than conventional alfalfa, and the events are thus susceptible to the same pest population as conventional alfalfa. Additionally, alfalfa events J101 and J163 are similarly affected by typical plant diseases found in alfalfa, and do not harbor an altered pest or pathogen community compared to other alfalfa varieties.

## **5. Transfer of genetic information to organisms with which it cannot interbreed**

Horizontal gene transfer and expression of DNA from a plant species to bacteria is unlikely to occur. First, many genomes (or parts thereof) have been sequenced from bacteria that are closely associated with plants including *Agrobacterium* and *Rhizobium* (Kaneko et al. 2000, Wood et al. 2001, Kaneko et al. 2002). There is no evidence that these organisms contain genes derived from plants. Second, in cases where review of sequence data implied that horizontal gene transfer occurred, these events are inferred to occur on an evolutionary time scale on the order of millions of years (Koonin et al. 2001, Brown 2003). Third, transgene DNA promoters and coding sequences are optimized for plant expression, not prokaryotic bacterial expression. Thus even if horizontal gene transfer occurred, proteins corresponding to the transgenes are not likely to be produced. Fourth, the Food and Drug Administration (FDA) has evaluated horizontal gene transfer from the use of antibiotic resistance marker genes. The FDA concluded that the likelihood of transfer of antibiotic resistance genes from plant genomes to microorganisms in the gastrointestinal tract of humans or animals, or in the environment, is remote (<http://vm.cfsan.fda.gov/~dms/opa-armg.html>). Therefore APHIS concludes that horizontal gene transfer is unlikely to occur and thus poses no significant environmental or plant pest risk.

## **Conclusion**

APHIS has reviewed and conducted a plant pest risk assessment on alfalfa events J101 and J163 alfalfa. Due to the lack of plant pest risk from the inserted genetic material, the lack of weediness characteristics of alfalfa events J101 and J163 alfalfa, the lack of atypical responses to disease or plant pests in the field, the lack of deleterious effects on non-targets or beneficial organisms in the agro-ecosystem, and the lack of horizontal gene transfer, APHIS concludes that Events J101 and J163 alfalfa are unlikely to pose a plant pest risk.

Alfalfa events J101 and J163 are also not plant pests as defined by the PPA. Neither alfalfa events J101 or J163, nor the EPSPS enzyme engineered into the alfalfa events, are any of the organisms listed in the statutory definition of a plant pest. Enzymes such as EPSPS are proteins that catalyze chemical reactions. Enzymes are not “living,” nor a “living stage” of any of the organisms (“articles”) listed in the PPA’s definition of a plant pest in subsections A-G of 7 U.S.C. 7702(14). Likewise, the EPSPS enzyme within alfalfa events J101 and J163 also does not fall within the statutory definition of a plant pest as listed in subsection ‘(H)’ of the PPA’s plant pest definition in 7 U.S.C. 7702(14).

An “article” as defined in the PPA at 7 U.S.C. 7702(1) is a “material or tangible object that could harbor plant pests.” In order to meet the PPA’s definition of a plant pest, the EPSPS enzyme in these alfalfa events would have to be **both** a living stage of one of the organisms (articles) listed in subsections A-G and would also have to be able to harbor a plant pest. However, an enzyme is not a living stage of one of the organisms (articles) listed in subsections A-G. Moreover, because enzymes are non-living, sub-cellular components of living cells, they are not of the scale

to “harbor” another living organism. Therefore, an enzyme (including the EPSPS enzyme in the alfalfa events J101 and J163) does not fall within the PPA’s definition of a plant pest.

Alfalfa events J101 and J163 also are clearly not living stages of any of the organisms (articles) listed in subsections A-G of 7 U.S.C. 7702(14). Nor are alfalfa events J101 and J163 a living stage of any article (organism) similar to or allied with any of the articles specified in subsections A-G as required by subsection H of 7 U.S.C. 7702(14). Thus, alfalfa events J101 and J163 are not plant pests as defined by the PPA.

APHIS has determined that neither the alfalfa events J101 and J163, nor the EPSPS enzyme in these GT alfalfa events, are a “living stage” of any of the organisms (articles) listed in subsections A-H of the PPA’s plant pest definition. Moreover, neither the alfalfa events J101 and J163, nor the EPSPS enzyme in GT alfalfa is an article that harbors plant pests.

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