Appendix G. Effects of Glyphosate-Resistant Weeds in Agricultural Systems

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Effects of Glyphosate-Resistant Weeds in Agricultural Systems

Executive Summary

Alfalfa is grown for forage, grazing, seed production, human consumption (sprouts), and to facilitate honey production. Dry hay forage represents the majority of cultivated acreage. In 2005, 22,439,000 acres of dry hay alfalfa was harvested, with certified organic production representing 0.9 percent of total harvest (204,380 acres). Organic production of alfalfa utilizes mechanical and cultural methods, but precludes the use of synthetic pesticides or crop varieties produced through genetic engineering. Conventional farming of alfalfa allows for the use of mechanical and cultural methods in addition to 16 herbicides to control weeds. Glyphosate-tolerant (GT) alfalfa allows for the application of glyphosate directly onto growing plants, providing more options for weed control over conventional and organic systems. Additionally, GT alfalfa allows for flexible timing of glyphosate application to control weeds. In the two years that GT alfalfa seed was on the U.S. market, approximately 200,000 acres were planted across 1,552 counties in 48 states.

Alfalfa Growing Regions

There are seven alfalfa growing regions in the U.S. Each region utilizes 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 according the 2007Census of Agriculture.

Crop Rotations

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

Alfalfa Stand Removal

Glyphosate, plus other herbicides and/or tillage, are the primary tools used to remove conventional alfalfa stands. Use of herbicides other than glyphosate for removal of GT alfalfa is the 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. However, 11 other herbicides and tank mixtures of those herbicides are available to control volunteer GT alfalfa.

These are the same herbicides and tank mixtures that are used to control non-GT alfalfa with the exception that glyphosate can be used to control non-GT alfalfa.

Weeds in Alfalfa

Cultural (rotation, companion crops, monitoring) and mechanical (tillage) methods are permitted for organic production of alfalfa. In addition to cultural and mechanical methods, weeds are additionally controlled in conventional alfalfa with herbicide applications. GT systems allow for the direct application of glyphosate onto alfalfa plants to control weeds. Weeds are undesirable because they compete with crops for limited resources (e.g., nutrients, sunlight, and water), leading to lower yields and reduced nutritional value of crops. Additionally, the presence of weeds in crop products can be poisonous or unpalatable to livestock, cause off flavors in milk, and lead to trouble with bailing. At least 129 different weed species are identified as minor or major problems in alfalfa. Twenty-one weeds that are either resistant or tolerant to glyphosate and traditionally listed as problems in alfalfa include: common ragweed, horseweed, Italian ryegrass, perennial ryegrass, Johnsongrass, Palmer Amaranth, tall waterhemp, buckhorn plantain, goosegrass, junglerice, kochia, 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 21 weeds are candidates for becoming more prevalent than glyphosate-sensitive weeds in rotations that include GT alfalfa.

Glyphosate-Resistant/Glyphosate-Tolerant Weed Distribution

Nineteen states and over two million acres of cropland contain glyphosate-resistant/glyphosate-tolerant weeds. The heaviest infestations are in the Southeast and Midwest. Current 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/glyphosate-tolerant weed locations and alfalfa hay acreage, there is potential for rapid shifts of glyphosate-resistant/glyphosate-tolerant weeds into GT alfalfa fields if best management practices are not utilized following GT alfalfa adoption. California is a concern because glyphosate-resistant/glyphosate-tolerant 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. Potential effects of farming with GT alfalfa on non-agricultural ecosystems are discussed in other appendices. In this appendix, different types of alfalfa cropping systems are described. Regional differences in alfalfa farming practices 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 practices involving weed management and does not include discussion of disease control, vertebrate and invertebrate pests, or management of field fertility and soil conservation.

Weed management is an important aspect of alfalfa production. Some 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 compete for sunlight, nutrient, and water resources.
- Weeds can lower the nutritional quality of alfalfa hay because many weeds are lower in protein and higher in fiber relative to alfalfa.
- Poisonous weeds can make alfalfa hay unmarketable (e.g., common groundsel, fiddleneck, yellow starthistle, and poison hemlock).
- Under some conditions, weeds can accumulate toxic concentrations of nitrate and oxalate (e.g., lambsquarters, kochia, and pigweed).
- Some weeds 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 (either beef or milk).
- Some weeds can contribute to off flavors in milk (e.g., wild celery, Mexican tea, creeping swinegrass, and mustards).
- Weeds can increase the overall moisture level of a bail, leading to problems such as mold, off-color hay, and high bale temperatures.

Weed-free hay is high in protein and desired for many alfalfa uses. Marten and Andersen (1975) evaluated the nutritive value of a seven-weed mixture commonly found with alfalfa in Rosemount, Minnesota. The alfalfa field was harvested at first flower, followed by hand separation of alfalfa and weed species. The seven species of weeds present in the mixture included redroot pigweed, common lambsquarters, common ragweed, Pennsylvania smartweed, yellow foxtail, giant foxtail, and barnyardgrass. *In vitro* digestible dry matter (IVDDM), acid detergent fiber (ADF), acid detergent lignin (ADL), and crude protein (CP) were determined for both the alfalfa and the collective weed mixture, due to insufficient quantities of individual weed species from the plot for quantitative analysis. The IVDDM of the weed mixture and the alfalfa was not statistically different. However, the weed mixture contained significantly less crude protein compared to alfalfa. This was expected because none of the weeds were legumes and the soil was nitrogen deficient (following two years of cropping with corn). The weed mixture contained more fiber than the alfalfa, though this fiber was also less lignified. However, when a nearby weed nursery was fertilized and harvested before flowering, redroot pigweed, common

lambsquaters, and common ragweed yielded similar nutritative values as alfalfa. Thus, specific conditions may alleviate the negative impact of weeds on alfalfa quality. However, the remainder of this appendix will focuses on alfalfa uses where weeds are strongly undesirable due to the negative effects listed above.

In hand-weeded stands, alfalfa can grow at a density of about 12 plants per square foot at the end of year one. Stands infested with fiddleneck, a common alfalfa weed, can have less than one alfalfa plant per square foot (Canevari et al. 2007). In California, weeds that are not effectively controlled can represent up to 76 percent of the first cutting yields (Gianessi et al. 2002). Proper timing of pre-emergence and post-emergence herbicides in alfalfa can be difficult; often times, weeds grow beyond the susceptible stage before the ideal application time of the alfalfa plant (Gianessi et al. 2002). GT alfalfa was developed to overcome this obstable of proper timing, so that the broad spectrum herbicide, glyphosate, could be applied directly to alfalfa fields to control weeds. Although all GT alfalfa have had the GT trait introduced through genetic engineering, GT resistance has arisen naturally in some weeds due to strong selective pressure resulting from decades of glyphosate use.

1.1 Methodology

A literature search was conducted to identify peer-reviewed articles and grey literature (e.g., government reports, State Agricultural Extension Office publications) on weeds commonly associated with alfalfa fields (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 the USDA National Agricultural Statistics Service (http://www.nass.usda.gov/index.asp). In addition, the USDA 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 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/noxiousDriver#invasive).

2.0 Alfalfa Cropping Systems

This chapter discusses the farming practices for growing alfalfa and the alfalfa growing regions in the United States.

2.1 Alfalfa Farming Practices

Alfalfa farming practices are categorized as organic, conventional, or GT alfalfa. Only aspects of farming related to weed control are discussed here. Practices for controlling disease, vertebrate and invertebrate pests, and management of field fertility and soil conservation are not discussed.

2.1.1 Organic Farming

For this report, organic production is defined as 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 and herbicides, 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 as a crop in organic systems because it is genetically engineered and because glyphosate application is not permitted in organic systems.

2.1.2 Conventional Farming

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 can be used in conventional farming of alfalfa are summarized in table J-1 (OMAFRA 2008, Canevari et al. 2007, Rogan and Fitzpatrick 2004, Loux et al. 2007). Additionally, conventional farming permits the use of genetically engineered crops. However, genetically engineered GT alfalfa is considered separately for this report.

2.1.3 GT Farming

GT alfalfa can be integrated into conventional farming practices. Farming GT alfalfa and conventional farming of non-GT alfalfa is similar 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 fields, non-glyphosate herbicides 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 further discussed in Appendix J.

Another important difference to some farmers is that non-GT crops are limited as companion crops for GT alfalfa. For farmers that plant pure alfalfa stands, this difference does not matter. However, this consideration is important for farmers that traditionally use companion crops. Companion crops can increase overall forage yield but decrease hay quality (McCordick et al. 2008).

3.0 Alfalfa Growing Regions

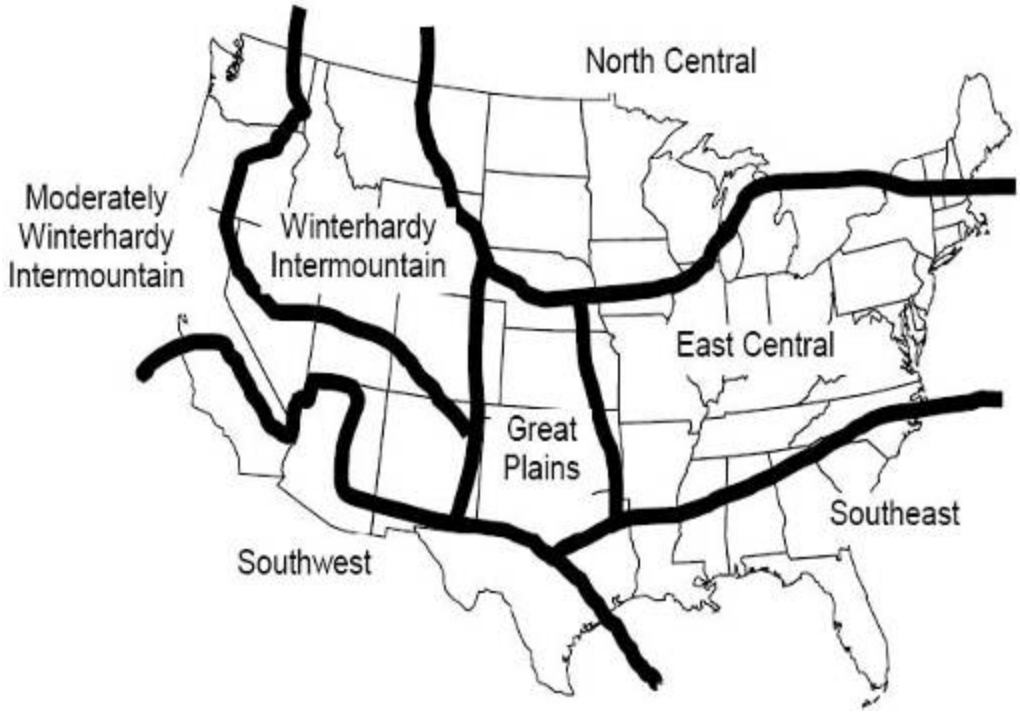

Figure G-1: Alfalfa growing regions (Reproduced from Rogan and Fitzpatrick 2004)

The National Alfalfa and Miscellaneous Legumes Variety Review Board and USDA Plant Variety Protection Office recognize seven growing regions in the United States (Figure G-1).

The National Alfalfa & Forage Alliance (NAFA) publishes a list of varieties and their corresponding rating for winter survival, fall dormancy, and susceptibility to various crop stresses (NAFA 2008). 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 might be specific to their farming situation (Orloff et al. 1997).

Table G-1. 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-2. 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 nondormant

Table G-3 presents the 2005 alfalfa harvest of each U.S. state. In 2005, 22,439,000 acres of dry hay alfalfa was harvested, and 204,380 (0.9%) of those acres were certified organic (USDA-ERS 2005b, USDA-NASS 2007a.). The number of acres harvested in a state does not indicate the quantity of the harvest. For example, as shown in table G-4, 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-3. 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

Table G-3. 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
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. A comparison of California and Wisconsin (table G-4) shows that in California ~97 percent of the farms irrigate, whereas in Wisconsin only 0.5 percent of the farms irrigate. Another difference is farm size. The average farm size in California is much larger than 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 might not include all alfalfa farms.

Table G4. 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

Table G4. 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
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

Table G4. 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
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 identify of individual farms

2.3 Summary of Findings

Alfalfa is grown for forage, grazing, seed production (forage and sprouts), human consumption, and facilitates honey production. The most acreage is for dry hay forage. Alfalfa is currently grown in organic farming, conventional farming, and glyphosate-tolerant systems. Organic farming does not allow synthetic pesticides or the use of crop varieties produced through genetic engineering. In addition to mechanical and cultural techniques, conventional farming allows for the use of 16 herbicides to control weeds in alfalfa. GT alfalfa allows for the application of glyphosate directly onto growing plants, which provides increased options for weed control over organic and conventional systems. In 2005, 22,439,000 acres of dry hay alfalfa were 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 might 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.

3.0 Glyphosate-Tolerant Alfalfa (Roundup Ready®)

When glyphosate-tolerant (GT) alfalfa was deregulated in 2005 and by 2006, an estimated 80,000 ha (~200,000 acres) were planted in the United States (Beckie and Owen 2007).[1] USDA APHIS lists all the counties in the United States where GT alfalfa has been planted (http://www.aosca.org/VarietyReviewBoards/Alfalfa/Alfalfa.html). GT alfalfa has been planted in 1,552 counties and 48 states. GT alfalfa is not cultivated in Alaska or Hawaii. In March of 2007, USDA published a notice in the Federal Register stating the reclassification of GT alfalfa as a regulated article. Shortly after, 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 gene flow between GT and non-GT alfalfa (Hubbard 2008).

3.1 Using GT Alfalfa

Recommended application of glyphosate to GT alfalfa is 0.75 to 1.5 pounds acid equivalent (AE) per acreat the three to five trifoliolate stage during stand establishment and up to five days before harvest in established stands (Dillehay and Curran 2006).

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. Earlier applications allowed for late germination of weeds, whilelater applications during the 6 to 9 trifoliate stage allowed weeds to compete with alfalfa. For example, in the intermountain region, applications before the 3 to 4 trifoliate stage resulted in invasion by prickly lettuces and henbit and required a second application. However, a second application of glyphosate may be required despite effectivenss of the first application. In San Joaquin Valley, where the timing of all glyphosate applications were effective early in the growing season, a second flush of bluegrass and canarygrass germinated in early December and required a second application of glyphosate for control. No other herbicide controlled this second flush of weeds effectively.

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 companion-seeded (alfalfa and oats). In both of these seeding regimes glyphosate, imazamox + crop oil concentrate (clear-seeded) or imazamox + clethodim + crop oil concentrate (companion-seeded), 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 in 2004. No alfalfa injury was observed due to glyphosate application in 2005. Clear seeded alfalfa treated with glyphosate yielded the highest alfalfa dry matter in both years, even though combined forage yield was higher in the untreated oat companion crop. When no herbicide was applied, the oat companion crop had lower weed biomass than clear seeded alfalfa in both years.

GT alfalfa is an option for weed control; however it might not be appropriate in the following situations (Dillehay and Curran 2006, Dillehay et al. 2009):

- Alfalfa-grass mixtures and alfalfa seeded with companion/nursery crops.
- Fields that have a history of low weed populations.
- Fields that are rotated between GT alfalfa and other GT crop varieties (e.g., Roundup Ready® soybean), although GT alfalfa can be rotated with other GT crop varieties after effective stand removal.

3.1.1 Stand Establishment

Forage alfalfa is typically planted in the spring in most of the U.S (Hower et al. 1999). 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 (Rogan and Fitzpatrick 2004). However, use of GT alfalfa also allows weed control during late-summer and fall establishment. Glyphosate can be used to prepare a field for alfalfa in the stand establishment year and also to mitigate areas of GT alfalfa fields that fail to establish following seeding, preventing the buildup of mature weed populations within field boundaries. Farmers can apply glyphosate early to weed patches within fields that have failed to establish followed with reseeding of GT alfalfa (Rogan and Fitzpatrick 2004).

Because of alfalfa polyploidy, any given seed lot may have off-type seed. Due to the polyploid genetics of alfalfa, 3 to 7 percent of the seedlings do not have the GT trait and will experience seedling mortality following early glyphosate application (Van Deynze et al. 2004). This termination of non-GT alfalfa nulls during the seedling stage is preferred, as later glyphosate application once non-GT nulls are established may cause gaps in the field where weeds can grow (Orloff et al. 2009).

3.1.2 Stand Removal

One of the management differences between conventional alfalfa and GT alfalfa occurs during stand removal. Whereas glyphosate can be included in herbicide mixtures used to kill old stands of conventional alfalfa for crop rotations, GT alfalfa has to be removed with tank mixtures that do not contain glyphosate. Application of an herbicide (e.g., 2,4-D, dicamba (Banvel®), or clopyralid (Stinger®)) and tillage is effective. In no-till systems 2,4-D and dicamba can be applied together. Dicamba, however, cannot be used before planting soybean (Dillehay and Curran 2006).

Figure G-2 shows Monsanto's guidance for GT alfalfa stand removal (Monsanto 2008).

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 G-2: Monsanto's guidance for GT alfalfa stand removal (Reproduced from Monsanto 2008)

3.2 Volunteer GT Alfalfa

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 might harbor insect and disease pests. For example, volunteer GT cotton in GT soybean can harbor boll weevil, a serious cotton pest. This is problematic, as boll weevil is not monitored in soybean (York 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
- Halsulfuron and dicamba
- Acetochlor

- Acetochlor and atrizine
- Acetochlor and atrizine and dicamba
- Atrizine and dicamba
- Clopyralid and flumetsulam

Monsanto demonstrated in their Deregulation Petition that a variety of herbicides and mixes on the above list can control volunteer GT alfalfa in no-till corn (Rogan and Fitzpatrick 2004). Clopyralid is effective at controlling volunteer alfalfa in broccoli (Tickes 2002). Clopyralid or 2,4-D provides control of volunteer alfalfa in different crops. Exceptions include potatoes, tomatoes, sudan grass, and popcorn (Rogan and Fitzpatrick 2004).

Control of volunteer herbicide–resistant crops has been reviewed by Beckie and Owen (2007). Herbicide–resistant soybean and cotton were reported to have lower potential for volunteer control issues, similar to conventional soybean and cotton, because both crops tend not to have weedy tendencies such as seed dormancy, ability to survive the winter, and high competitiveness. Alternatively, herbicide–resistant canola and corn, similar to conventional canola and corn, had a higher potential for volunteer control issues, because of lost seeds (shattering or ear drop) and competitiveness with the planted crop. While there might be additional costs associated with control of herbicide–resistant volunteers, there remain available and effective options for control. In fact, the cost to control volunteers likely has not had a significant impact on the adoption of herbicide–resistant crops, as volunteer management is done in conventional crops as well.

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 within the U.S.

Glyphosate, plus other herbicides and/or tillage, are the primary tools used to remove conventional alfalfa stands. Use of non-glyphosate herbicides for removal of GT alfalfa is a 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, 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, utilization of alfalfa in corn rotations benefited corn yield and suppressed weeds (Clay and Aguilar 1998). The effectiveness of alfalfa as a weed suppression tool depends on which weed species are present (Entz et al. 1999). 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 generally found that herbicide application resulted in increased protein and total digestible nutrients compared to untreated control plots. All herbicides successfully controlled down brome. However, efficacy of broadleaf weed control was dependent on the herbicide examined. Of the commonweeds in alfalfa listed by the University of California Pest Management Guidelines, six weeds are partially controlled by glyphosate: pepperweeds, goosegrass, field bindweed, yellow nutsedge, buckhorn plantain, and burning nettle. In an evaluation of perennial and biennial spring/summer weed susceptibility to herbicide control by Rogan and Fitzpatric (2004), field bindweed, yellow nutsedge, and buckhorn plantain were not fully controlled by glyphosate or any of the other herbicides tested.

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.

4.1 Glyphosate Resistance/Tolerance in Weeds

Herbicide resistance can be defined as the inherited ability of a weed population to survive and reproduce following an herbicide application that is normally lethal to the vast majority of individuals of that species (Stoltenberg and Jeschke 2003). Farmers are concerned about glyphosate-resistant weeds (Johnson and Gibson 2006). Figure G-3 represents the different weed populations in alfalfa. Since 1996, 20 new glyphosate-resistant weeds have been found globally. Eleven of these new glyphosate-resistant weeds are present in the United States. Eight of the new glyphosate-resistant weeds known globally are also known to be weeds in U.S. alfalfa stands (see appendix G-3 in this technical report for list of weeds in alfalfa). At least 20 weeds that have a natural tolerance to glyphosate exist. Ten of these glyphosate-tolerant weeds are known to be a problem in alfalfa. Table G-5 lists the weeds known to be glyphosate-resistant or -tolerant.

Note that the Weed Science Society of America (WSSA) official definitions for resistance and tolerance are as follows (WSSA 1998):

> Herbicide resistance: "Herbicide resistance is the inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type. In a plant, resistance might be naturally occurring or induced by such techniques as genetic engineering or selection of variants produced by tissue culture or mutagenesis."

Herbicide tolerance: "Herbicide tolerance is the inherent ability of a species to survive and reproduce after herbicide treatment. This implies that there was no selection or genetic manipulation to make the plant tolerant; it is naturally tolerant."

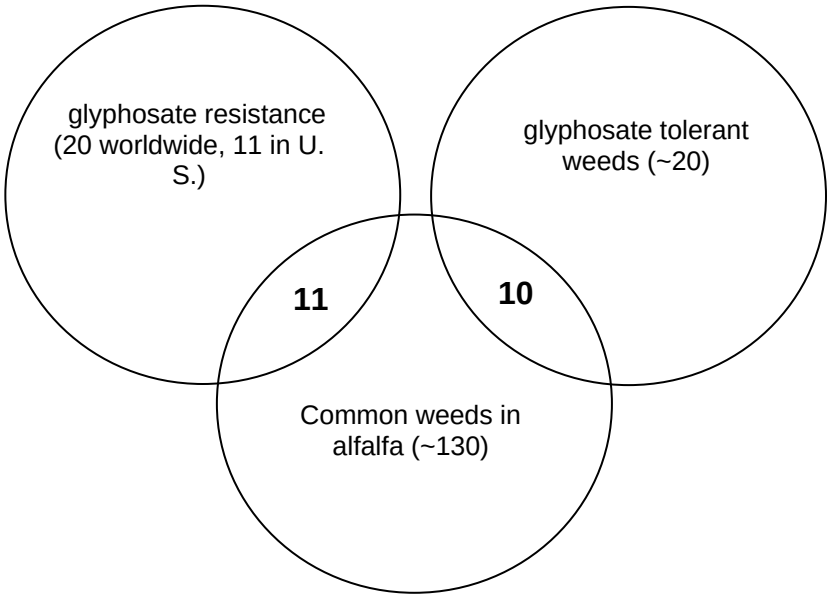

Figure G-3: Weeds in alfalfa

Table G-5. Glyphosate-resistant and -tolerant 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	*Ambrosia artemisiifolia*	Yes	Yes	Yes (with resistant biotype note)	Heap et al. 2010
Tall Waterhemp	*Amaranthus tuberculatus(syn. rudis)*	Yes	Yes	Yes (with resistant biotype note)	Heap et al. 2010, Nandula et al. 2005
Giant Ragweed	*Ambrosia trifida*	Yes	No	Yes (with resistant biotype note)	Heap et al. 2010
Hairy Fleabane	*Conyza bonariensis*	Yes	No	Yes	Heap et al. 2010, Nandula et al. 2005
Horseweed	*Conyza canadensis*	Yes	Yes	Yes (with resistant biotype note)	Heap et al. 2010, Nandula et al. 2005
Italian Ryegrass	*Lolium multiflorum*	Yes	Yes	Yes (with resistant biotype note)	Heap et al. 2010, Nandula et al. 2005
Perennial Ryegrass	*Lolium perenne*	No	Yes	Yes	Heap et al 2010
Johnsongrass	*Sorghum halepense*	Yes	Yes	Yes (mixture also recommended)	Heap et al. 2010
Palmer Amaranth	*Amaranthus palmeri*	Yes	Yes	No	Heap et al. 2010
Rigid Ryegrass	*Lolium rigidum*	Yes	No	No	Heap et al. 2010, Nandula et al. 2005 Yu et al. 2007
Buckhorn Plantain*	*Plantago lanceolata*	No	Yes	No	Heap et al. 2010
Goosegrass	*Eleusine indica*	No	Yes	Yes	Heap et al. 2010, Nandula et al. 2005
Junglerice	*Echinochloa colona*	No	Yes	Yes (mixture also recommended)	Heap et al. 2010
Sourgrass	*Digitaria insularis*	No	No	No	Heap et al. 2010
Wild Poinsettia	*Euphorbia heterophylla*	No	No	No	Heap et al. 2010
Kochia	*Kochia scoparia*	Yes	Yes	Yes	Heap et al. 2010
Sumatran fleabane	*Conyza sumatrensis*	No	No	No	Heap et al. 2010
Ragweed Parthenium	*Parthenium hysterophorus*	No	No	No	Heap et al. 2010
Annual bluegrass	*Poa annua*	Yes	Yes	Yes	Heap et al. 2010

Table G-5. Glyphosate-resistant and -tolerant weeds

Common Name	Scientific Name	Resistant Biotype Reported in U.S.	Identified Problem in Alfalfa (appendix G-3)	Listed on Roundup® Label	Source
Liverseedgrass	*Urochloa panicoides*	No	No	No	Heap et al. 2010
Historically Naturally Tolerant					
Asiatic dayflower	*Commelina communis*		No	No	Nandula et al. 2005
Birdsfoot trefoil	*Lotus corniculatus*		No	No	Nandula et al. 2005
Bermudagrass	*Cynodon dactylon*		Yes	Yes (partial control notes)	Cerdeira and Duke 2006
Burning nettle	*Urtica uren*		Yes	No (mixture recommended)	Van Deynze et al. 2004, Canevari et al. 2004
Cheeseweed	*Malva parviflora*		Yes	No (mixture recommended)	Van Deynze et al. 2004
Chinese foldwig	*Dicliptera chinensis*		No	No	Nandula et al. 2005
Common lambsquarters	*Chenopodium album*		Yes	Yes (mixture also recommended)	Nandula et al. 2005
Field bindweed*	*Convolvulus arvensis*		Yes	No (mixture recommended)	Nandula et al. 2005
Filaree	*Erodium* spp.		Yes	Yes (mixture also recommended)	Van Deynze et al. 2004
Florida pellitory	*Parietara debilis*		No	No	Cerdeira and Duke 2006
Hemp sesbania	*Sesbania exalta*		No	Yes	Cerdeira and Duke 2006
Large crabgrass	*Digitaria sanguinalis*		Yes	Yes (mixture also recommended)	Cerdeira and Duke 2006
Morning glory	*Ipomoea purpurea*		Yes	Yes (mixture also recommended)	Hilgenfeld et al. (2004, Cerdeira and Duke 2006
Nutsedge*	*Cyperus* spp.		Yes	Yes	Cerdeira and Duke 2006
Oval-leaf false buttonweed	*Spermacoce latifolia*		No	No	Cerdeira and Duke 2006
pillpod sandmat	*Chamaesyce hirta*		No	No	Cerdeira and Duke 2006
Purslane	*Portulaca oleracea*		Yes	Yes (mixture also recommended)	Van Deynze et al. 2004
Tropical Mexican clover	*Richardia brasiliensis*		No	No	Cerdeira and Duke 2006
Tropical spiderwort	*Commelina benghalensis*		No	No	Nandula et al. 2005
Velvet leaf	*Abutilon theophrasti*		No	Yes (mixture also recommended)	Nandula et al. 2005

Eleven weeds with newly identified resistance and found in the U.S., and ten weeds known to have some natural tolerance to glyphosate and are found as weeds in alfalfa fields are briefly described below.

4.1.1 New Glyphosate-Resistant Weeds since 1998

Common ragweed, horseweed, Italian ryegrass, perennial ryegrass, Johnsongrass, Palmer Amaranth, tall waterhemp, buckhorn plantain, goosegrass, junglerice, and kochia are weeds found commonly in alafalfa. Glyphosate-resistant biotypes of these eleven weeds have recently been identified. There is no evidence, however, that the glyphosate-resistant biotypes are common in alfalfa. Each is briefly discussed below.

Common ragweed (*Ambrosia artemisiifolia*) begins germinating in May, flowers in August to September, and sets seed August through 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 elements, 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, Undated a). Common ragweed has a biotype that has multiple herbicide resistance to acetolactate synthase (ALS) inhibitors and PPO inhibitors (Heap et al. 2010).

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 (up to 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). Viable horseweed seeds have been found (0.0017 seeds per square meter) at altitudes of 140 meters, which is high enough to be considered the planetary boundary layer. Based on settlement velocity and wind speeds is it likely that during a single flight a seed can travel 550 kilometers (Shields et al. 2006). Seeds are able to germinate in no-till fields (undisturbed soil, includes noncrop 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 Undated, 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 might cause mucosal and skin irritation in livestock (especially horses) and humans (Steckel, Undated 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 can result in situations where it 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. 2010). Multiple herbicides may be required to control glyphosate-resistant horseweed during burndown prior to seeding, as demonstrated in GT soybean (Eubank et al. 2008). Over 500,000 acres in the Midwest are reported to be infested with glyphosate-resistant horseweed (Cline 2004).

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 might out-compete 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. 2010).

Perennial Ryegrass (*Lolium perenne)* is a perennial grass used in some pasture mixes as well as in residential lawns. It is a weed in alfalfa in the moderate intermountain region of the United States. Glyphosate-resistant biotypes were identified in 2008 in Argentina (Heap et al 2010). In Germany, a biotype that is resistant to both ALS inhibitors and acetyl-CoA carboxylase (ACCase) inhibitors has been identified (Heap et al 2010).

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. If herbicides are not used it can be controlled by intense grazing and mowing for two years until the rhizomes are depleted (CDFA Undated a, Lanini Undated b). There are separate biotypes of Johnsongrass that have resistance to ACCase inhibitors, dinitroanilines, and ALS inhibitors (Heap et al. 2010).

Palmer amaranth (*Amaranthus palmeri*) is closely related to waterhemp and is the dominant pigweed in the Southwest. It is susceptible to herbicides when it is 4 to 8 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. 2010).

Tall waterhemp (*Amaranthus tuberculatus (syn. rudis))* is a major annual dicot weed in agricultural fields. It has a long germination window, making it difficult to control with herbicides. Plants grow rapidly and produce many seeds. Biotypes of tall waterhemp have been identified with resistance to photosystem II inhibitors, PPO inhibitors, and ALS inhibitors (Heap et al. 2010).

Buckhorn Plantain (*Plantago lanceotata*) competes with crops for soil nutrients, water, and light and does well in droughts. It reproduces by seed and by taproot. 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. 2010).

Goosegrass (*Eleusine indica*) is an annual grass with an extensive root system that can produce 50,000 seeds per plant (Duble Undated). It is one of the five most troublesome weeds world-wide. 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 Undated 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 resistances to ACCase inhibitors and glyphosate was found (Heap et al. 2010).

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 Undated). 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. 2010).

Kochia (*Kochia scoparia)* is an annual plant that forms a long tap root, allowing it to tolerate drought. It is an important weed in alfalfa. Kochia plants form a tumbleweed when mature, allowing rapid spread of seeds. Under some conditions it can accumulate toxic oxalate concentrations (Agricultural Knowledge Centre 2007). With proper management, kochia may be used as a feed. Depending on the stage of maturity, kochia may be fed in cattle diets for up to 40 percent of the diet if the kochia was baled at later stages of maturity. If kochia was baled at an earlier maturity stage, beef recommendations suggest feeding at up to 30 percent of the diet (Agricultural Knowledge Centre 2007). In 2007, glyphosate-resistant biotypes were identified in Kansas in corn and soybean fields (Heap et al. 2010).

4.1.2 Glyphosate-Tolerant Weeds Found in Alfalfa

Ten weeds that are common in alfalfa and have natural tolerance for glyphosate[1] 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).

[1] Tolerance was not gained through herbicide pressures.

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). In Australia, a biotype resistant to photosystem II inhibitors has been identified (Heap et al. 2010).

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 Undated). It is very competitive in alfalfa and, once established, is difficult to control. The fatty acids malvalic acid and sterculic acid might cause the plant to be toxic to horse, cattle, and sheep (Canevari 1997). Nitrate concentration has also been cited as the cause of toxicity (, USU Undated,).

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 Undated c). Biotypes that are resistant to photosystem II inhibitors and ALS inhibitors have been identified in the United States (Heap et al. 2010).
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 binweed 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 Undated 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 wasteplaces. 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 Undated). 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. 2010).

Morning glory (*Ipomoea purpurea*) is a perennial climbing vine that reproduces by seed (Pittwater Council Undated). It is a problem in crops because of competition. Morning glory seeds are toxic to humans (Filmer Undated). Morning glory foliage is toxic to livestock due to nitrates. Symptoms of acute nitrate poisoning are trembling, staggering, rapid breathing, and death. Chronic poisoning could 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, glyphosate does not translocate to the tuber, and, therefore, does not effectively control growth (Wilen 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 when compared to continuously grown cotton 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. 2010).

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 Resistance or Tolerance

Glyphosate inhibits 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), 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 including target site mutations (mutations in EPSPS) and non-target site mutations (Cerdeira and Duke 2006, Stoltenberg and Jeschke Undated, Nandula et al. 2005, Gaines et al. 2010, Yuan et al. 2010, Funke et al. 2006, Yuan et al, 2006, Service 2007):

Resistant EPSP synthase - A version of EPSPS that is not affected by glyphosate has been found in *Agrobacterium tumefaciens* and has been transferred into crop plant genomes. Also, the maize version of EPSPS has been modified by site directed mutagenesis to be resistant to glyphosate.

Increased copy number of EPSP gene - Glyphosate-resistant populations of *Amaranthus palmeri* found in Georgia were found to have 5 to 160 fold more copies of the *EPSPS* gene in their genomes compared to glyphosate sensitive populations. Furthermore, the extra copies were found to be distributed among all the chromosomes, suggesting a transposon mediated amplification. The resulting overexpression of EPSPS likely confers resistance to glyphosate (Gaines et al. 2010, Powles, 2010).

Degrade glyphosate - A glyphosate-degrading enzyme has been found in bacteria (*Ochrobactrum anathropi*) and has been transferred into crop plant genomes (Yong-Sheng et al. 2010).

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 (Castle et al. 2004).

Subcellular sequestration – Glyphosate-resistant horseweed has been shown to exhibit vacuolar sequestration. By compartmentalizing glyphosate away from the cyptoplasm, plant cells can keep glyphosate from coming in contact with EPSP synthase (Ge et al. 2009)

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. Similar molecular mechanisms might exist for nontarget herbicide resistance across multiple resistant plants from different locations, even though resistance among these resistant plants likely evolved independently and available evidence suggests resistance has evolved at least four separate times (Yuan et al. 2010).

4.2 Weed Shifts and Development of Resistant Weeds in GT Alfalfa

Development of weed resistance is a phenotypic change (based on a genotypic change) in a population of weeds that was previously susceptible to an herbicide. Weeds shifts occur when the local population of weeds changes due to the changing pressures of differing management strategies. Shifts in weed species composition from highly susceptible toward more tolerant species will happen more rapidly than selection of resistance (Shaner 2000).

The evolution of weed resistance can be the result of continued herbicide application which applies selection pressure on the weed population (Orloff et al. 2009, Johnson et al. 2009, Neve et al. 2007). Weed resistance is primarily a result of management practices not the crop itself. The plant GT trait does not exert selection pressure on weeds directly. So the plant itself does not influence weed resistance development, but rather the agricultural practices associated with weed control during cultivation of the plant exerts selection pressure on weeds (Owen 2008, Boerboom and Owen 2007). Weed resistance is less common than weeds shifts. Gylphosate has a lower level of rate of resistance development compared to other chemicals, considering the widespread use of glyphosate. This hasn't been fully explained but might be due to the number or frequency of mutations that might be required to confer resistance (Orloff et al. 2009). The relative risk of weed resistance development is highly correlated to the herbicide mode of action (Sammons et al. 2007).

Weeds have a large amount of genetic diversity that allows them to adapt under a wide range of conditions (Prather 2000). Resistance problems usually go undetected until about 30 percent of the weed control failure is observed for a particular species (Prather 2000). Gene flow through pollen or seed movement from herbicide resistant populations can provide a source of herbicide resistant alleles in non-herbicide resistant populations or fields, though this is less likely than evolved resistance (Beckie 2006). In addition, weed biotypes shift in time to avoid herbicides.

Neve (2008) used a simulation model to explore the influence of biological, ecological, genetic and operational (management) factors on the probability and rate of glyphosate resistance in model weed species. The results indicated that glyphosate use for weed control prior to crop emergence is associated with low risks of resistance. These low risks can be further reduced by applying glyphosate in sequence with other broad-spectrum herbicides prior to crop seeding.

Legleiter and Bradley (2009) conducted field experiments in corn to evaluate the influence of herbicide treatments on glyphosate resistant waterhemp. Pre-emergence (PRE), preemergence followed by post-emergence (PRE fb POST), and post-emergence-only (POST-only) herbicide experimental programs were evaluated for use in conventional, glyphosate-resistant, or

glufosinate-resistant corn hybrids. All programs containing a PRE herbicide, conventional POST herbicide, or glufosinate resulted in greater than 98 percent control of glyphosate-resistant waterhemp and reduced seed production by at least 99 percent. Waterhemp densities were also reduced by programs that contained a PRE herbicide, conventional POST herbicide, or glufosinate. The highest waterhemp density and poorest control occurred with a sequential glyphosate program.

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). A change 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, field trial studies comparing the GT weed management system to conventional control strategies in San Joaquin Valley, CA, demonstrated that ineffective control of burning nettle with glyphosate can lead to significant increases in the population of this weed over a three-year period in GT alfalfa (Van Deynze et al. 2004). This shift in burning nettle abundance is not surprising, as burning nettle is not listed on the Roundup label and is thus not effectively controlled. Other weeds that are difficult to control with glyphosate, such as dodder and cheeseweed, might need to be treated early and require a second application (Van Deynze et al. 2004). 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 nonherbicide 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. Changes in weed species diversity and richness was primarily due to species substitution, where glyphosate use lead to a rapid reduction of early emerging weed species increase of late emerging broad leaved species across the all field trials. This general trend was observed regardless of rotation sequence or tillage sytem. 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.

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 might be restricted by glyphosate more than the wild buckwheat biomass. Therefore after glyphosate application the plant might 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 21 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. In the absence of herbicide application, the weed populations slowly return to pre-glyphosate composition, but the new species that shifted into the field or the resistant biotypes would not disappear (Orloff et al. 2009).

Attributes of alfalfa that discourage weed shifts include the competitiveness of the crop after establishment, frequent cutting, lack of soil disturbance reduces opportunities for germination of some weed species and the interval between cuttings is short enough that seed production is reduced compared to annual crops that allow completion of the weeds' life cycle (Orloff et al. 2009).

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
  - Alternating herbicides with different modes of action
  - Tank mixing herbicides
  - Sequences of herbicides
  - Application timing (e.g., apply at a more sensitive lifestage)
- Cultural
  - Rotation between GT cultivars and non-GT cultivars
  - Rotation to nonalfalfa crops (e.g., grains)
  - Rotation to crops having tolerance to a different mode of herbicide action
  - Spot burning
  - Flood irrigation
  - 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
  - Mowing (harvesting)
  - Hand weeding

- Mechanical
- Tillage cultivation

As discussed above, there are two different causes for herbicide related weed shifts: weed shifts caused by herbicide resistance and weed shifts caused by repeated use of an herbicide below the recommended rate or at less susceptible plant growth stage for a particular herbicide. In the former case, the above list is applicable. In the latter case, there is also the option to address the issue by using the recommended rate at the recommended times and growth stages. It is not unusual for individual weeds to respond differently to 'low' rates of any herbicide. Label rates are developed to provide the most consistent control over many locations and years. The maximum allowed labeled rate for a single application is 1.55 lb ae glyphosate per acre per application (44 oz of Roundup WeatherMax). The total amount allowed in alfalfa per year by EPA is 4.6 lb ae per acre, allowing for multiple applications per year. At 44 oz per acre, annual weeds listed on the Roundup WeatherMax label can be controlled when applications are made at the appropriate growth stage. For labeled perennial weeds, a single or sequential application of 44 oz per acre would provide suppression (burndown or reduced growth) and control of species such as johnsongrass, quackgrass, perennial ryegrass, and wirestem muhly, which are present in many alfalfa growing areas. Glyphosate will also provide suppression or control of dodder, with repeat applications being needed for complete control. For perennial weeds that cannot be effectively controlled with a single or multiple applications of glyphosate at 1.55 lb ae per acre per application (following label recommendations) or if the glyphosate applications need to be made at sub-optimal timings, it is possible that certain weed populations could shift over time. However, there are published recommendations to tank mix glyphosate with other herbicides for management of these situations. Additionally, growers have an option to apply glyphosate before stand establishment where higher rates and application timing can be optimized for better control.

Monsanto's Technology/Stewardship Agreement (MTA) requires growers to follow the applicable provisions in the Monsanto Technology Use Guide (TUG), which includes Monsanto's weed resistance management stewardship program for GT alfalfa (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 per acre 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.

Monsanto's stewardship program to address potential weed resistance is consistent with guidance developed by EPA, as part of that agency's regulation of pesticides, including herbicides such as glyphosate, under the authority of FIFRA. EPA encourages pesticide manufacturers to provide growers with information regarding an herbicide's mode of action to aid growers in planning herbicide use practices and to foster the adoption of effective weed-resistance management practices (U.S. EPA 2001). The EPA pesticide resistance guidance

provides labeling guidelines by which a pesticide registrant can alert users to steps they can take to delay pesticide resistance.

Herbicide-resistance management education and training programs directed at growers and retailers/dealers, are also an important component of any resistance management program (Boerboom and Owen 2007). State alfalfa agronomists and weed scientists, along with weed scientists focused on other crops, have active education and training programs to alert growers to the risk of weed resistance to any herbicide. These programs provide weed management options to prevent or delay the onset of herbicide resistance and for remediation when resistance populations already exist.

Outreach and education to farmers is crucial because surveys have demonstrated that 92 precent of corn, soybean and cotton farmers in the United States are very confident or somewhat confident that industry will deliver new technologies of products in the next 3 to 5 years to manage glyphosate problems (Foresman and Glasgow 2008). During the time glyphosate resistant crops have been on the market, the herbicide industry has declined by about $1 billion (20 percent), causing herbicide companies to back out of the shrinking market (Service 2007). However researchers from the University of Nebraska have developed genetically engineered soybean that are resistance to dicamba and Monsanto has licensed the technology (Behrens et al. 2007). In another United State's survey, 30 percent of corn, soybean, and cotton farmers thought glyphosate resistant weeds were, or, could become a serious problem and a majority of survey respondents thought that following the glyphosate label rate recommendation was the most effective strategy for reducing or preventing glyphosate resistant weeds. Very few thought that tillage and rotating to a non-GT crop would be effective strategies (Johnson et al. 2009).

Recommended best management practices to control against weed resistance include : a) identifying weeds and monitoring for escapes to determine if current practices need to be modified to achieve acceptable levels of weed control, b) using proper herbicide rates and timing, c) using crop rotation to facilitate use of different modes of action over time, d) using agronomic management practices to supplement herbicide weed control, e) alternating herbicides with different modes of action, and e) tank mixing herbicides of different modes of action (HRAC 2010, Orloff et al 2009, Monsanto 2010). Although the perception is that glyphosate-resistant weed control is simplistic, in practice a weed control strategy should be tailored to the situation. The complexity of the strategy increases if multiple weed pressures exist (Boerboom and Owen 2007). In 2007 a group of 50 weed experts convened the National Glyphosate Stewardship Forum II: A Call to Action which discussed the following proposed actions (Boerboom and Owen 2007):

- Stewardship statements on all glyphosate labels.
- Grower agreements/education upon seed purchase.
- Stewardship compliance requirements in licensing agreements to seed companies to support above action.
- Industry programs for grower rebate of trait cost if glyphosate-resistance trait is not used.
- Industry only warranties for glyphosate performance when stewardship plan is in effect.
- Defined goal (i.e. level of adoption) of glyphosate stewardship and time for this goal to be reached.

Alfalfa hay harvesting usually takes place in the form of repeated mowing. This practice is effective in retarding weeds from setting seed, especially broadleaf weeds, because the growing point is at the top of the plant, which will be removed by mowing. Retarding or preventing a plant from setting seed will reduce the opportunity for weed species to flower, minimizing weed multiplication opportunities. Also because alfalfa is a perennial crop (a single stand can typically last 3 to 7 years) the selection of a glyphosate-only versus a multiple-herbicide program depends on the growth stage of the crop. For example, glyphosate offers significant crop safety advantages at seeding of GT alfalfa (Canevari et al. 2004). In contrast, after stand establishment, growers might be more inclined to use a soil residual herbicide, since glyphosate does not have soil residual activity. The use of a soil residual product will reduce the total number of post-emergence herbicide applications. This would translate into a natural alternation of herbicides, which is a practice recommended to reduce the selection pressure on glyphosate or any other herbicide.

Orloff et al. (2009) provides a state-of-the-art guide to control of weeds in GT alfalfa. Table G-6 adapted from Orloff et al. (2009) is an example of the rotational herbicide strategy, which is recommended. The frequency of herbicide rotation depends on the weed species and escapes. Diligent monitoring for weed escapes it essential for planning herbicide rotations. The key for reducing selection pressure is to not rely on repeated applications of glyphosate year after year, application after application (Orloff et al. 2009).

Table G-6. Comparison of weed management strategies for GT alfalfa (adapted from Orloff et al. 2009).

Year	Objective	Season	Continuous glyphosate strategy	Rotational herbicide strategy
Seeding	Control weeds that compete during stand establishment	Fall	Glyphosate	Glyphosate
1	Control late-emerging weeds during establishment	Winter (late)	Glyphosate	Glyphosate*
	Summer annual weed control might not be needed the first year	Spring		
		Summer		
		Fall		
2	Control winter annual weeds and/or pre-emergence control of summer weeds	Winter	Glyphosate	Soil residual herbicide or tank mix* of soil residual herbicide with glyphosate**
	Summer annual weed control/dodder	Spring		
		Summer	Glyphosate	
		Fall		
3	Control winter annual weeds and/or pre-emergence control of summer weeds	Winter	Glyphosate	Soil residual herbicide or tank mix* of soil residual herbicide with glyphosate**
	Control of summer annual grassy weeds/dodder	Spring	Glyphosate	
		Summer	Glyphosate	
		Fall		
4	Control winter annual weeds	Winter	Glyphosate	Glyphosate
	Control summer annual grassy weeds/dodder	Spring	Glyphosate	
		Summer (mid)	Glyphosate	Glyphosate
	Stand take out	Fall (late)	Tillage and/or 2,4-D + dicamba as necessary	Tillage and/or 2,4-D + dicamba as necessary
4 years	**Total number of glyphosate applications**		**10**	**4-6**
	Total number of other herbicide applications (tank mix or not)		**Mix at stand take out**	**2 plus mix at stand stake out**

Note: A combination of soil residual herbicides and different modes of action is recommended to prevent weed shifts and herbicide resistance. These are examples only – appropriate strategies should be modified for different regions and weed pressures.
* Tank mixing with another herbicide is advised if significant populations of glyphosate-tolerant weeds such as burning nettle are present.
** Soil residual herbicide (depending on location and weed spectrum, use hexazinone, diuron or metribuzin) for pre-emergence control of winter annual weeds. An application of a dinitroaniline herbicide (pendimthalin or trifluralin) applied at this time will control summer annual grassy weeds.

Industry acknowledges that weed resistance is a problem, but also offers solutions. For example. Chuck Foresman, manager of weed resistance strategies for Syngenta said "Syngenta estimates that more than 7 million row crop acres were infested with glyphosate-resistant weeds last year [2008]. With an expected 40 percent average compounded annual growth rate, we estimate that more than 38 million row crop acres could be infested with glyphosate-resistant weeds by 2013, or one in every four acres."

Syngenta hosts www.resistancefighter.com, a resource for resistance management information, expert recommendations, and solutions. The site features:

- The Solution Builder, which creates practical, solutions customized by crop, weed, location, preferred management practices and history of resistance to fight glyphosate-resistant weeds based on answers to a few simple questions
- Answers to common glyphosate resistance questions
- University research and information
- Crop strategies to build a resistance management program
- The opportunity to join the conversation about glyphosate weed resistance, including the blog from Syngenta experts, articles and radio broadcast clips

Syngenta also recommends a proactive, integrated weed management program that includes alternating modes of action and using a residual pre-emergence herbicide as the best strategy.

For cotton, the current recommendations for managing glyphosate-resistant Palmer amaranth in Georgia includes PRE mixtures of fomesafen, pyrithiobac, and pendimethalin followed by glyphosate and metolachlor POST, followed by a lay-by directed application of MSMA and diuron, for a total of seven different herbicide modes of action (Webster and Sosnoskie 2010).

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.

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. Sometimes, however, 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).

There is some concern that dependence on herbicides causes knowledge of other weed management strategies to be lost. A case study shows that "Argentinean farmers were deskilled, becoming weed "illiterates" as they forgot early attempts to integrate pest management" (Binimelis et al. 2009).

4.3 Distribution of Glyphosate-Resistant or -Tolerant Weeds

Table G-7 shows that currently 24 U.S. states are affected by glyphosate-resistant weeds. Most new glyphosate-resistant weeds are located in the Midwest. The overlap with the major alfalfa producing states in the Intermountain regions seems to be minimal at this point (table G-8). However, given that there is overlap between glyphosate-resistant weed locations and alfalfa hay acreage, there is potential for 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. More detailed records of local weed infestations might be kept by State extension offices.

Table G-7. Glyphosate-Resistant Weed Infestations by State (Heap et al. 2010)

State	Weed species	~ Number of Sites in State Infested	~ Number of Acres in State Infested	Situation	Year Reported
Alabama	***Amaranthus palmeri*** Palmer Amaranth	1 increasing	51-100 increasing	Soybean	2008
Arkansas	***Conyza canadensis*** Horseweed	6-10 increasing	1,001-10,000 increasing	Cotton	2003
	Ambrosia artemisiifolia Common Ragweed	1	11-50	Soybean	2004
	Ambrosia trifida Giant Ragweed	6-10 increasing	101-500 increasing	Soybean	2005
	Amaranthus palmeri Palmer Amaranth	1,001- 10,000 increasing	100,001-1,000,000	Soybean	2006
	Sorghum halepense Johnsongrass	1	unknown	Soybean	2007
	Lolium multiflorum Italian Ryegrass	11-50 increasing	1,001-10,000 increasing	Wheat	2008
California	***Lolium rigidum*** Rigid Ryegrass	11-50 increasing	1,001-10,000 increasing	Almonds	1998
	Conyza canadensis Horseweed	1	unknown	Roadside	2005
	Conyza bonariensis Hairy Fleabane	2-5	unknown	Roadside	2007
	Conyza bonariensis Hairy Fleabane*	2-5	unknown	Roadsides Vineyards	2009
Delaware	***Conyza canadensis*** Horseweed	101-500	10,001-100,000	Soybean	2000
Georgia	***Amaranthus palmeri*** Palmer Amaranth	10,001-100,000 increasing	1-2 million increasing	Cotton Soybean	2005
	Amaranthus palmeri Palmer Amaranth*	101-500 increasing	1,001-10,000 increasing	Soybean	2009
Illinois	***Conyza canadensis*** Horseweed	1,001-10,000 increasing	100,001-1,000,000 increasing	Soybean	2005
	Amaranthus rudis Common Waterhemp*	1 increasing	51-100 increasing	Corn Soybean	2006
Indiana	***Conyza canadensis*** Horseweed	2-5 increasing	101-500 increasing	Soybean	2002
	Ambrosia trifida Giant Ragweed	1 increasing	11-50 increasing	Soybean	2005
Iowa	***Amaranthus rudis*** Common Waterhemp	2-5	Unknown	Corn Soybean	2009
	Ambrosia trifida Giant Ragweed	6-10	unknown	Corn Soybean	2009
Kansas	***Conyza canadensis*** Horseweed	51-100 increasing	10,001-100,000 increasing	Cotton Soybean	2005
	Ambrosia trifida Giant Ragweed	2-5 increasing	501-1,000 increasing	Soybean	2006
	Amaranthus rudis Common Waterhemp	2-5 increasing	101-500 increasing	Soybean	2006

Table G-7. Glyphosate-Resistant Weed Infestations by State (Heap et al. 2010)

State	Weed species	~ Number of Sites in State Infested	~ Number of Acres in State Infested	Situation	Year Reported
	Kochia scoparia Kochia	2-5	51-100	Corn Soybean	2007
	Kochia scoparia Kochia	1	11-50	Cotton	2007
	Ambrosia artemisiifolia Common Ragweed	1 increasing	11-50 increasing	Soybean	2007
Kentucky	***Conyza canadensis*** Horseweed	2-5 increasing	51-100 increasing	Soybean	2001
Louisiana	***Amaranthus palmeri*** Palmer Amaranth	1 increasing	101-500 increasing	Cotton	2010
Maryland	***Conyza canadensis*** Horseweed	6-10 increasing	501-1,000 increasing	Soybean	2002
Michigan	***Conyza canadensis*** 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
	Conyza canadensis Horseweed*	1	11-50 increasing	Cropland	2007
	Lolium multiflorum Italian Ryegrass	Unknown	1,001-10,000 increasing	Cotton Soybean	2005
	Amaranthus palmeri Palmer Amaranth*	Unknown	Unknown	Cropland	2008
	Amaranthus rudis Common Waterhemp	2-5 increasing	101-500 increasing	Soybean	2010
Missouri	***Conyza canadensis*** Horseweed	101-500 increasing	10,001-100,000 increasing	Cotton	2002
	Ambrosia artemisiifolia Common Ragweed	2-5	51-100	Soybean	2004
	Amaranthus rudis Common Waterhemp*	101-500 increasing	100,001-1,000,000 increasing	Corn Soybean	2005
	Amaranthus palmeri Palmer Amaranth	6-10 increasing	1,001-10,000 Increasing	Cotton Soybean	2008
	Poa annua Annual Bluegrass	1 increasing	6-10 increasing	Turf	2010
Nebraska	***Conyza canadensis*** Horseweed	51-100 increasing	1,001-10,000 increasing	Soybean	2006
New Jersey	***Conyza canadensis*** Horseweed	6-10 increasing	101-500 increasing	Soybean	2002
New Mexico	***Amaranthus palmeri*** Palmer Amaranth	2-5 increasing	51-100 increasing	Orchards	2007
North Carolina	***Conyza canadensis*** Horseweed	2-5 increasing	6-10 increasing	Cotton	2003
Ohio	***Amaranthus palmeri*** Palmer Amaranth	unknown	100,001-1,000,000 increasing	Corn Cotton Soybean	2005

Table G-7. Glyphosate-Resistant Weed Infestations by State (Heap et al. 2010)

State	Weed species	~ Number of Sites in State Infested	~ Number of Acres in State Infested	Situation	Year Reported
	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
	Ambrosia trifida Giant Ragweed*	1	101-500	Soybean	2006
	Ambrosia artemisiifolia Common Ragweed	1	501-1,000	Soybean	2006
Oregon	***Lolium multiflorum*** Italian Ryegrass	1	1-5	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	1,001-10,000 increasing	100,001-1,000,000 increasing	Corn Cotton Soybean	2006
	Ambrosia trifida Giant Ragweed	101-500 increasing	1,001-10,000 increasing	Cotton Soybean	2007

* multiple herbicide resistance biotypes.

4.4 Summary of Findings

At least 129 different weed species are identified as minor or major problems in alfalfa. Out of 20 new glyphosate-resistant weeds found since 1998, eleven are known to be weeds in alfalfa. Out of at least 20 weeds that have natural tolerance to glyphosate, ten are known to be a problem in alfalfa. These 21 weeds that are both resistant to glyphosate and traditionally listed as problems in alfalfa include: common ragweed, horseweed, Italian ryegrass, perennial ryegrass, Johnsongrass, Palmer Amaranth, tall waterhemp, buckhorn plantain, goosegrass, junglerice, kochia, 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 21 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, increased copy number of the EPSP gene, 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 and the benefits of tank mixing with 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 nonagricultural ecosystems (former title: Increase in RR resistant weeds in noncrop 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 tolerant*
Glyphosate resistant*
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 wasin the early bud stage (UNCUT) or had been cut 3 to 4 d earlier and baledfor hay (CUT). *Alfalfa* control and corn yield were measured in nontreatedplots 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 toCUT *alfalfa*. Glyphosate plus dicamba applied AP controlled *alfalfa*better than the other AP treatments resulting in increased corn yield compared with other AP...Post-emergence applications of glyphosate alone ortank-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 percent 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
wide row planting systems were investigated in 1997 and...
 ...pest and beneficial insects. Populations of adult bean leaf beetle,Cerotoma trifurcata (Forster), and
threecornered *alfalfa* hopper,Spissistilus festinus (Say), and larvae of green cloverworm, Hypenascabra (F.),
and velvetbean caterpillar, Anticarsia gemmatalis (Hubner),were not affected by genetically altered *Roundup*
Ready soybean or byapplications 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
{threecornered *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. gemmatalis were not reducedin genetically altered *Roundup*
Ready soybean, or by recommended (bylabel) or delayed applications of glyphosate. Numbers of G.

punctipesalso were not reduced in *Roundup* *Ready* soybean, but were reduced byrecommended applications of glyphosate during weeks three and four
following.....been indirectly reduced by glyphosate within sample weeks two
and threebecause of variations in *weed* densities after treatment with the
herbicide.
...ORGANISMS: Spissistilus festinus {*alfalfa* hopper} (Homoptera.....oil crop, *Roundup* *Ready* line...
Roundup *Ready* productionsystems.....*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 troublesomeannual and perennial *weeds* , and new cultivars that are tolerant of glyphosate application have been developed. The crop response of glyphosateon these new varieties has not been reported. This research examined*alfalfa* tolerance under field conditions, and high rates were used tochallenge 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 yearor in the subsequent two...of 9 lb a.e./acre over a 3-year period caused noreduction in *alfalfa* yield or nutritive value at any cutting in any of thethree 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: Glyphosare-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. Seedingmethods included clear seeding and companion seeding with oats. Herbicidetreatments 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 imazarnox + clethodim. In 2004, total seasonal forageyield, which consisted of *alfalfa*, *weeds*, and oats (in sometreatments), 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 totalseasonal forage production. *Alfalfa* established with the clear-seededmethod 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 wasapplied, *alfalfa* yield was higher in the clear-seeded system. The oatcompanion 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.1501BACKGROUND: *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 andCanada have the largest plantings of GRCs. Herbicide use patterns wouldindicate that over 50 percent of *glyphosate*-*resistant* (GR) maize hectares and70 percent of GR cotton hectares receive alternative mode-of-action treatments... ...production system. Tillage was likely used for multiple purposes rangingfrom seed-bed preparation to *weed* management.CONCLUSION: GRCs representone of the more rapidly adopted *weed* management technologies in

recenthistory. Current use patterns would indicate that GRCs will likely continueto be a popular *weed* management choice that may also include the use ofother herbicides to complement glyphosate. Stacking...

7/K,6/8 (Item 8 from file: 55)DIALOG(R)File 55:(c) 2008 The Thomson Corporation. All rts. reserv.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 rts. reserv.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 controland other conventional *alfalfa* varieties for compositional assessment.Field trials were conducted using a randomized complete block design withfour replication blocks at each site. *Alfalfa* forage was harvested atthe 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 rts. reserv.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 stagesreduced seed yield. The current RR *alfalfa* timeline predicts thecommercial 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 rts. reserv.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 rts. reserv.

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.uwyo.edu/CES/PUBS/B1173.pdfDESCRIPTORS:
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 percent petroleum hydrocarbon adjuvant at 125 and 250 mL ha SUP -1 ,
respectively. Overall *weed* control varied from 85 percent, up to 95 percent. *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 threatening sustainable 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 ofsites in southern Australia. The *evolution* of paraquat resistance occursafter a prolonged period of use, often up to 20 years...
... will lead to a better understanding of how resistance is spread as wellas 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 (Hordeumglaucum Steud. and H. leporinum Link.) in South Australia.Book Title: *Weed* management: balancing people, planet, profit. 14thAustralian *Weeds* Conference, Wagga Wagga, New South Wales, Australia,6-9 September 2004: papers and proceedingsPublication 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 seedmovement 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 thatboth independent *evolution* and seed movement are important in thedistribution 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 differentsoils having (a) 0.96 percent organic matter (OM) and pH of 5.4 and (b) 2.61 percent OMand pH of 6.1. The *weed* control efficiency of oxyfluorfen and mixture ofdiuron+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 dayafter planting in moistened soil. In...
... plants. Oryzalin was selective to the crop, providing a better controlof grasses and broadleaved *weeds* at the 2 highest doses, regardless ofthe 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 appliedonly at the lowest dose tested, regardless of OM content in the soil,providing good control of some broadleaved *weeds*, with spraying offluazifop-P-butyl [fluazifop-P] needed in post-emergence. The herbicidesshowed, in average, 10 percent more control of the *weeds* in soil with 2.61 percent ofOM and pH of 6.1, in comparison to the *weeds* in the soil with 0.96 percent ofOM and pH of 5.4. Lucerne budding...
.. oxyfluorfen up to 12 days after application; this herbicide presentedgood potential for post-lasting *weed* control and excellent pre-emergencecontrol. 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* problemsassociated 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. 14thAustralian *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 currentlyprofitable to plant lucerne (*Medicago* sativa) on the scale requiredfor salinity abatement. However, these investigations have not incorporated the long-term benefits that accrue from the use of lucerne toenhance management of *weeds* , especially for those growers facing thethreat 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 ofcontinuous cropping, because of improved *weed* management, reduced chemical use and through increasing yields in subsequent cereal crops. Thefirst 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)
DIALOG(R)File 55:(c) 2008 The Thomson Corporation. All rts. reserv.
0019917724 BIOSIS NO.: 200700577465
New annual and short-lived perennial pasture legumes for Australianagriculture - 15 years of revolution
2007
ABSTRACT: Fifteen years ago subterranean clover (Trifolium subterraneum)and annual medics (*Medicago* spp.) dominated annual pasture legumesowings in southern Australia, while limited pasture legume options
existed...
...glanduliferum), arrowleaf (Trifolium vesiculosum), eastern star(Trifolium dasyurttm) and crimson (Trifolium incarnatum) clovers andsphere (*Medicago* sphaerocarpos), button (*Medicago* orbicularis) andhybrid disc (*Medicago* tornata x *Medicago* littoralis) medics have beencommercialised. Improved cultivars have also been developed ofsubterranean (T. subterraneum), balansa (Trifolium michelianum), rose(Trifolium hirtum), Persian (Trifolium resupinatum) and purple (Trifoliumpurpureum) clovers, burr (*Medicago* polymorpha),

strand (M. littoralis),snail (*Medicago* scutellata) and barrel (*Medicago* 'truncatula) medicsand 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.2007.07.018Use 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, seedlingand established pastures; *weed* control in grass pastures only -broadleaf *weeds*; *herbicide* *resistance* management; direct drill andsurface sowing; perennial grass *weed* control; approximate retail pricesof 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 rotationwith other annual crops.Publication Year: 2003 ... determine the tolerance of fenugreek (cv. Amber) to several herbicides and their efficacy on various *weeds* (Avena fatua, Setariaviridis 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 percent to total dry matter production. When imazamox/imazethapyr, or combinations of imazamoz/imazethapyr or imazethapyr with ethalfluralin was applied, *weed*contents were 5 percent of the total dry matter and the herbicides did notreduce fenugreek yield compared to the hand-*weeded* control. Total foragesamples with a low *weed* content had lower fibre content and higherprotein and digestible dry matter content than forages with a high *weed*content. When imazamox/imazethapyr was used for *weed* control, fenugreekyields and *weed* biomass were similar after direct seeding and aftercultivation plus seeding. In addition, the effect...
... and the previous crop by seeding method interaction was not significantfor fenugreek yield and *weed* biomass. Therefore, irrigated fenugreek canbe successfully grown in conservation tillage systems in rotation withseveral 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 UnitedStates because of an expanding horse-hay market. However, *weed* controlin mixed *alfalfa*-orchardgrass stands is problematic, as herbicides mustbe safe for both species. Most growers rely solely on the competitivenessof the crop for *weed* control, which is often insufficient, especiallyin older stands. Field experiments were established in northernCalifornia to determine the efficacy and crop safety of severalherbicides 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 percent *weed* control and caused significant injury to orchardgrass, which wasstill 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
Eleucine 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
Junglerice
Echinochloa junglerice
Burning nettle
Utica uren
Erodium filaree
Purslane weed
Large crabgrass in alfalfa
Bermudagrass weed alfalfa
Weeds taste in milk
Horseweed Italian ryegrass
Italian ryegrass weed
Palmer amaranth
Buckhorn plantain
Goosegrass
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-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
African mustard	*Brassica tournefortii* Asian mustard wild turnip	Broadleaf	WA								X	Rogan and Fitzpatrick 2004
Barnyardgrass	*Echinochloa crus-galli,* cockspur grass, Japanese millet watergrass cockspur watergrass	Grass	SA	X	X			X	X	X	X	Rogan and Fitzpatrick 2004
Bermudagrass	*Cynodon spp.*	Grass	P			X		X			X	Rogan and Fitzpatrick 2004
Blessed milk thistle	*Silyburn marianum* blessed milkthistle milk thistle spotted thistle variegated thistle	Dicot	A								X	Canevari et al. 2007
Blue mustard	*Chorispora tenella,* beanpodded mustard chorispora crossflower purple mustard tenella mustard	Broadleaf	WA		X		X					Rogan and Fitzpatrick 2004
Bluegrass (annual)	*Poa annua* walkgrass, annual bluegrass	Grass	WA			X		X			X	Rogan and Fitzpatrick 2004
Bluegrass (perennial)	*Poca* spp. Perennial bluegrass	Broadleaf	P		X							Rogan and Fitzpatrick 2004
Bristly oxtongue*	*Picris echioides*	Dicot	WA								X	Canevari et al. 2007
Bromes	*Bromus* spp.	Grass	WA								X	Rogan and Fitzpatrick 2004

[2] Source: http://plants.usda.gov/java/invasiveOne.

Table G-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Buckhorn plantain	*Plantago lanceolata* English plantain buckhorn plantain lanceleaf plantain narrowleaf plantain ribgrass ribwort *Plantago major* broadleaf plantain buckhorn plantain common plantain rippleseed plantain	Broadleaf	P					X		X		Rogan and Fitzpatrick 2004
Buffalobur	*Solanum rostratum* Colorado bur Kansas thistle Mexican thistle Texas thistle Buffalobur nightshade	Broadleaf	SA					X				Rogan and Fitzpatrick 2004
Bulbous bluegrass	*Poa bulbosa*	Grass	P							X		Rogan and Fitzpatrick 2004
Bull thistle	*Cirsium lanceolatum*	Broadleaf	P							X		Rogan and Fitzpatrick 2004
Burcucumber	*Sicyos angulatus* Wall bur cucumber	Broadleaf	SA			X						Rogan and Fitzpatrick 2004
Burning nettle	*Urtica dioica* California nettle slender nettle stinging nettle tall nettle	Broadleaf	A								X	Canevari et al. 2004, Canevari et al. 2006
Bushy wallflower	*Ersimum repandum* Treacle mustard	Broadleaf	WA					X				Rogan and Fitzpatrick 2004
California burclover	*Medicago polymorpha* burclover	Dicot	WA-P								X	Canevari et al. 2007
Canada thistle	*Cirsium arvense* Californian thistle creeping thistle field thistle Cirsium thistle	Broadleaf	P	X	X		X			X		Rogan and Fitzpatrick 2004

Table G-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Canarygrass	*Phalaris arundinacea* canary grass reed canarygrass *Phalaris canariensis* canary grass *Phalaris minor* canarygrass littleseed canarygrass	Grass	WA								X	Rogan and Fitzpatrick 2004
Carolina geranium	*Geranium carolinianum*	Broadleaf	WA			X						Rogan and Fitzpatrick 2004
Cheatgrass	*Bromus tectorum* downy brome early chess military grass thatch bromegrass	Grass	WA	X	X		X	X	X	X	X	Rogan and Fitzpatrick 2004
Cheeseweed	*Malva neglecta* buttonweed cheeseplant little mallow common mallow	Broadleaf	WA-P							X	X	Rogan and Fitzpatrick 2004
Chickweed (common)	*Stellaria media*	Broadleaf	WA	X	X	X		X	X			Rogan and Fitzpatrick 2004
Chicory	*Cichorium intybus* blue sailors chicory coffeeweed succory	Broadleaf	P							X		Rogan and Fitzpatrick 2004
Coastal fiddleneck	*Amsinckia menziesii* var. *intermedia* coast buckthorn coast fiddleneck common fiddleneck fiddleneck	Broadleaf	WA							X		Rogan and Fitzpatrick 2004
Cocklebur (common)	*Xanthium strumarium* cocklebur common cocklebur rough cocklebur	Broadleaf	SA	X	X	X			X			Rogan and Fitzpatrick 2004

Table G-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Cornflower	*Centaurea cyanus* bachelor's button garden cornflower	Broadleaf	WA			X						Rogan and Fitzpatrick 2004
Crabgrass	*Digitaria bicornis* Asian crabgrass *Digitaria ciliaris* Henry's crabgrass fingergrass kukaepua'a saulangi smooth crabgrass tropical crabgrass *Digitaria ischaemum* small crabgrass smooth crabgrass *Digitaria Sanguinalis* hairy crabgrass large crabgrass purple crabgrass	Grass	SA	X	X	X		X				Rogan and Fitzpatrick 2004
Creeping swinecress	*Coronopus didymus* lesser swinecress *Coronopus squamatus* creeping wartcress swinecress	Dicot	WA								X	Canevari et al. 2007
Cupgrasses	*Eriochloa gracilis* southwestern cupgrass tapertip Cupgrass *Eriochloa contracta* prairie cupgrass *Eriochloa villosa* woolly cupgrass	Grass	SA					X			X	Rogan and Fitzpatrick 2004

Table G-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Curly dock	*Rumex crispus* narrowleaf dock sour dock yellow dock Rumex dock	Broadleaf	P	X	X	X		X				Rogan and Fitzpatrick 2004
Cutleaf eveningprimrose	*Oenothera laciniata* cut-leaved evening primrose	Broadleaf	WA					X				Rogan and Fitzpatrick 2004
Dallisgrass	*Paspalum dilatatum* dallies grass herbe de miel herbe sirop hiku nua palpalum dilate water grass	Grass	P								X	Canevari et al. 2007
Dandelion (common)	*Taraxacum officinale* blowball common dandelion faceclock	Broadleaf	P	X	X		X	X		X		Rogan and Fitzpatrick 2004
Dodder	*Cuscuta* 50 common names for species in the genus	Broadleaf	SA					X	X	X	X	Rogan and Fitzpatrick 2004
Fall panicum	*Panicum dichotomiforum* western witchgrass	Grass	SA	X		X						Rogan and Fitzpatrick 2004
Fescue	*Festuca* spp. 66 common names for species in the genus	Grass	P			X				X		Rogan and Fitzpatrick 2004
Fescue (tall)	*Festuca arundinacea* *Festuca pratensis* Alta fescue coarse fescue reed fescue tall fescue	Grass	SA							X		Rogan and Fitzpatrick 2004

Table G-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Field bindweed	*Convolvulus arvensis* creeping jenny European bindweed morningglory perennial morningglory smallflowered morningglory	Broadleaf	P	X			X					Rogan and Fitzpatrick 2004
Field pepperweed	*Lepidium campestre*	Dicot	WA				X			X		Orloff et al. 1997
Flixweed	*Descurainia sophia* flixweed pinnate tansymustard	Broadleaf	WA				X	X		X		Rogan and Fitzpatrick 2004
Foxtail (giant)	*Setaria faberi* Chinese foxtail Chinese millet giant bristlegrass giant foxtail nodding foxtail	Grass	SA	X	X	X		X	X			Rogan and Fitzpatrick 2004
Foxtail (green)	*Setaria viridis* 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)	*Setaria glauca* pearl millet pigeongrass wild millet yellow bristlegrass yellow foxtail	Grass	SA	X	X	X	X	X	X			Rogan and Fitzpatrick 2004
Foxtail barley	*Hordeum jubatum*	Grass	P				X			X		Rogan and Fitzpatrick 2004
Goosegrass	*Eleusine indica* crowsfoot grass Indian goosegrass manienie ali'I silver crabgrass wiregrass	Grass	SA			X		X				Rogan and Fitzpatrick 2004
Groundsel (common)	*Senecio vulgaris* ragwort old-man-in-the-Spring	Dicot	WA								X	Canevari et al. 2007

Table G-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Hairy nightshade	*Solanum sarrachoides* hairy nightshade hoe nightshade	Broadleaf	SA							X		Rogan and Fitzpatrick 2004
Hare barley	*Hordeum leporinum* hare barley leporinum barley wild barley	Dicot	WA				X			X	X	Orloff et al. 1997
Henbit	*Lamium amplexicaule* deadnettle	Broadleaf	WA	X	X	X		X		X		Rogan and Fitzpatrick 2004
Hoary alyssum	*Berteroa incana* hoary false alyssum hoary false madwort	Broadleaf	P		X							Rogan and Fitzpatrick 2004
Hoary alyssum	*Berteroa incana* hoary false alyssum hoary false madwort	Broadleaf	SA	X								Rogan and Fitzpatrick 2004
Horseweed	*Conyza canadeniss* horseweed fleabane mares tail fleabane	Broadleaf	SA/WA					X				Rogan and Fitzpatrick 2004
Japanese brome	*Bromus japonicus* Japanese bromegrass Japanese chess	Grass	WA					X				Rogan and Fitzpatrick 2004
Jimsonweed	*Datura stramonium* Jamestown weed mad apple moonflower stinkwort thorn apple	Broadleaf	SA	X		X						Rogan and Fitzpatrick 2004
Johnsongrass	*Sorghum halepense* aleppo milletgrass herbe de cuba sorgho d' Alep sorgo de alepo zacate johnson	Grass	P			X		X				Rogan and Fitzpatrick 2004
Jointed goatgrass	*Aegilops cylindrical* jointgrass	Grass	P					X				Rogan and Fitzpatrick 2004

Table G-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Junglerice	*Echinochloa colona* junglerice watergrass	Grass	SA								X	Rogan and Fitzpatrick 2004
Kentucky bluegrass	*Poa prantensis*	Grass	P							X		Rogan and Fitzpatrick 2004
Knawel	*Sclerantus annus* German knotgrass	Broadleaf	WA			X						Rogan and Fitzpatrick 2004
Knotweed	*Polygonum arenastrum* common knotweed doorweed matweed ovalleaf knotweed prostrate knotweed	Broadleaf	SA						X		X	Rogan and Fitzpatrick 2004
Kochia	*Kochia scoparia* Mexican burningbush Mexican fireweed fireweed mock cypress summer cypress	Broadleaf	SA		X			X	X			Rogan and Fitzpatrick 2004
Lambsquarters (common)	*Chenopodium album* Lambsquarters White goosefoot	Broadleaf	SA	X	X	X	X	X	X	X	X	Rogan and Fitzpatrick 2004
Little barley	*Hordeum pusillum* little wildbarley	Grass	WA					X				Rogan and Fitzpatrick 2004
London rocket	*Sisymbrium irio*	Grass	WA								X	Rogan and Fitzpatrick 2004
Meadow foxtail*	*Alopecurus pratensis*	Grass	P							X		Rogan and Fitzpatrick 2004
Mexican sprangletop	*Leptochloa uninervia*	Grass	SA								X	Rogan and Fitzpatrick 2004
Mexican tea	*Chenopodium ambrosioides*	Dicot	P								X	Canevari et al. 2007
Miner's lettuce	*Claytonia perfoliata*	Dicot	WA-P								X	Canevari et al. 2007
Morningglory	*Ipomoea* spp.	Broadleaf	SA			X						Rogan and Fitzpatrick 2004

Table G-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Muhly	*Muhlenbergia frondosa* wirestern muhly *Muhlenbergia racemosa* green muhly marsh muhly	Grass	P							X		Rogan and Fitzpatrick 2004
Musk thistle	*Caruus nutans* Nodding plumeless thistle chardon penche nodding thistle plumeless thistle	Broadleaf	WA					X				Rogan and Fitzpatrick 2004
Mustards	*Brassica* spp.	Broadleaf	WA			X	X					Rogan and Fitzpatrick 2004
Mustards	*Brassica* spp.	Broadleaf	SA			X						Rogan and Fitzpatrick 2004
Nettleleaf goosefoot	*Chenopodium murale*	Broadleaf	SA								X	Rogan and Fitzpatrick 2004
Night-flowering catchfly	*Silene noctiflora* nightflowering silene sticky cockle	Broadleaf	WA		X							Rogan and Fitzpatrick 2004
Nightshade	*Solanum sarrachoides* hairy nightshade hoe nightshade	Broadleaf	SA			X			X			Rogan and Fitzpatrick 2004
Nightshade (E. black)	*Solanum ptychanthum* Eastern black nightshade black nightshade	Broadleaf	SA	X	X							Rogan and Fitzpatrick 2004
Nutsedge (yellow)	*Cyperus esculentus* yellow nutgrass yellow nutsedge	Grass	P	X								Rogan and Fitzpatrick 2004
Nutsedges	*Cyperus esculentus* yellow nutgrass yellow nutsedge *Cyperus rotundus* chaguan humatag cocograss kili'o'opu nutgrass pakopako purple nutsedge	Grass	P								X	Rogan and Fitzpatrick 2004

Table G-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Palmer amaranth	*Amaranthus palmeri* carelessweed (type of pigweed)	Broadleaf	SA					X				Rogan and Fitzpatrick 2004
Pennycress	*Thlaspi arvense* Frenchweed Fanweed field pennycress pennycress stinkweed	Broadleaf	WA	X	X				X			Rogan and Fitzpatrick 2004
Pepperweeds	*Lepidium densiflorum* common pepperweed greenflower pepperweed peppergrass	Broadleaf	WA					X		X		Rogan and Fitzpatrick 2004
Persian speedwell	*Veronica persica* birdeye speedwell winter speedwell	Broadleaf	WA							X		Rogan and Fitzpatrick 2004
Pigweed spp.	*Amaranthus* 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 Steckel, L (undated b)
Plains coreopsis	*Coreopsis tinctoria* golden tickseed	Broadleaf	WA					X				Rogan and Fitzpatrick 2004
Plantains	*Plantago major* common plantain broadleaf plantain buckhorn plantain rippleseed plantain	Broadleaf	P			X		X				Rogan and Fitzpatrick 2004

Table G-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Poverty sumpweed	*Iva axillaris* Iva poverty weed Lesser marshelder mouseear povertyweed poverty sumpweed poverty weed smallflowered marshelder	Broadleaf	P							X		Rogan and Fitzpatrick 2004
Prickly lettuce	*Lactuca serriola* China lettuce wild lettuce	Broadleaf	WA					X	X	X		Rogan and Fitzpatrick 2004
Purslane	*Portulaca oleracea* akulikuli-kula common purslance duckweed parsley pusley wild portulaca	Broadleaf	SA						X			Rogan and Fitzpatrick 2004
Quackgrass	*Elytrigia repens* couchgrass quackgrass quickgrass quitch scutch twitch *Elymus repens* couchgrass dog grass	Grass	P	X	X				X	X		Rogan and Fitzpatrick 2004
Rabbitsfoot grass	*Polypogon monspelienisis* rabbitfoot polypogon rabbitfootgrass	Grass	WA								X	Rogan and Fitzpatrick 2004
Ragweed (common)	*Ambrosia artemisiifolia* 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*	*Glausium carniculatum*	Broadleaf	WA					X				Rogan and Fitzpatrick 2004

Table G-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Red sprangletop*	*Leptochloa filiformis*	Grass	SA								X	Rogan and Fitzpatrick 2004
Redstem filaree	*Erodium cicutarium* redstem stork's bill alfilaree filaree stork's bill	Broadleaf	WA							X		Rogan and Fitzpatrick 2004
Rescuegrass	*Bromus catharticus* rescue brome	Grass	WA					X				Rogan and Fitzpatrick 2004
Roughseed buttercup*	*Ranunculus muricatus*	Dicot	WA-P								X	Canevari et al. 2007
Russian thistle	*Salsola kali* tumbleweed *Salsola iberica* prickly Russian thistle tumbleweed tumbling thistle	Broadleaf	SA		X			X	X	X		Rogan and Fitzpatrick 2004
Ryegrass	*Lolium multiforum* Italian ryegrass annual ryegrass	Grass	WA			X				X		Rogan and Fitzpatrick 2004
Ryegrass (perennial)	*Lolium perenne* Perennial ryegrass	Grass	WA							X		Rogan and Fitzpatrick 2004
Sandbur	*Cenchrus echinatus* burgrass common sandbur field sandbur konpeito-gusa se mbulabula vao tui tui	Grass	SA					X	X			Rogan and Fitzpatrick 2004
Shepardspurse	*Capsella bursa-pastoris* Shephardspurse	Broadleaf	WA	X	X	X	X	X	X	X	X	Rogan and Fitzpatrick 2004
Silversheath knotweed*	*Polygonum argyrocoleon*	Broadleaf	WA								X	Rogan and Fitzpatrick 2004
Smartweed	*Polygonum persicaria* lady's thumb ladysthumb smartweed	Broadleaf	SA	X	X	X						Rogan and Fitzpatrick 2004
Sowthistle	*Sonchus* spp. (5 species)	Broadleaf	P						X			Rogan and Fitzpatrick 2004

Table G-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Spiny sowthistle	*Sonchus asper* perennial sowthistle prickly sowthistle	Broadleaf	WA					X				Rogan and Fitzpatrick 2004
Sprangletops	*Leptochloa fascicularis* bearded sprangletop Also other *leptochloa*	Grass	SA					X				Rogan and Fitzpatrick 2004
Squirreltail*	*Sitanion hystrix*	Grass	P							X		Rogan and Fitzpatrick 2004
Stinkgrass	*Eragrostis cilianensis* candy grass lovegrass strongscented lovegrass	Grass	SA							X		Rogan and Fitzpatrick 2004
Sunflower (common)	*Helianthus annuus* annual sunflower common sunflower sunflower wild sunflower	Broadleaf	SA				X		X	X		Rogan and Fitzpatrick 2004
Swamp knotweed*	*Polygonum coccineum*	Broadleaf	P							X		Rogan and Fitzpatrick 2004
Tall waterhemp	*Amaranthus tuberculatus* roughfruit amaranth tall waterhemp	Broadleaf	SA		X			X				Rogan and Fitzpatrick 2004
Tansy mustard	*Descurainia pinnata* green tansymustard tansymustard	Broadleaf	SA		X			X	X	X		Rogan and Fitzpatrick 2004
Toad rush	*Juncus bufonius*	Grass	WA								X	Canevari et al. 2007
Tumble mustard	*Sisymbrium altissimum* Jim hill mustard tall mustard tumble mustard tumbleweed mustard	Broadleaf	SA						X	X	X	Rogan and Fitzpatrick 2004

Table G-8. Weeds in Alfalfa

Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Velvetleaf	*Abutilon theophrasti* Indian mallow butterprint buttonweed	Broadleaf	SA	X	X	X						Rogan and Fitzpatrick 2004
Virginia pepperweed	*Lepidium virginicum* Virginia Pepperweed Virginia peppercress peppergrass poorman's pepper	Broadleaf	WA			X						Rogan and Fitzpatrick 2004
Volunteer grains		Grass	WA-SA	X		X		X	X	X		Rogan and Fitzpatrick 2004
White cockle	*Silene latifolia* bladder campion evening lychnis white campion	Broadleaf	P		X							Rogan and Fitzpatrick 2004
Wild celery*	*Apium graveolens*	Dicot	SA-P								X	Canevari et al. 2007
Wild mustard	*Brassica arvensis* wild mustard *Brassica kaber* canola charlock mustard kaber mustard rapeseed wild mustard	Broadleaf	SA	X	X				X			Rogan and Fitzpatrick 2004
Wild oats	*Avena fatua* flaxgrass oatgrass wheat oats	Grass	SA-WA		X				X	X	X	Rogan and Fitzpatrick 2004
Wild radish	*Raphanus raphanistrum*	Broadleaf	SA	X	X	X						Rogan and Fitzpatrick 2004
Windmillgrass	*Chloris verticillata* tumble windmill grass windmillgrass	Grass	P					X				Rogan and Fitzpatrick 2004
Witchgrass	*Panicum capillare* panicgrass ticklegrass tumble panic tumbleweed grass witches hair	Grass	SA	X						X		Rogan and Fitzpatrick 2004

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Common Name	Scientific Name and Synonyms[2]	Type	Season	East Central	North Central	Southeast	Winter Hardy Inter-mountain	Great Plains	PNW	Moderate Inter-mountain	Southwest	Source
Yellow rocket	*Barbarea vulgaris* garden yellow rocket winter cress	Broadleaf	P	X	X							Rogan and Fitzpatrick 2004
Yellow starthistle	*Cantaurea solstitialis*	Dicot	WA				X			X		Canevari et al. 2007
Yellowflower pepperweed	*Lepidium perfoliatum* clasping pepperweed	Dicot	WA				X			X		Orloff et al. 1997

For appendix G-3 - Regional review of weeds in alfalfa. Monsanto. Cites the following sources:

Canevari, M., Orloff, S.B., Hembree, K., and Vargas, R.N. (2004), Roundup Ready Alfalfa Research Results: California and the U.S. Proceedings, National Alfalfa Symposium, 13-15 December 2004, San Diego, CA; UC Cooperative Extension, University of California, Davis 95616. http://alfalfa.ucdavis.edu

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