Supplemental Information to Support the NEPA Analysis for the Determination of Nonregulated Status of Dicamba-Tolerant Soybean MON 87708 and Dicamba- and Glufosinate-Tolerant Cotton MON 88701

Impact and Benefits of Dicamba-Tolerant Soybean and Dicamba and Glufosinate-Tolerant Cotton on Weed Resistance Management

OECD Unique Identifiers: MON-877Ø8-9 (soybean) and MON-887Ø1-3 (cotton)
Monsanto Petition Numbers: 10-SY-210U (soybean) and 12-CT-244U/ 12-CT-244U-S (cotton)
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Certification

The undersigned submits this supplement under 7 CFR §340.6 to request that the Administrator make a determination that the article should not be regulated under 7 CFR Part 340

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Introduction and Background

Monsanto has developed a new biotechnology-derived soybean (*Glycine max*), designated as event MON 87708 ("DT soybean"), that is tolerant to dicamba herbicide, and a new biotechnology-derived cotton (*Gossypium* spp.), designated as event MON 88701 ("DGT cotton"), that is tolerant to dicamba and glufosinate herbicides. Monsanto submitted petitions for determinations of nonregulated status for DT soybean and DGT cotton three and one years ago, respectively, and has provided the U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) with lengthy scientific materials and Environmental Reports.[1,2] This document addresses the impact and benefits of DT soybean and DGT cotton on weed resistance management. As discussed herein, the approval of DT soybean and DGT cotton, will provide growers with an important new tool to manage weeds and mitigate the further evolution of resistance to some current U.S. herbicides.

Associated with the cultivation of DT soybean and DGT cotton will be an increase in use of dicamba, which will potentially result in increased selection pressure for resistant biotypes. This risk can be significantly mitigated by incorporating dicamba into a diversified weed management program. To evaluate this risk Monsanto has conducted an analysis to understand the risk of cross-over resistance (i.e., resistance that may evolve in soybean or cotton and then impact other dicamba crop uses) by evaluating: (1) the primary weed targets and the current extent of dependence on dicamba for weed management, and (2) the potential overlap of weed species across these cropping systems. Overall, the analysis indicates that risk of cross-over resistance is low, and because of the low dependency of farmers on dicamba for weed management in these areas combined with the availability of other herbicide options, the potential socio-economic impact of cross-over resistance would be low.

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[1] Petition for the Determination of Nonregulated Status for Dicamba-Tolerant Soybean MON 87708, Monsanto Petition Number: 10-SY-201U (July 6, 2010) ; Supplemental Information to Support the NEPA Analysis for the Determination of Nonregulated Status of Dicamba-Tolerant Soybean MON 87708, Petition # 10-188-01p (Oct. 11, 2012); Supplemental Information to Support the NEPA Analysis for the Determination of Nonregulated Status of Dicamba-Tolerant Soybean MON 87708, Petition # 10-188-01p (Dec. 14, 2012); Supplemental Information to Support the NEPA Analysis for the Determination of Nonregulated Status of Dicamba-Tolerant Soybean MON 87708, Petition # 10-188-01p (Jan. 31, 2013); Petitioner's Environmental Report for Dicamba-Tolerant Soybean MON 87708 and Dicamba- and Glufosinate-Tolerant Cotton MON 88701, Monsanto Petition Numbers 10-188-01p and 12-185-01p_al) (Nov. 25, 2013).

[2] Petition for the Determination of Nonregulated Status for Dicamba and Glufosinate-Tolerant Cotton MON 88701, Monsanto Petition Number: 12-CT-244U (July 2, 2012); Petitioner's Environmental Report for Dicamba and Glufosinate-Tolerant Cotton MON 88701, Monsanto Petition Number: 12-CT-244U-S (USDA Petition #12-185-01p_al) (May 6, 2013); Petitioner's Environmental Report for Dicamba-Tolerant Soybean MON 87708 and Dicamba- and Glufosinate-Tolerant Cotton MON 88701, Monsanto Petition Numbers 10-188-01p and 12-185-01p_al) (Nov. 25, 2013).

Background – Legal

On May 16, 2013, APHIS announced its intention to prepare a full Environmental Impact Statement (EIS) not only to address jurisdictional plant pest issues under the Plant Protection Act (PPA), but also to examine the possible environmental impacts of dicamba herbicide uses, including the potential for development of herbicide-resistant weeds.[3] As discussed in previous submissions to APHIS, Monsanto does not believe that addressing the impacts of herbicide uses in an EIS, as described by APHIS's May 16, 2013 Notice of Intent (NOI), is required by the National Environmental Policy Act (NEPA) or any other law.

First, the PPA does not give APHIS regulatory authority over herbicide uses or impacts, or to address herbicide resistance. Indeed, Congress expressly transferred regulatory authority over herbicides from APHIS to EPA over four decades ago[4], and APHIS itself has long recognized the strict limits on its PPA authority.[5] On the other hand, EPA's authority to regulate herbicides under FIFRA includes an evaluation of, and measures to address, the development of herbicide resistance in weeds associated with the use of those products.[6] Accordingly, APHIS has no jurisdiction over herbicides or the development of herbicide resistance in weeds that may be associated with herbicide use, and no authority to consider herbicide impacts under the PPA. Consequently, APHIS has no obligation under NEPA to consider herbicide resistance in weeds (or any other environmental impacts of dicamba or glufosinate use, or to consider alternatives to deregulation based on these factors) as "effects" since there is no reasonable alternative to deregulation once APHIS finds DT soybean and DGT cotton do not pose a greater plant pest risk than their conventional counterparts.[7] As discussed in previous documentation submitted to APHIS, this longstanding understanding of NEPA was recently confirmed by the U.S. Court of Appeals for the Ninth Circuit.[8]

It is likewise inappropriate for APHIS to identify weed resistance as a "cumulative impact" under 40 C.F.R. §1508.7. As discussed above, any decisions regarding restrictions of the use of

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[3] 78 Fed. Reg. 28796.

[4] *Ruckelshaus v. Monsanto Co.*, 467 U.S. 986, 991(1984) (observing that "the Department of Agriculture's FIFRA responsibilities were transferred to the then newly created Environmental Protection Agency…."); *see also* Pub.L. No. 92-516, 86 Stat. 973 (1972).

[5] *See* Center for Food Safety v. Vilsack, 718 F.3d 829, 840 (9th Cir. 2013).

[6] *See*, *e.g.*, EPA, Pesticide Registration (PR) Notice 2001-5, "Guidance for Pesticide Registrants on Pesticide Resistance Management Labeling," p. 2 (2001), available at http://www.epa.gov/PR_Notices/pr2001-5.pdf (labeling measures to assist in pesticide resistance management). Additionally, pesticide registrants must report resistance to EPA as an adverse effect in order to ensure the pesticide continues to meet FIFRA requirements for registration. 40 C.F.R. § 159.188(c).

[7] *DOT v. Public Citizen*, 541 U.S. 752, 770, 769 (2004) (where an agency has no ability to prevent a certain effect due to its limited statutory authority over the relevant actions, the agency cannot be considered a legally relevant "cause" of the effect, and is therefore not required to analyze the environmental impact of an action it could not refuse to perform).

[8] For further discussion of the litigation, see Section I.B.4 of Petitioner's Environmental Report for Dicamba-Tolerant Soybean MON 87708 and Dicamba- and Glufosinate-Tolerant Cotton MON 88701, Nov. 25, 2013.

dicamba (including any such measures related to weed resistance) are within the sole purview of EPA; APHIS has no control whatsoever over the nature of any such restrictions. Lacking such control, APHIS is not required to address the EPA decision on dicamba, or the consequences of such decision, as cumulative impacts.[9] In short, any weed resistance impacts associated with herbicide uses are not caused by APHIS's PPA determinations, and cannot trigger a need to perform NEPA review in connection with a PPA determination. And, of course, weed resistance and any responses thereto, cannot constitute significant environmental impacts of an APHIS PPA determination. Indeed, multiple federal courts have held that EPA's review under FIFRA is the "functional equivalent" of NEPA.[10] Thus, APHIS's review of resistance issues would duplicate the NEPA-equivalent analyses already being performed by EPA under its authorities.

If APHIS intends nevertheless to include such material in its EIS, it should make clear that it is exercising its discretion to perform that analysis in the document, not that it is legally required to include that material under NEPA or any other statute.

Background – Herbicide Use

In the decades since the introduction of the first herbicide (2,4-D) for weed control in corn in early 1940s, herbicide use has become a critical agronomic tool that is used on the vast majority of cropland in the United States. By 1962, farmers had access to approximately 100 herbicides available in approximately 6000 formulations. According to a 2006 study, farmers routinely use herbicides on more than 90% of the area of most crops grown in the U.S. (Gianessi and Reigner 2006).

Weed control in crop production is essential for optimizing yields because weeds compete with crops for light, nutrients, and soil moisture. Weeds can also harbor insects and diseases, and can interfere with harvest, causing extra wear on harvest equipment. A study by CropLife America demonstrated that in 2005 the use of herbicides saved U.S. farmers 337 million gallons of fuel, produced $16 billion in crop yield increases, and cut weed control costs by $10 billion as compared to production without the use of herbicides (Gianessi and Reigner 2006). Additionally, without herbicides growers would have to abandon no-till and other conservation tillage production practices, which reduce soil erosion. If U.S. growers stopped using herbicides and resumed tillage on the number of acres not tilled in 2005, an additional 356 billion pounds of

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[9] *DOT v. Public Citizen*, 541 U.S. 753, 767 (2004).

[10] *Envtl. Def. Fund, Inc. v EPA*, 489 F.2d 1247, 1256 (D.C. Cir. 1973) (holding that FIFRA's standard and processes are the "functional equivalent of a NEPA investigation" and that "[t]he law requires no more"); *Envtl. Def. Fund, Inc. v. Blum,* 458 F. Supp. 650, 662 n.6 (D.D.C. 1978) ("If the 'functional equivalent' requirement means anything, it surely means that the EPA [in conducting analysis under FIFRA] did not have to follow the detailed procedural requirements laid out by NEPA."); *Douglas Cnty. v. Babbitt*, 48 F.3d 1495, 1502-03 (9th Cir. 1995) ("FIFRA for NEPA to apply to FIFRA."); *Merrell v. Thomas*, 807 F.2d 776, 782 (9th Cir. 1986) ("FIFRA's review provisions do afford the public some opportunity to participate in pesticide registration decisions…. [And while that] opportunity would be greater if NEPA [also] applied[,] Congress has made its choice [not to do so].").

sediments would be deposited in streams and rivers, resulting in an estimated $1.4 billion in downstream damage (Gianessi and Reigner 2006).

Throughout the 70-year history of herbicide use, farmers have regularly dealt with resistance issues as herbicide uses have resulted in natural selection of existing tolerant weeds within weed populations. In fact, resistance is a natural and ordinary occurrence that, over time, the agricultural community has addressed by making adjustments to cultivation practices.

As noted by prominent weed scientists, the most effective crop weed management programs use a combination of cultural, mechanical, and/or herbicide control practices, called diversified weed management practices, instead of relying on one particular method of weed control (Beckie, et al. 2011; Hake, et al. 1996; Norsworthy, et al. 2012; University of California 2009; Vargas, et al. 1996). Examples of methods that can be used in a diversified weed management program include: (1) use multiple herbicides in mixtures, sequences, or rotation, (2) use mechanical tillage such as timely mowing or tillage, and/or (3) cultural practices such as crop rotation or other agronomic practices to increase crop competitiveness (WSSA Resistance management training modules at wssa.net).

The emergence of certain herbicide-resistant weeds over the past decade, including glyphosate-resistant weed biotypes in certain areas of the U.S., is simply another chapter in the history of herbicide uses. As has been the case in the past, natural selection of tolerant weeds has meant that growers have needed to continue to adapt and implement evolving weed management strategies. These types of adaptations in resistance management strategies are not new as weed resistance has occurred for decades. As of January 2014, 416 herbicide-resistant weed biotypes have been reported to be resistant to 21 different herbicide modes-of-action worldwide (Heap 2014d). Glyphosate-resistant weeds, which occur in certain areas of the U.S., account for approximately 6% of U.S. herbicide-resistant biotypes, while weeds resistant to herbicides that inhibit acetolactate synthase (ALS) and photosynthesis at photosystem (PSII) inhibitors account for 33% and 17% of the herbicide-resistant biotypes, respectively (Heap 2014e). Dicamba-resistant and glufosinate-resistant weeds account for 1% and 0.5% of resistant biotypes respectively (Heap 2014f; g). Again, resistance occurs naturally in weed populations, and the use of herbicides selects for the resistant plants within a population. As discussed further below, Monsanto continues to rely upon the consensus recommendations of leading academic weed scientists who, for several years, have recommended multiple modes of action.

Where necessary to manage herbicide-resistant weeds in soybean and cotton production, growers in certain areas of the U.S. have increased herbicide application rates, increased the number of herbicides (number of modes of action), and, in some cases, returned to more traditional tillage practices (Monsanto 2013a) and hand-weeding (Culpepper, et al. 2011; NRC 2010). In an effort to manage glyphosate-resistant Palmer amaranth, certain non-glyphosate herbicides have been reported as being used in conditions and practices that have the potential to result in increased selection of resistant biotypes to those herbicides, thereby putting certain agricultural herbicides in some major herbicide classes at risk (Nichols, et al. 2010; Prostko 2011) (Dr. Larry Steckel and Dr. Stanley Culpepper, personal communications, August 2012). While effective options for managing *Ambrosia* spp., and *Amaranthus* spp., including Palmer amaranth, waterhemp and other key broadleaf weeds exist, weed scientists have concluded that there is a need for additional herbicide modes-of-action (MOA) to mitigate the potential for development of resistance to the key herbicides essential for weed management in soybean and cotton (Tranel, et al. 2010).

In addition, there has been an increase in the detection of weed populations with resistance to multiple herbicide modes-of-action (multiple resistance) in certain weed species, for example, *Amaranthus* spp. (Tranel et al. 2010). This development further highlights the need for additional modes of action on certain species. Presently there are six broadleaf species known to have populations with multiple resistance in the U.S., thus limiting the number of herbicide options available for weed control in fields where these populations exist (see Table 1). The emergence of these resistant biotypes demonstrates the continued need to utilize diversified weed management practices, including the need for additional herbicide modes-of-action that are effective in major crops. The WSSA reports: “Weed scientists know that the best defense against weed resistance is to proactively use a combination of agronomic practices, including the judicious use of herbicides with alternative modes-of-action either concurrently or sequentially” (WSSA 2010). Refer to Appendix B of the November 2013 Petitioner’s Environmental Report for DTS and DGT Cotton (petitions 10-188-01p and 12-185-01p_a1) (Monsanto 2013b) for additional details on herbicide resistance.

Importantly, however, evidence to date indicates that resistance to dicamba and auxins is a lower probability than many other herbicides. Indeed, there is no evidence of cross-resistance to other herbicide modes-of-action after more than 50 years of use of any auxinic herbicide and where resistance mechanisms for dicamba have been studied, there is little to no evidence for the type of mechanism that would suggest the possibility for cross-resistance to other herbicides modes-of-action. Thus, leading experts on resistance to auxinic herbicides, and in particular dicamba and 2,4-D, are clear in their judgment that the evolution of resistance to dicamba is not likely to result in cross-resistance to herbicides with other modes-of-action and therefore the risk of dicamba resistance is no greater than the risk of resistance to most other herbicides.

Table 1 – Multiple Resistant Broadleaf Weeds in Soybean and Cotton Production Areas[1]

Weed Species	**Biotypes with Known Resistant**	
	Soybean Production[2] Herbicide MOAs Classes[5]	**Cotton Production[3] Herbicide MOAs Classes[5]**
Waterhemp	ALS / PS II	ALS/PPO
	ALS / PPO	ALS/PPO/GLY
	ALS / GLY	
	ALS / PS II / PPO	
	ALS / PPO / GLY	
	ALS / PS II / HPPD	
	ALS / PS II / HPPD / GLY	
Palmer amaranth	ALS / GLY	ALS/GLY
	ALS / PS II / HPPD	
Marestail	ALS / GLY	GLY/Bipyridilium
	GLY / Bipyridilium	
Ragweed spp.	ALS / PPO	
	ALS / GLY	
Redroot pigweed	ALS / PS II	
Kochia[4]	ALS / PS II	

[1] Source: (Heap 2014c)

[2] If weed populations with resistance to multiple herbicide modes-of-action are reported in corn or cropland in states where soybean is grown, these populations were also included.

[3] If weed populations with resistance to multiple herbicide modes-of-action are reported in soybean or cropland in states where cotton is grown, these populations were also included.

[4] Populations with resistance to dicamba exist; however, no known populations with resistance to both dicamba and glyphosate exist.

[5] ALS (acetolactate synthase inhibitors), PS II (photosystem II inhibitors), PPO (protoporhpyrinogen oxidase inhibitors), GLY (glycines), HPPD (p-hydroxyphenyl pyruvate dioxygenase), Bipyridilium (paraquat)

Benefits of DT Soybean and DGT Cotton for Weed Control and Resistance Management

New herbicide options are needed in soybean and cotton in order to manage present and future growth of resistant weed species, including glyphosate resistant weeds, and species with resistance to multiple herbicides. Today in U.S. soybean and cotton areas the weed species of most concern are broadleaf species, specifically summer annual species such as those in the *Amarathus* and *Ambrosia* genus. Dicamba is an effective herbicide on these and other targeted summer broadleaf species, is compatible and complementary to glyphosate and will be an essential tool to assist soybean and cotton growers to effectively manage weeds and weed resistance in general. The ability to use dicamba on DT soybean and DGT cotton will offer farmers an additional option for management of broadleaf weeds at a time when current herbicide options are becoming more limited because of the spread of biotypes with resistance to multiple herbicides and multiple herbicide modes of action. Dicamba will almost exclusively be used in combination with other herbicides including glyphosate, glufosinate and other soil residual and postemergence active herbicides currently labeled for use in either soybean or cotton. In soybean, there are three basic weed management systems today; a diversified system including multiple herbicides with different modes of action, herbicides combined with non-herbicide management options, and, to a lesser degree, systems that still rely solely on glyphosate. In cotton, most farmers in the southeast, mid-south and Texas regions are using diversified weed management programs today, whereas cotton farmers in the western states are primarily relying only on glyphosate. Dicamba will be incorporated into these existing diversified weed management approaches in both soybean and cotton, but will replace in whole or part the use of some currently used non-glyphosate herbicides. Furthermore, it is anticipated that the ability to safely use dicamba over the top of soybean and cotton and the subsequent benefits (e.g., simplicity, flexibility, effectiveness) of using dicamba will encourage farmers currently relying solely on glyphosate to incorporate more diversity into their weed management programs.

The net effects of dicamba use for weed control in soybean and cotton will be to: (1) further mitigate the potential for evolution of herbicide resistance to glyphosate, dicamba and other herbicides; (2) provide overall better weed control for herbicide resistant weeds such as Palmer amaranth and waterhemp, and hard-to-control weeds such as morningglory and wild buckwheat; (3) help to manage glyphosate-resistant weeds, therefore preserve and grow conservation tillage acres and its associated environmental benefits; (4) increase the adoption of proactive measures to mitigate the evolution and spread of herbicide resistant broadleaf populations[11]; and (5)

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[11] Grower adoption of recommended weed resistance management programs has increased in recent years, however inconvenience, difficulty or concerns associated with these programs (e.g., plant back intervals, rainfall and/or soil restrictions, crop safety concerns) have been a factor in adoption. Because of the compatibility and complementary

displace, in part, some herbicides that have less benign human health and environment profiles compared to dicamba (e.g., paraquat).

DT soybean and DGT cotton will be sold only in soybean and cotton varieties that also contain glyphosate-tolerance. Stacking DT soybean and/or DGT cotton with glyphosate-tolerant traits would enable use of a combination of different herbicide modes of action on these crops, an approach that is expected to manage existing hard-to-control and resistant weeds, and mitigate the potential for future development of herbicide-resistant weeds (Duke and Powles 2009). The use of dicamba for soybean, and dicamba and glufosinate for cotton, provides enhanced weed management options in soybean and cotton cultivation to control a broad spectrum of broadleaf weed species. These uses of dicamba and glufosinate also provide effective control of herbicide resistant broadleaf weeds that have arisen in certain areas of the U.S. and which are impacting both conventional and existing genetically engineered (GE) crops. Existing GE crops have provided enormous benefits to farmers in recent decades, including improved yields, lower costs, decreased emissions from farm equipment, increased use of conservation tillage and associated environmental benefits, and the ability to use herbicides with a more benign human health and environmental profile. These existing GE crops continue to offer these benefits, and the availability of new herbicide tools should be used to offset the development of more widespread selection of resistant weeds so that glyphosate continues to be an important weed management tool nationwide. Today, successful integration of DT soybean and DGT cotton can enhance weed management systems by providing additional in-crop herbicide modes-of-action, while fostering growers’ use of established production practices, reduced tillage systems, and the same planting and harvesting machinery. DT soybean and DGT cotton will also help growers maintain yield and quality to meet the growing need for food, feed and fiber, both domestically and for export markets.

Equally important are the potential negative impacts may result if new herbicide tools such as DT soybean and DGT cotton are not available to U.S. growers: (1) the number of herbicide resistant weed species and the number of acres infested with resistant weed populations would be expected to grow, consequently, additional financial and environmental challenges are likely; and (2) important herbicide options may lose their effectiveness forcing growers to incorporate other less economical cultural practices. Many weed scientists have speculated that for certain herbicides and weed species (i.e., glufosinate or PPO herbicides such as flumioxizin and fomesafen in *Amaranthus* spp.) resistance will evolve and grow in the absence of new herbicide options (Tranel et al. 2010). Since these herbicides are currently major tools used to manage glyphosate and ALS resistant *Amaranthus* spp. in soybean and cotton, farmers will be forced to incorporate mechanical practices which will be less effective and result in a general reduction in yields, as well as loss of conservation tillage acres.

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nature of dicamba with the glyphosate-tolerant cropping system, the reluctance of some farmers to implement recommended resistant management programs may be reduced.

Dicamba Resistance: Potential

The auxin herbicide group is the oldest class of herbicides and includes 2,4 D - the first herbicide commercialized in the U.S. in the late 1940's. To date, globally there are only 29 species with confirmed resistance to auxins. Of these 29 species, there are five species globally with confirmed resistance to dicamba, including four species in the U.S. and Canada, and 17 species with confirmed resistance to 2,4-D in the U.S. (Heap 2014e). This is a relatively low incidence of resistance considering the length of time these products have been used and the volume of use in the U.S. and worldwide. This low level of resistance is most likely due to inherent physiological activity of auxins in plants and genetic factors, as well as how they are generally used in farm level weed management programs (i.e., they are often used in conjunction with other herbicide mode of actions).

From a physiological and genetics perspective the potential for resistance to evolve to dicamba is considered low by leading academic experts. A full explanation of these factors was provided by Dr. Mithila Jugulam and J. Christopher Hall as presented in comments submitted on June 24, 2013 to USDA during the DT soybean and DGT cotton EIS Notice of Intent comment period (See Appendix A). These authors also published a scientific paper in 2011 that provided a thorough review of what is known about auxin resistance (Mithila, et al. 2011). As presented and summarized there, the low rate of evolution of resistance to auxins is likely due to: (1) the rare presence of alleles imparting resistance; (2) a fitness penalty associated with resistant alleles; (3) the complex mode of action of these herbicides; (4) the mode of action in plants may be governed by multiple genes which in turn may mean multiple genes are needed for resistance; and (5) in some species, resistance may be conferred only by recessive genes. Dicamba, 2,4-D and most other auxins such as MCPA are commonly used in combinations with other herbicides either as mixtures or in sequences. For dicamba, this is demonstrated in the data provided in Table 2. Also, in use areas such as pastures and turf, non-chemical weed management activities such as mowing are also used in building diversified weed management programs and assists in retarding the selection and proliferation of auxin resistant biotypes. While resistance to dicamba and other auxins has evolved in some species, the evidence indicating a low potential for resistance to evolve does suggest that reasonable resistance management practices can be implemented to effectively mitigate or prevent widespread resistance from evolving.

Table 2: Summary of Dicamba Use in U.S. Agricultural Practices

U.S. Total	2012 Treated Acres			% Dicamba Only
	Total Dicamba (mixtures + alone)	Dicamba Only	Dicamba Mixtures	
Corn	11,919,841	441,945	11,477,896	4%
Fallow	6,665,137	17,757	6,647,380	0.3%
Winter Wheat	3,622,105	135,020	3,487,085	4%
Pastureland	3,221,382	492,671	2,728,711	15%
Spring Wheat	1,804,741	79,148	1,725,593	4%
Sorghum	1,683,586	49,491	1,634,095	3%
Cotton	1,455,312	79,093	1,376,219	5%
Soybeans	1,055,926	3,215	1,052,711	0.3%
Sugarcane	190,317	-	-	0%

Source: BASF Corporation market research

Cross-resistance to other auxin herbicides and herbicides with different modes of action also needs to be considered. The best understood case of cross resistance between different herbicides with different modes of action involves metabolic resistance, specifically hydroxylation of cytochrome P450's (Powles and Yu 2010). As presented by Drs. Jugulam and Hall in their comments to USDA, the relative potential of dicamba resistance to be a source of cross-resistance to herbicides with different modes of action is low based upon the research conducted to date. As they state, "Of the 5 species (with resistance to auxins) where metabolism has been studied, in only 1 species and herbicide combination (MCPA resistant hemp-nettle) has metabolism been suspected." However, the potential for cross-resistance to other herbicides within the auxin group, particularly cross-resistance between dicamba and 2,4-D exists, and a few confirmed 2,4-D resistant biotypes have exhibited resistance to dicamba. However according to available research not all weed species or populations with resistance to 2,4-D are cross-resistant to dicamba and vice versa (Mithila et al. 2011).

Impact of Dicamba Resistance

As for any herbicide, there is always the potential for resistance to evolve as a function of its use. However, this potential can be reduced by farmer adoption of certain best management practices, foremost of which is to use herbicides in a diversified weed management program within a specific crop and/or across a crop rotation. With the approval of DT soybean and DGT cotton, the use of dicamba for weed control is expected to increase relative to uses in currently approved crops and farming systems. As such, the potential exists for new species to evolve resistance to dicamba. However, the probability of resistance developing depends on the weed management practices utilized in current dicamba crops and farming systems, as well as the practices that will be employed for the new uses of dicamba in DT soybean and DGT cotton. In evaluating the impact of dicamba resistance, should it arise, it is also important to evaluate the impact of resistance on current uses of dicamba. The following is an assessment of the risk of, and mitigation of the potential for, dicamba resistance in crops and farming systems where dicamba use is currently approved.

Methods

For this analysis, BASF Corporation market research information was used to identify and characterize weed management practices in the major markets where dicamba is used today. The analysis was conducted by regions because dicamba use and weed management practices can vary across different regions of the U.S. States were divided into four regions and the states in each region were selected on the basis of where soybeans and cotton are primarily grown. The states assigned to each region are listed in Table 3.

Table 3: Regional Classifications Used in Assessment

Region	States
Plains[1]	North Dakota, South Dakota, Nebraska, Oklahoma, Kansas, Texas
Delta (Midsouth)[2]	Mississippi, Arkansas, Louisiana, Tennessee
Southeast[3]	North Carolina, South Carolina, Georgia, Alabama
Midwest[4]	Iowa, Illinois, Indiana, Ohio, Minnesota, Wisconsin, Missouri, Michigan

[1] The Plains region above is included in Table II.B-2 U.S. Soybean Production by Region and State in 2012: Midwest and Plains Regions from the November 2013 Environmental Report. Cotton is not typically produced in this region, except for Oklahoma and Texas.

[2] The Mid-South region above is included in Table II.B-4 Common Weeds in Soybean Production: Southeast region and Table II.B-15 Common Weeds in Cotton Production in the Mid-South Region of the U.S. from the November 2013 Environmental Report.

[3] The Southeast region above is included in Table II.B-4 Common Weeds in Soybean Production: Southeast region and Table II.B-14 Common Weeds in Cotton Production in the Southeast Region of the U.S. from the November 2013 Environmental Report.

[4] The Midwest region above is included in Table II.B-3 Common Weeds in Soybean Production: Midwest Region from the November 2013 Environmental Report. Cotton is not typically produced in this region.

Results and Discussion

Current Dicamba Uses and Identification of Highest Risk Areas

Dicamba herbicides are currently registered for use in asparagus, conservation reserve programs, corn, cotton, fallow croplands, general farmstead (non cropland), sorghum, grass grown for seed, hay, proso millet, pasture, rangeland, small grains, soybeans, sugarcane, and turf (BASF Corporation 2008). In each region, a subset of labeled crop uses was examined in a market research analysis, see Table 4. The analysis focused on these market segments because they represent the crop segments that could be impacted the most if resistance evolved due to the use of dicamba in DT soybean and DGT cotton. They also represent the highest volumes of dicamba use today. Some dicamba uses listed in the Clarity herbicide label were not considered relevant to this analysis and have been excluded as follows: (1) grass grown for seed and proso millet because crop production tends to be concentrated in the western U.S., which is outside the primary areas of soybean and cotton production; (2) turf uses because the weed targets are different; (3) asparagus because the crop acreage and use of dicamba is minor; and (4) conservation reserve programs and general farmstead because their weed targets and dicamba use patterns would be similar to uses in fallow and pasture and rangeland.

Dicamba is an effective broadleaf herbicide and is limited to preplant uses in broadleaf crops that lack crop safety[12]; in other crops, dicamba is used in-crop when there is adequate selectivity/crop safety. Dicamba is used in-crop in corn, wheat, grass pastures and sorghum. In soybeans and cotton, dicamba can be safely used prior to planting when established plant back intervals are observed.

Table 4: Dicamba Use by Crop and Year

Crop/Year	**2006**	**2008**	**2010**	**2012**
	Dicamba Treated Acres			
Corn	8,080,614	8,113,801	6,459,632	11,919,844
Fallow	2,144,260	3,017,717	4,274,678	6,665,140
Wheat, Winter	2,348,897	3,742,572	2,577,953	3,622,102
Pastureland	1,454,649	1,218,179	2,604,944	3,221,382
Wheat, Spring	1,569,079	1,351,665	1,512,894	1,804,742
Sorghum (Milo)	550,795	1,114,162	955,997	1,683,584
Cotton	590,953	589,919	854,649	1,455,309
Soybeans	279,275	529,638	648,509	1,055,926
Sugarcane	198,042	177,089	225,295	190,317
Barley	108,393	211,067	101,158	47,144

Source: BASF Corporation Market Research

Within the above defined geographical regions, the combined use of dicamba in currently labeled crops and farming systems (e.g., fallow) generally represents a low percentage of total planted acreage of these crops and farming systems (see Table 5). Only in the Plains states – where dicamba is a primary weed control tool in corn, fallow and sorghum – is dicamba used on more than 10% of the total production area across the crops and farming situations where dicamba is approved for use. (See Table 6 for detailed information on dicamba uses in each of the defined geographical regions.) The relatively low use of dicamba today across these regions indicates an overall low level of resistance selection pressure on the targeted weeds.

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[12] Injury can occur when broadleaf crops come in contact with dicamba.

Table 5: Dicamba Treated Acres by Region

Region/Year	2012
	Dicamba Treated Acres as % of Planted Area of Crops listed in Table 2
Plains	14%
Midsouth	9%
Southeast	4%
Midwest	3%

Monsanto proprietary grower survey data from 2013

Dicamba Weed Targets

The primary weed targets for dicamba as identified by farmers in the market research surveys for each crop/farming system are listed in Table 6. Based on the known weed control spectrum of dicamba, growers applied dicamba to primarily target annual, biennial, and perennial broadleaf weeds, but also targeted a mixture of warm season (summer germinating/growing) and cool season (fall, winter, and spring germinating/growing) species. Where the weed spectrum is dominated by cool season species, dicamba applications would most likely be in the fall or spring. Conversely, if the weed spectrum is dominated by warm season species, the applications would be in the late spring and summer. Information on current application timing of dicamba in the various labeled crops is summarized in Table 7.

Characterizing the timing of dicamba applications and associated weed targets is important to understand the intensity of selection pressure on specific species, particularly those that are the target of in-crop applications of dicamba in DT soybean and DGT cotton. In DT soybean and DGT cotton, a summer spectrum (e.g., warm season) of broadleaf weeds will be the primary weed targets. Preplant / preemergence uses of dicamba prior to planting of DT soybean or DGT cotton will be similar to current uses of dicamba in soybeans and cotton today except for the elimination of planting intervals that will allow dicamba to be applied before, at and after planting. The major warm season weeds that are the target of dicamba applications in current crop uses are listed in Table 8 through Table 11.

Per the information found in Tables 6 and Appendix B, there will be some overlap of dicamba targeted weed spectrums between the new uses in DT soybean and DGT cotton and other crops/farming systems where dicamba is currently used, but in many cases there is no overlap of weed species. Note: Appendix B contains a breakdown of common weeds in soybean and cotton by region. In particular, there will be little overlap in the cool season and perennial species that are the focus of dicamba applications today in wheat and pastureland with weed targets for the new uses in DT soybean and DGT cotton. Species common to both current and new uses of dicamba are the warm season species *Amaranthus* spp. (i.e., Palmer amaranth, waterhemp, redroot pigweed), *Ambrosia* spp. (i.e., ragweed), morningglory, wild buckwheat, kochia, cocklebur, and lambsquarters. Another important target weed common to current and new uses of dicamba is the cool season species, *Conyza* spp. (i.e., horseweed or marestail). Therefore, with this overlap, a key to managing the potential risk for dicamba resistance in these species due to combined selection pressure across current and new uses is the diversified weed management systems in which dicamba is currently used and expected to be used in DT soybean and DGT cotton. Diversified weed management programs are the key to managing increased selection pressure. Weed management system recommendations in DT soybean and DGT cotton, as defined in Monsanto‗s submissions to USDA, will include a combination of herbicides with different modes of action in addition to dicamba and glyphosate, and glufosinate in the case of cotton. The weed management systems in which dicamba is used in currently approved crops and farming systems are defined in the next section.

Weed Management Systems for Current Dicamba Uses

The grower market research data used in this analysis indicates that dicamba is primarily used today in combination with other herbicides with overlapping activity on dicamba targeted weeds. This is because dicamba expands or complements the broadleaf activity of a wide range of herbicides. According to market research data (see Table 2) the application of dicamba in the absence of another herbicide is at or below 5% of the total dicamba treated acres in each crop/farming system except in pastureland, where approximately 15% of dicamba‗s applications are made in the absence of other herbicides. This provides additional evidence that dicamba is generally used in a diversified weed management program with other herbicides and as such will significantly mitigate the evolution of dicamba resistance as a function of dicamba use in current labeled crops and in DT soybean and DGT cotton, even though there is some overlap of weed species between soybean and cotton, and other crops where dicamba can be used. Additionally this will significantly mitigate the potential for evolution of dicamba resistance in possible crop rotation systems where dicamba could be used in each rotation.

Herbicide Options to Control Weeds in Current Dicamba Crop Uses

Should resistance to dicamba evolve over time to any of the targeted weed species due to any use of dicamba, there will be multiple herbicide options available in the crops and farming systems where dicamba is currently being used. A listing of some of these herbicide options is presented in Table 8 through Table 11. It is important to note that there are multiple herbicide options and multiple modes of action available across the dicamba-labeled crops. Therefore, even if populations where resistance to more than one herbicide mode of action is present, there is likely to be an alternative herbicide available for use and therefore minimal impact on production and herbicide uses in traditional dicamba use areas would be expected.

Scope and Impact of Existing Dicamba Resistant Species

Dicamba-resistant weeds account for 1% of resistant biotypes today (Heap 2014f). To date, there are four species with known resistant biotypes to dicamba in the U.S./Canada after over 40 years of use: common hempnettle (*Galeopsis tetrahit*), wild mustard (*Sinapis arvensis),* kochia (*Kochia scoparia),* and prickly lettuce (*Lactuca serriola* L.) (Heap 2014f).

The dicamba resistant biotypes identified in Canada include common hempnettle and wild mustard. Common hempnettle biotypes identified in barley, cereals, cropland, and wheat in 1998 demonstrated resistance to dicamba, fluroxypyr, and MCPA (Heap 2014h). Hempnettle is an annual weed most common in the northern plains of the U.S. and Canada, where it is generally a target for control in small grains. It is not a common or problematic weed species in soybean or cotton production (See Tables II.B.3 -5 and II.B.14 -17 in the November 2013 Environmental Report).

Wild mustard biotypes with resistance to 2,4-D, dicamba, dichlorprop, MCPA, mecoprop, and picloram were identified in Canada in 1990 in barley, cropland and wheat (Heap 2014a). Wild mustard is a common cool season weed in many areas of the U.S. It is most often a weed target in no-till situations at the early burndown application before planting crops such as soybeans or cotton. Wild mustard has not been identified as a major weed in soybean and cotton production (See Tables II.B.3 -5 and II.B.14 -17 in the November 2013 Environmental Report).

Only kochia and prickly lettuce dicamba resistant biotypes have been identified in the U.S. Dicamba resistance kochia has been confirmed in ND and MT in wheat (1995), ID on roadsides (1997), and NE in corn (2010) (Heap 2014b). Kochia is not a common or problematic weed species in most soybean and cotton producing areas. However, kochia is a problematic weed in western sections of Kansas and Nebraska where some soybean is produced. (See Tables II.B.2-4 and Tables II.B.14-17 in the November 2013 Environmental Report). Kochia can also be found in the north Texas cotton growing areas. Additional herbicide options such as glyphosate, glufosinate, pendimethalin, clomazone, paraquat, fumioxazin, and metribuzin are some of the options available to use in place of dicamba to control dicamba resistant kochia in these areas. While Kochia populations have also been identified with glyphosate, PSII (e.g. atrazine, metribuzin) and ALS (e.g. imazethapyr, thifensulfuron) resistance, not all populations are resistant to these herbicides and they remain effective in many situations.

Prickly lettuce with 2,4-D resistance and cross-resistance to MCPA and dicamba was identified in Washington in 2007. Prickly lettuce is an annual or biennial that is found throughout the U.S. It is not commonly a targeted weed for control in soybeans or cotton since it is primarily found in cereals, orchards, pastures, roadsides, railroads, and waste areas (See Tables II.B.3 -5 and II.B.14-17 of the November 2013 Petitioner’s Environmental Report (Monsanto 2013a)).

The persistence of herbicide resistant biotypes is in part related to the presence or absence of a fitness penalty that may be associated with the resistant alleles. A fitness penalty is characterized as resistant biotypes being less competitive with non-resistant biotypes of the same species and therefore less persistent in the environment. As reviewed by Mithila et al. (2011), there is evidence of reduced fitness in some auxin resistant biotypes. The presence of a fitness penalty has been suggested to be a reason why auxin resistant biotypes do not appear to persist in the environment.

In summary, of the species with known resistance to dicamba today, the primary species of concern relative to the new uses of dicamba in DT soybean and DGT cotton is kochia: its geographical distribution overlaps with some of the soybean and cotton production areas, it is a summer annual, and it would be an in-crop weed target. The key to mitigating dicamba resistance is implementation of a diverse weed control program that includes redundant, effective control measures, and scouting to eliminate weed escapes, as noted above, however, there are other herbicide options to manage any dicamba-resistant populations should they arise in both soybeans and cotton.

Weed Resistance Management Stewardship

To support the introduction of varieties containing DT soybean and DGT cotton, Monsanto will use multiple methods to distribute technical and stewardship information to growers, academics and grower advisors regarding the use of the product as part of a diversified weed management system. Growers who purchase Monsanto varieties containing DT soybean or DGT cotton sign a limited use license known as the Monsanto Technology Stewardship Agreement (MTSA). The MTSA obligates growers to comply with certain requirements, including the Monsanto Technology Use Guide (TUG). The TUG will set forth the requirements and best practices for the cultivation of DT soybean and DGT cotton including recommendations on weed resistance management practices. Monsanto provides up to date information and resources to assist growers in implementing weed resistance management strategies through its weed management website[13] and mobile applications.

Conclusions

With the approval of DT soybean and DGT cotton, there will be an increase in dicamba use and therefore some possibility of an increased potential for resistance to evolve. However, this risk will be greatly mitigated by the fact that dicamba is used in diversified weed management systems today, in current markets, and will likewise be used in diversified weed management systems when dicamba is approved for use in DT soybean and DGT cotton. Monsanto, BASF,

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[13] http://www.monsanto.com/weedmanagement/Pages/field-management-guidelines.aspx

the Weed Science Society of America (WSSA), academics and extension service agents have made significant progress in changing grower behavior to adopt diversified weed management practices. On-going and planned educational efforts will continue to stress the importance of using dicamba in a diversified program, therefore adoption of diversified weed management practices is expected to continue. Moreover, in many instances weeds that are targeted by a dicamba application (i.e., *Amaranthus* sp. such as Palmer amaranth and waterhemp) require the use of multiple weed control practices in order to meet grower weed control expectations, this provides additional assurances that dicamba will be used in a diversified program.

When a herbicide is used in a diversified weed management system that includes other herbicides with overlapping spectrum of control and different modes-of-action, it can be used repeatedly within a cropping season and across multiple seasons without significantly impacting the risk of resistance (Beckie and Reboud 2009). Therefore, the potential for development of dicamba resistance can be significantly mitigated when dicamba-tolerant crops are rotated with each other and/or with crops where dicamba is currently approved. There is strong scientific justification for this conclusion, as indicated by theories of resistance evolution and management supported by field and resistance modeling studies (Beckie and Reboud 2009; Neve, et al. 2011) and the weed science academic community.[14,15,16]

However, the possibility of gradual evolution of resistance (through selection) to any herbicide cannot be completely eliminated if the benefits of the use are to be realized. Therefore, an understanding of the impact of this potential resistance and ways to mitigate the impact are an important part of weed resistance risk assessment. In this case, options for managing key dicamba targeted weeds in each of the major crops and farming systems where dicamba is used today was evaluated. This analysis supports that the availability of multiple herbicide options with different modes of action will mitigate any potential future impacts of dicamba resistance. Likewise, there are multiple options to manage dicamba resistant populations of kochia should this become an issue in some of the western soybean and cotton growing regions where DT soybeans and DGT cotton may be grown. In addition, the potential for development of additional dicamba resistant populations will be mitigated through the use of diversified weed management programs, which include the use of multiple herbicides, in DT soybeans and DGT cotton. The availability of options to manage dicamba resistant populations, plus the indications that resistant biotypes are not as competitive as non-resistant biotypes, both point to low impact of resistant populations on farming operations and the environment.

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[14] APHIS-2013-0043-0019, *available at* http://www.regulations.gov/#!documentDetail;D=APHIS-2013-0043-0019

[15] APHIS-2013-0043-0027, *available at* http://www.regulations.gov/#!documentDetail;D=APHIS-2013-0043-0027

[16] APHIS-2013-0043-0054 *available at* http://www.regulations.gov/#!documentDetail;D=APHIS-2013-0043-0054

Lastly, leading experts on resistance to auxinic herbicides, and in particular dicamba and 2,4-D, are clear in their judgment that the evolution of resistance to dicamba is not likely to result in cross-resistance to herbicides with other modes of action and therefore the risk of dicamba resistance is no greater than the risk of resistance to most other herbicides. In fact, evidence to date indicates that resistance to dicamba and auxins is a lower probability than many other herbicides. The main reasons for this judgment are that definitive mechanisms for resistance to auxinic herbicides have yet to be defined; there is no evidence of cross-resistance to other herbicide modes of action after more than 50 years of use of any auxinic herbicide and where resistance mechanisms for dicamba have been studied, there is little to no evidence for the type of mechanism that would suggest the possibility for cross-resistance to other herbicides modes of action.

In closing, the keys to minimizing the impact of resistance to any herbicide are first to mitigate the risk of resistance evolving, and second, to have economical and practical options for managing resistance should it evolve. In the case of the proposed new uses of dicamba in DT soybean and DGT cotton, there is ample evidence that the impact of dicamba resistance is minimal and manageable and does not rise to a level of concern that would adversely impact the environment nor be of a significant economic burden to producers. In the unlikely case that broadleaf weeds were to evolve or develop resistance to dicamba over time, existing cultivation and alternative herbicide tools (see Section II.B.2.d in the November 2013 Environmental Report (Monsanto 2013a)) for a description of alternative herbicides) would remain potential options to provide effective control. Additionally, any potential risks are far outweighed by the benefits that can be derived from dicamba use to mitigate resistance to other herbicides in an economical fashion.

Table 6. Dicamba Weed Targets [1]

Crop	**Dicamba Treated Acres**	**Total Crop Acres**	**Dicamba Treated as % of Total**	**Dicamba Weed Targets (listed in order of treated acres)**								
Midwest Region												
Corn	3,403,861	56,350,032	6%	lambs-quarters	giant ragweed	velvetleaf	red pigweed	waterhemp	cocklebur	ragweed	morning-glory	marestail
Cotton	210,863	375,002	56%	marestail	red pigweed	chickweed	henbit	Palmer amaranth				
Pasture-land	48,788	19,222,408	0%	musk thistle	bull thistle	ragweed	Canada thistle					
Soybeans	85,474	43,690,011	0%	marestail	waterhemp	sweet clover						
Wheat, Spring	10,000	1,400,016	1%	red pigweed	wild mustard							
Wheat, Winter	33,543	3,225,000	1%	chickweed	velvetleaf	giant ragweed						
Total for Region	**3,792,529**	**124,262,469**	**3%**									
Southeast Region												
Corn	324,511	1,795,003	18%	morning-glory	red pigweed	giant ragweed	marestail	lambs-quarter	bur-cucumber	cocklebur	sicklepod	
Cotton	73,815	2,469,994	3%	marestail	evening primrose							
Pasture-land	121,618	6,734,886	2%	wild carrot	Canada thistle	bitter sneezeweed	red pigweed	dandelion	dog fennel			
Soybeans	52,800	2,610,001	2%	marestail	smartweed							
Total for Region		**572,744**	**4%**									

Table 6 (continued). Dicamba Weed Targets [1]

Delta (Midsouth) Region

Crop	Dicamba Treated Acres	Total Crop Acres	Dicamba Treated as % of Total	Dicamba Weed Targets (listed in order of treated acres)								
Cotton	670,995	1,769,995	38%	marestail	red pigweed	curly dock	ragwort	evening primrose	hebit			
Soybeans	670,148	7,732,424	9%	marestail	dock	ragweed	redroot pig	Morning-glory	sicklepod	Palmer amaranth		
Corn	452,712	2,861,058	16%	marestail	Palmer amaranth	redroot pig	morning-glory	hebit	dock			
Sugarcane	186,911	425,003	44%	morning-glory	redroot pigweed	clover						
Pasture-land	175,758	10,065,529	2%	thistle	red pigweed	blue vervain	marigold	dogfennel	croton	Canada thistle		
Wheat, Winter	64,992	888,010	7%									
Sorghum (Milo)	22,578	269,999	8%									
Fallow	630	91,858	1%									
Total for Region	**2,244,724**	**24,103,876**	**9%**									

Table 6 (continued). Dicamba Weed Targets [1]

Plains Region

Crop	Dicamba Treated Acres	Total Crop Acres	Dicamba Treated as % of Total	Dicamba Weed Targets (listed in order of treated acres)								
Barley	12,199	1,174,988	1%									
Corn	6,234,992	26,270,008	24%	kochia	redroot pigweed	waterhemp	Russian thistle	lambs-quarters	Palmer amaranth	wild buckwheat	morning glory	velvetleaf
Cotton	499,636	7,197,966	7%	marestail	Russian thistle	wild mustard	ironweed	kochia	henbit	redroot pigweed		
Fallow	3,391,068	6,798,789	50%	kochia	Russian thistle	redroot pigweed	field bindweed	puncture vine	wild buckwheat	Palmer amaranth	devils claw	marestail
Pastureland	2,539,862	32,306,093	8%	ragweed	broomweed	marshelder	St. johnswort	milkweed	sunflower	Texas blueweed	mild mustard cocklebur	thistle
Sorghum (Milo)	1,556,474	5,404,998	29%	kochia	redroot pigweed	Russian thistle	filed bindweed	mild mustard	tumple pigweed	Palmer amaranth	marestail	puncture vine
Soybeans	244,253	18,309,988	1%	marestail	kochia	red pigweed	henbit	waterhemp	pennycress	wild mustard	pepperweed	
Wheat, Spring	1,127,246	8,108,004	14%	kochia	Canada thistle	buckwheat	field bindweed	Russian thistle	ragweed	moneywort	wild mustard	
Wheat, Winter	2,688,190	24,299,994	11%	kochia	redroot pigweed	Russian thistle	yellow mustard	wild mustard	field bindweed	wild buckwheat	fireweed	hebit
Total for Region	**18,293,920**	**129,870,828**	**14%**									

Table 7. Timing of Dicamba Applications for Current Crop Uses[1]

Crop and Application Timing	Sum of Total Area Treated	Weed Spectrum of primary application timing
Corn		
At Planting	104,159	
Before Crop Emergence	638,605	
Early Post (Herbicides)	672,194	
Last Fall	446,739	
Late Post (Herbicides)	7,986,902	warm season
Prior to Planting	2,071,242	cool season
Corn Total*	11,919,841	
Cotton		
Last Fall	161,528	
Prior to Planting	1,293,784	warm and cool season
Cotton Tota*l	1,455,312	
Soybean		
Last Fall	70,909	
Late Post (Herbicides)		
Prior to Planting	985,017	warm and cool season
Soybeans Total*	1,055,926	
Sorghum (Milo)		
At Planting	37,631	
Before Crop Emergence	113,617	
Early Post (Herbicides)	22,094	
Last Fall	593,529	warm season
Late Post (Herbicides)	148,849	
Prior to Planting	767,866	warm season
Sorghum (Milo) Total*	1,683,586	
Sugarcane		
At Planting	1,116	
Before Crop Emergence		
Early Post (Herbicides)	7,958	
Last Fall	8,658	
Late Post (Herbicides)	94,344	warm season
Prior to Planting	78,241	warm season
Sugarcane Total*	190,317	

Table 7 (continued). Timing of Dicamba Applications for Current Crop Uses[1]

Crop and Application Timing	Sum of Total Area Treated	Weed Spectrum of primary application timing
Barley		
Before Crop Emergence	239	
Early Post (Herbicides)		
Last Fall	4,764	
Late Post (Herbicides)	19,055	warm season
Prior to Planting	23,086	cool season
Barley Total*	47,144	
Wheat, Spring		
At Planting	26,401	
Before Crop Emergence	55,983	
Early Post (Herbicides)	2,499	
Last Fall	448,317	cool season
Late Post (Herbicides)	631,465	warm season
Prior to Planting	640,076	cool season
Wheat, Spring Total*	1,804,741	
Wheat, Winter		
At Planting	6,838	
Before Crop Emergence	12,127	
Early Post (Herbicides)		
Last Fall	1,176,545	warm and cool season
Late Post (Herbicides)	2,426,595	warm season
Wheat, Winter Total*	3,622,105	
Fallow		
Last Fall	855,875	
This Year (Pasture, Fallow)	5,809,262	warm and cool season
Fallow Total*	6,665,137	
Pastureland		
Last Fall	72,524	
This Year (Pasture, Fallow)	3,148,858	warm and cool season
Pastureland Total*	3,221,382	

[1] 2012 BASF Market Research Data

* Individual crop totals vary slightly from the total dicamba values shown in Table 2 due to rounding of the individual values for each application timing prior to summing all application timing acres for each crop.

Table 8. Herbicide Options to Control Primary Weed Targets in Midwest Region (IA, IL, IN, OH, MN, WI, MO, MI)*

Cotton									
	Marestail[3]	**Pigweed, redroot[3]**	**Chickweed[3]**	**Henbit[3]**	**Palmer amaranth[3]**				
	glufosinate	diuron	glyphosate	glyphosate	diuron				
	prometryn	fluometuron	paraquat	oxyflurorfen	fluometuron				
		metolachlor	glufosinate	paraquat	metolachlor				
		fomesafen	prometryn	prometryn	fomesafen				
Number herbicide MOA available	**2**	**4**	**4**	**4**	**3**				
Corn									
	Lambsquarters[1]	**Giant ragweed[1]**	**Velvetleaf[1]**	**Pigweed, redroot[1]**	**Waterhemp[1]**	**Cocklebur[1]**	**Ragweed, common[1]**	**Morningglory[1]**	**Marestail[1]**
	acetochlor	atrazine	atrazine	acetochlor	acetochlor	atrazine	acetolchlor	atrazine	atrazine + paraquat
	atrazine	mesotrione	isoxaflutole	atrazine	atrazine	mesotrione	Atrazine	saflufenacil	rimsulfuron + mesotrione + atrazine
	mesotrione	saflufenacil	bentazon	isoxaflutole	isoxflutole	saflufenacil	saflufenacil	mesotrione	metolachlor + atrazine + mesotrione
	saflufenacil	tembotrione	halosulfuron	mesotrione	mesotrione	tembotrione	tembotrione	carfentrazone	saflufenacil + glufosinate
	tembotrione		mesotrione	tembotrione	tembotrione	bentazon	bentazon	nicosulfuron	
Number herbicide MOA available	**4**	**3**	**5**	**4**	**4**	**4**	**5**	**5**	**7**

Table 8 (continued). Herbicide Options to Control Primary Weed Targets in Midwest Region (IA, IL, IN, OH, MN, WI, MO, MI)*

Soybean			
	Marestail[1]	**Waterhemp**[1]	**Sweet clover**[2]
	saflufenacil + glufosinate	metolachlor	saflufenacil + glyphosate
	metribuzin + glufosinate	sulfentrazone	saflufenacil
	chlorimuron + glyphosate	flumioxazin	glyphosate + fumioxazin
		fomesafen	
		lactofen	
Number herbicide MOA available	**5**	**2**	**2**
Spring Wheat			
	Pigweed, redroot[1]	**Wild mustard**[1]	
	carfentrazone	prosulfuron	
	sulfosulfuron	sulfosulfuron	
	florasulam	florasulam	
	prosulfuron	pyroxsulam	
Number herbicide MOA available	**2**	**1**	

Table 8 (continued). Herbicide Options to Control Primary Weed Targets in Midwest Region (IA, IL, IN, OH, MN, WI, MO, MI)*

Winter Wheat				
	Chickweed[1]	**Velvetleaf[4]**	**Giant ragweed[1]**	
	propoxycarbazone	carfentrazone	prosulfuron	
	florasulam	prosulfuron	florasulam	
	prosulfuron			
	pyroxsulam			
Number herbicide MOA available	**1**	**2**	**1**	
Pastureland				
	Thistle, musk[5]	**Thistle, bull[3,5]**	**Ragweed[6]**	**Thistle, canada[5]**
	metsulfuron	metsulfuron[5]	metsulfuron	metsulfuron
		chlorsulfuron[3]	metsulfuron + chlorsulfuron	
Number herbicide MOA available	**1**	**1**	**1**	**1**

*Source for weed targets was Monsanto proprietary grower survey data from 2012. Weeds listed in descending order according to acres treated with dicamba. Alternative herbicides actives were rated 7-8 and above (good) for control of targeted weed.

[1] Loux, et al. 2013
[2] University of Nebraska-Lincoln 2013
[3] Mississippi State University 2013
[4] University of Missouri 2013
[5] University of Arkansas 2013
[6] Penn State University 2013

Table 9. Herbicide Options to Control Primary Weed Targets in Southeast Region (NC, SC, GA, AL)*

Cotton								
	Marestail[5,6]	**Evening primrose**[5]						
	paraquat + diuron[5]	tribenuron + thifensulfuron						
	glufosinate[6]	paraquat						
	prometryn[6]	prometryn						
		glufosinate						
Number herbicide MOA available	**4**	**4**						
Corn								
	Morningglory[1]	**Pigweed, redroot**[1]	**Giant ragweed**[2]	**Marestail**[3]	**Lambsquarters**[1]	**Burcucumber**[1]	**Cocklebur**[1]	**Sicklepod**[1]
	atrazine	acetochlor	atazine	mesotrione + atrazine	atrazine	atrazine	atrazine	atrazine
	flumetsulam	atrazine	mesotrione	glufosinate	flumetsulam	primsulfuron	flumetsulam	flumetsulam
	mesotrione	flumetsulam	saflufenacil	tembotrione + atrazine	mesotrione	paraquat	mesotrione	primsulfuron
	foramsulfuron	mesotrione	tembotrione	topramezone + atrazine	carfentrazone	foramsulfuron	carfentrazone	glyphosate
Number herbicide MOA available	**4**	**4**	**4**	**3**	**4**	**4**	**4**	**3**

Table 9 (continued). Herbicide Options to Control Primary Weed Targets in Southeast Region (NC, SC, GA, AL)*

Soybean							
	Marestail[4]	**Smartweed**[4]					
	paraquat + metribuzin	metribuzin					
	glufosinate	clomazone					
		bentazon					
		lactofen					
Number herbicide MOA available	**3**	**4**					
Pastureland							
	Wild carrot	**Thistle, canada**[7]	**Bitter sneezeweed**[7]	**Thistles**[7]	**Pigweed, redroot**[7]	**Dandelion**[7]	**Dogfennel**[7]
		metsulfuron + chlorsulfuron	metsulfuron	metsulfuron + chlorsulfuron	flumioxazin	flumioxazin	metsulfuron + chlorsulfuron
		metribuzin	tebuthiuron	metribuzin	metsulfuron	metsulfuron	tebuthiuron
		hexazinone	metsulfuron + chlorsulfuron	hexazinone	metribuzin	tebuthiuron	
					hexazinone	hexazinone	
Number herbicide MOA available		**2**	**2**	**2**	**3**	**4**	**2**

*Source for weed targets was Monsanto proprietary grower survey data from 2012. Weeds listed in descending order according to acres treated with dicamba.

[1] University of Georgia 2013c

[2] Loux et al. 2013

[3] University of Tennessee 2013

[4] University of Georgia 2013a

[5] University of Georgia 2013b
[6] Mississippi State University 2013
[7] McCullough 2008

Table 10. Herbicide Options to Control Primary Weed Targets in Delta Region (MS, AR, LA, TN)*

Cotton						
	Marestail[1]	**Pigweed, redroot**[1]	**Dock, curly**[1]	**Ragwort, tansy**	**Evening primrose**[1]	**Henbit**[1]
	glufosinate	diuron	tribenuron + thifensulfuron		tribenuron + thifensulfuron	tribenuron + thifensulfuron
	prometryn	fluometuron	oxyflurorfen		paraquat	glyphosate
		metolachlor	paraquat		prometryn	paraquat
		glufosinate	prometryn		glufosinate	prometryn
		pendimethalin				
Number herbicide MOA available	**2**	**4**	**4**		**4**	**4**
Corn						
	Marestail[2]	**Palmer amaranth**[1]	**Pigweed, redroot**[1]	**Morningglory**[1]	**Henbit**[3]	**Dock**[3]
	mesotrione + atrazine	atrazine	atrazine	atrazine	glyphosate	glyphosate
	glufosinate	acetochlor	acetochlor	simazine	paraquat	glyphosate + flumioxazin
	tembotirone + atrazine	saflufenacil	saflufenacil	pyroxasulfone	glyphosate + flumioxazin	
	topramezone + atrazine	mesotrione	mesotrione	mesotrione		
				glyphosate		
Number herbicide MOA available	**3**	**4**	**4**	**4**	**3**	**2**

Table 10 (continued). Herbicide Options to Control Primary Weed Targets in Delta Region (MS, AR, LA, TN)*

Soybean

	Marestail[3]	**Dock, sour[1,3]**	**Ragweed[1]**	**Pigweed, redroot[1]**	**Morningglory[1]**	**Sicklepod[1]**	**Palmer amaranth[1]**
	metribuzin + chlorimuron	tribenuron + thifensulfuron[1]	metribuzin	dimethenamid	imazaquin	fumioxazin	dimethenamid
	flumioxazin	glyphosate + oxyflurorfen[1]	paraquat	fomesafen	fumioxazin	metribuzin	metribuzin
	metribuzin	glyphosate + fumioxazin[3]	fomesafen	metribuzin	chlorimuron	chlorimuron	fomesafen
	chloransulam		fumioxazin	pendimethalin	metribuzin	fomesafen	acetochlor
			chlorimuron	chlorimuron	glyphosate	chloransulam	fumioxazin
Number herbicide MOA available	**3**	**3**	**4**	**5**	**4**	**3**	**3**

Sugarcane

	Morningglory[5,6]	**Pigweed, redroot[5,6]**	**Clover[5]**
	atrazine	atrazine	atrazine
	flumioxazin	flumioxazin	flumioxazin
	sulfentrazone	sulfentrazone	sulfentrazone
	metribuzin	metribuzin	metribuzin
Number herbicide MOA available	**2**	**2**	**2**

Table 10 (continued). Herbicide Options to Control Primary Weed Targets in Delta Region (MS, AR, LA, TN)*

Pastureland							
	Thistle[3]	**Pigweed, redroot**[3]	**Ragweed**[3]	**Vervain, blue**	**Marigold, dwarf**	**Dogfennel**[3,4]	**Croton, woolly**[3]
	metsulfuron + chlorsulfuron	metsulfuron + chlorsulfuron	metsulfuron + chlorsulfuron			metsulfuron + chlorsulfuron[3]	nicosulfuron + metsulfuron
	chlorsulfuron	chlorsulfuron	metsulfuron			tebuthiruron[4]	metsulfuron
		nicosulfuron + metsulfuron					
Number herbicide MOA available	**1**	**1**	**1**			**2**	**1**

*Source for weed targets was Monsanto proprietary grower survey data from 2012. Weeds listed in descending order according to acres treated with dicamba. Alternative herbicides actives were rated 7-8 and above (good) for control of targeted weed.

[1] Mississippi State University 2013
[2] University of Tennessee 2013
[3] University of Arkansas 2014
[4] University of Georgia 2013a
[5] Louisiana State University 2013
[6] Product Labels on CDMS website [http://www.cdms.net/LabelsMsds/LMDefault.aspx?t=]

Table 11. Herbicide Options to Control Primary Weed Targets in Plains Region (ND, SD, NE, KS, OK, TX)*

Cotton							
	Marestail	**Thistle, Russian**	**Mustard, wild**	**Ironweed**	**Kochia**	**Henbit**	**Pigweed, redroot[4]**
							pendimethalin
							fluometuron
							diuron
							metolachlor
							fumioxazin
							carfentrazone
							lactofen
Number herbicide MOA available							**4**

Table 11 (continued). Herbicide Options to Control Primary Weed Targets in Plains Region (ND, SD, NE, KS, OK, TX)*

Corn									
	Kochia[1]	**Pigweed, redroot**[1]	**Waterhemp**[1]	**Thistle, Russian**[1]	**Lambsquarters**[1]	**Palmer amaranth**[1]	**Buckwheat, wild**[2]	**Morningglory**[1]	**Velvetleaf**[1]
	atrazine	atrazine	atrazine	atrazine	atrazine	atrazine	atrazine	atrazine	atrazine
	isoxaflutole	isoxaflutole	isoxaflutole	isoxaflutole	isoxaflutole	isoxaflutole	saflufenacil	saflufenacil	isoxaflutole
	mesotrione	mesotrione	mesotrione	mesotrione	mesotrione	mesotrione	glyphosate	carfentrazone	mesotrione
	saflufenacil	saflufenacil	saflufenacil	saflufenacil	saflufenacil	saflufenacil	glufosinate	foramsulfuron	saflufenacil
	primsulfuron	tembotrione	tembotrione	tembotrione	acetochlor	tembotrione	bentazon		carfentrazone
		acetochlor	acetochlor	glyphosate	carfentrazone	acetochlor	thiencarbazone + tembotrione		fluthiacet
					tembotrione				glyphosate
					glyphosate				tembotrione
Number herbicide MOA available	**5**	**5**	**5**	**5**	**6**	**5**	**6**	**3**	**5**

Table 11 (continued). Herbicide Options to Control Primary Weed Targets in Plains Region (ND, SD, NE, KS, OK, TX)*

Soybean							
	Marestail[1]	**Kochia[1]**	**Pigweed, redroot[1]**	**Henbit[1]**	**Waterhemp[1]**	**Pennycress[1]**	**Mustard, wild[3]**
	paraquat	pendimethalin	metolachlor	glyphosate	metolachlor	glyphosate	carfentrazone
	saflufenacil	clomazone	metribuzin	paraquat	metribuzin	paraquat	metribuzin
	flumioxazin/glyphosate	cloransulam	flumioxazin	imazethapyr	flumioxazin	imazethapyr	bentazon
	metribuzin/chlorimuron	metribuzin	cloransulam	imazaquin	pendimethalin	imazaquin	acifluorfen
	cloransulam	flumioxazin	Pendimethalin	saflufenacil	fluthiacet	saflufenacil	chlorimuron
		fluthiacet	fluthiacet		acifluorfen		fomesafen
Number herbicide MOA available	**5**	**5**	**5**	**4**	**4**	**4**	**4**

Spring Wheat								
	Kochia[1,5]	**Thistles[5]**	**Buckwheat[5]**	**Bindweed, field**	**Thistle, russian[1]**	**Ragweed**	**Moneywort**	**Mustard, Wild[5]**
	Carfentrazone[5]	triasulfuron**	Carfentrazone	no products found	metsulfuron**			triasulfuron
	Saflufenacil[5]	metsulfuron**	triasulfuron		triasulfuron**			metsulfuron
	Imazamethabenz**	chlorsansulam + metsulfuron	metsulfuron		prosulfuron**			florasulam
	triasulfuron[1]	prosulfuron	florasulam					prosulfuron
			prosulfuron					
Number herbicide MOA available	**2**	**1**	**2**	**1**				**1**

Table 11 (continued). Herbicide Options to Control Primary Weed Targets in Plains Region (ND, SD, NE, KS, OK, TX)*

Winter Wheat							
	Kochia[1,5]	**Pigweed, redroot[1]**	**Thistle, russian[1]**	**Mustard, yellow[5]**	**Mustard, wild[5]**	**Bindweed, field**	**Buckwheat, wild[5]**
	carfentrazone	metsulfuron	metsulfuron**	triasulfuron	triasulfuron	no products found	carfentrazone
	saflufenacil	triasulfuron	triasulfuron**	metsulfuron	metsulfuron		triasulfuron
	Imazamethabenz	prosulfuron	prosulfuron**	florasulam	florasulam		metsulfuron
	triasulfuron[1]			prosulfuron	prosulfuron		florasulam
							prosulfuron
Number herbicide MOA available	**2**	**1**	**1**	**1**	**1**		**2**

Sorghum								
	Kochia[1]	**Pigweed, redroot[1]**	**Thistle, russian[1]**	**Bindweed, field[6]**	**Mustard, wild**	**Pigweed, tumble[1]**	**Palmer amaranth[1]**	**Marestail[1]**
	dimethenamid/atr	atrazine	atrazine	quinclorac + atrazine		atrazine	atrazine	mesotrione/metolachlor/atrazine
	atrazine	acetochlor/atrazine	acetochlor/atrazine	Carfenterazone*		acetochlor + atrazine	acetochlor+ atrazine	saflufenacil
	saflufenacil	carfentrazone	saflufenacil			carfentrazone	carfentrazone	
		halosulfuron				halosulfuron	halosulfuron	
		saflufenacil				saflufenacil	saflufenacil	
Number herbicide MOA available	**3**	**4**	**3**	**1**		**4**	**4**	**4**

Table 11 (continued). Herbicide Options to Control Primary Weed Targets in Plains Region (ND, SD, NE, KS, OK, TX)*

Pastureland							
	Ragweed[4]	**Broomweed[4]**	**Marshelder**	**St. Johnswort**	**Milkweed**	**Sunflower[4]**	**Blueweed, Texas**
	metsulfuron	metsulfuron				metsulfuron	
	metsulfuron + chlorsulfuron	metsulfuron + chlorsulfuron				metsulfuron + chlorsulfuron	
	mowing					mowing	
Number herbicide MOA available	**1**	**1**				**1**	
	Mustard, wild	**Cocklebur, spiny[4]**	**Thistle[4]**				
		metsulfuron	metsulfuron				
		metsulfuron + chlorsulfuron	metsulfuron + chlorsulfuron				
		mowing	mowing				
Number herbicide MOA available		**1**	**1**				

*Source for weed targets was Monsanto proprietary grower survey data from 2012. Weeds listed in descending order according to acres treated with dicamba. Alternative herbicides actives were rated 7-8 and above (good) for control of targeted weed except where identified with ** which includes ratings of marginal control.

[1] University of Nebraska-Lincoln 2013

[2] Moechnig, et al. 2011

[3] Moechnig, et al. 2012a

[4] Kansas State University 2014

[5] Moechnig, et al. 2012b

[6] Moechnig, et al. 2010

Appendix A

Comments submitted by Dr. C. Hall and Dr. M. Jugulam to DT soybean MON 87708 and DGT Cotton MON 88701 Notice of Intent scoping comment period

Date: June, 24th 2013

To
The USDA,
Animal and Plant Health Inspection Service (APHIS)
Regulatory Analysis and Development, PPD, APHIS, Station 3A-03.8
4700 River Road, Unit 118
Riverdale, MD 20737-1238

RE: De-regulation of Dicamba-Tolerant Crops (Docket No. APHIS-2013-0043)

Dear Sir/Madam,

We (Drs. J. Christopher Hall and Mithila Jugulam) offer the following comments regarding the de-regulation of dicamba tolerant soybean and cotton and the associated use of dicamba in a diversified weed management program. These comments are based primarily upon a comprehensive review of a paper titled "Evolution of resistance to auxinic herbicides: Historical perspectives, mechanisms of resistance, and implications for broadleaf weed management in agronomic crops" which was published in Weed Science in 2011 (vol. 59; pp. 445-457); a copy of the review is attached.

[Dr. J.C. Hall is a professor and a Tier I Canada Research Chair (CRC) in Recombinant Antibody Technology at the University of Guelph, Canada. Dr. Hall is also a founder and Chief Scientific Officer of PlantForm Corporation, established in 2008. One of the major focuses of Dr. Hall's research is toward understanding the biochemical, physiological and molecular basis of mechanism of auxinic herbicide resistance in weeds. He has received Fellow of Weed Science Society of America award in 2002. Dr. Jugulam is an Assistant Professor at Kansas State University in weed physiology. Dr. Jugulam's research focuses toward understanding mechanisms and genetic basis of herbicide resistance in weeds/plants. She has been working in the area of genetic and physiological basis of auxinic herbicide resistance in weeds for more than a decade. She also teaches courses related to Herbicide Interactions and Integrated Weed Management at KSU].

We would like to emphasize the following points in regards to de-regulation of dicamba-tolerant crops; specifically in terms of evolution of resistance to auxinic herbicides (e.g. dicamba and others) in weed species.

- There is a potential for evolution of resistance to any herbicide and this potential can increase with an increased and repeated use of the same mode of action of herbicides, leading to herbicide selection; which is the primary cause for evolution of herbicide-resistant weeds. However, the risk of evolution of weed resistance to herbicides can be significantly mitigated through implementation of diversified weed management programs by farmers, that include: use of multiple herbicides with overlapping activity on target weeds and/or the inclusion of mechanical and/or cultural weed control practices. Furthermore, integrated weed management practices, specifically aimed at herbicide and crop rotations, prudent use of tillage, cover crops, competitive crop cultivars, will significantly minimize herbicide selection pressure.

- The probability of resistance does differ among the different groups and classes of herbicides. Compared with other herbicides families, the incidence of resistance to auxinic herbicides is relatively low and this has been attributed to; (1) the presence of rare alleles imparting resistance in natural weed populations, or that mutations conferring resistance may be lethal,

(2) the potential for fitness penalties due to mutations conferring resistance in weeds, and (3) the complex mode of action of auxinic herbicides in sensitive dicot plants.

- Information about fitness costs associated with auxin herbicides has been documented in a few species indicating that resistant plants are less fit in the absence of herbicide application. This could be a major reason for the limited occurrence of auxinic herbicide-resistant weeds. Additionally, this could explain why farmers continue to use and derive benefits from these products even after resistant populations have been identified.

- Studies on inheritance of auxinic herbicide resistance in weed species demonstrate that dicamba, 2,4-D, and picloram resistance in wild mustard is determined by a single dominant gene (Jasieniuk et al. 1995; Jugulam et al. 2005). In addition, dicamba resistance in kochia, is determined by a single allele with a high degree of dominance (Preston et al. 2009). Conversely, a single recessive gene controls clopyralid and picloram resistance in yellow starthistle (Sabba et al. 2003) and quinclorac resistance in false cleavers (*Galium spurium* L.) (Van Eerd et al. 2004). It has also been reported that two additive genes control MCPA resistance in common hemp-nettle (Weinberg et al. 2006). The recessive trait spreads much slower in a population than a dominant trait. Since the resistance to auxinic herbicides in some weeds is determined by recessive genes (as mentioned above), this may be one of the reasons for low occurrence of auxinic herbicide resistant weeds.

- Further indications supporting the low probability of resistance to auxin herbicides can be seen in the number of resistance species recorded since these herbicide products have been commercially used (since the 1940s in the case of 2,4-D, and the 1960s for dicamba). To date there are 30 species with known resistance to auxinic herbicides; 23 are dicots and 7 are monocots. Worldwide there are 17 dicot species with resistance to 2,4-D and 5 with resistance to dicamba. In 2 species (prickly lettuce and wild mustard) there is confirmed cross resistance between 2,4-D and dicamba. The 22 dicot species with known resistance to either 2,4-D or dicamba compares to 113 species with known resistance to ALS inhibitors, 71 species to Photosystem II inhibitors, 42 species to ACCase inhibitors and 24 species to glyphosate. In many cases the use and, thus, selection pressure of these auxinic herbicides has exceeded that of other herbicide groups to which resistance is more common.

- Definitive mechanisms of resistance to auxinic herbicides have yet to be defined. In part this is because of the difficulty in understanding the mechanism of action. The possibilities are; (1) target site in the form of reduced binding to proteins involved in an active transport process or increasing herbicide binding in the IAA receptor process and/or (2) non-target/metabolic site in the form of substrate conjugation or hydroxylation by cytochrome P450's. The potential for metabolic resistance mechanism being the basis for resistance in the suxinic herbicide resistant weeds is low. Of 5 species where metabolic type resistances have been studied, only in 1 species and herbicide combination (MCPA resistant hemp-nettle has metabolism been reported; (Weinberg et al. 2006)). This suggests a relatively low probability for cross resistance to other herbicide groups and classes that could occur because of common metabolic resistance pathways.

- In closing, the expected increase in use of dicamba in dicamba-tolerant crops will increase the potential for resistance to evolve. However, with the available scientific information, it appears that the probability is relatively low. This low probability in combination with stringent

implementation with integrated weed management practices should reduce risks of evolution of resistance to these herbicides.

Overall, the key is, educating the farmer of the negative consequences of continuous use of herbicides with the same mode of action and the positive consequences of implementing efficient weed-management practices such as herbicide rotations, use of multiple herbicides in mixtures and sequences, inclusion of tillage were necessary and other non-chemical-based weed management practices, which will help reduce the chances of evolution of herbicide-resistant weed populations.

Review article (attached):

Mithila, J., J.C. Hall, W.G. Johnson, K. B. Kelley, and D.E. Riechers. 2011. Evolution of resistance to auxinic herbicides: Historical perspectives, mechanisms of resistance, and implications for broadleaf weed management in agronomic crops. Weed Sci. 59: 445-457.

Other References:

Jasienuik, M., I. N. Morrison, and A. L. Brule-Babel. 1995. Inheritance of dicamba resistance in wild mustard (*Brassica kaber*). Weed Sci. 43:192–195.

Jugulam, M., M.D. McLean, and J.C. Hall. 2005. Inheritance of picloram and 2,4-D resistance in wild mustard (*Brassica kaber*). Weed Sci. 53:417–423.

Preston, C., D. S. Belles, P. H. Westra, S. J. Nissen, and S. M. Ward. 2009. Inheritance of resistance to the auxinic herbicide dicamba in kochia (*Kochia scoparia*). Weed Sci. 57:43–47.

Sabba, R.P., I. M. Ray, N. Lownds, and T. M. Sterling. 2003. Inheritance of resistance to clopyralid and picloram in yellow starthistle (*Centaurea solstitialis*) is controlled by a single nuclear recessive gene. J. Hered. 94:523–527.

Van Eerd, L. L., M. D. McLean, G. R. Stephenson, and J. C. Hall. 2004. Resistance to quinclorac and ALS-inhibitor herbicides in *Galium spurium* is conferred by two distinct genes. Weed Res. 44:355–365.

Wienberg, T., G. R. Stephenson, M. D. McLean, and J. C. Hall. 2006. MCPA (4-chloro-2-ethylphenoxyacetate) resistance in hemp-nettle (*Galeopsis tetrahit* L.). J. Agric. Food Chem. 54:9126–9134.

Finally, thank you for reviewing and considering our comments regarding the de-regulation of dicamba tolerant soybean and cotton and the associated use of dicamba in a diversified weed management program. These comments are based on current scientific literature to allow for a sound science-based determination.

Sincerely,

J. Christopher Hall

Mithila Jugulam

Appendix B

Common weeds in soybean and cotton production.

This appendix contains information on the common weeds in soybean and cotton by region from the November 2013 Petitioner's Environmental Report for DT Soybean MON 87708 and DGT Cotton MON 88701.

Common Weeds in Soybean Production: Midwest Region

- Foxtail spp. (12)[1]
- **Pigweed spp. (11)**
- **Velvetleaf (11)**
- **Lambsquarters (10)**
- **Cocklebur (9)**
- **Ragweed, common (7)**
- **Smartweed spp. (6)**
- **Morningglory spp. (5)**
- **Sunflower, spp. (5)**
- **Waterhemp spp. (5)**
- **Horseweed (marestail) (3)**
- Panicum, fall (3)
- **Ragweed, giant (3)**
- Shattercane (3)
- Quackgrass (3)
- **Buckwheat, wild (2)**
- Crabgrass spp. (2)
- **Kochia** (2)
- **Mustard, wild (2)**
- **Nightshade, Eastern black (2)**
- **Palmer amaranth (2)**
- **Canada thistle (1)**
- **Chickweed (1)**
- Cupgrass, woolly (1)
- **Dandelion (1)**
- Johnson grass (1)
- **Milkweed, honeyvine (1)**
- Nightshade, hairy (1)
- Oats, wild (1)
- **Pokeweed, common (1)**
- **Prickly sida (1)**
- Proso millet, wild (1)
- Sandbur, field (1)
- **Venice mallow (1)**
- Volunteer cereal (1)
- Volunteer corn (1)

Dicamba is effective on weeds highlighted in bold.

[1] Number provided in parenthesis is the number of states out of the thirteen total states in the Midwest region reporting each weed as a common weed.

Sources:

IL: University of Illinois (2002) and Aaron Hager, Extension Weed Specialist, University of Illinois - Personal Communication (2006).

IN: 2003-2005 Statewide Purdue Horseweed Weed Survey, Special database query and personal communication (2006), Bill Johnson, Extension Weed Specialist, Purdue University.

IA, MN, OH, WI: (WSSA 1992).

KS: Dallas Petersen, Extension Weed Specialist, Kansas State - Personal communication (2006).

KY, MO: (Webster, et al. 2005).

MI: (Davis, et al. 2005).

NE: Alex Martin, Extension Weed Specialist, University of Nebraska – Personal communication (2006).

ND: (Zollinger and Lym 2000).

SD: Michael Moechnig, Extension Weed Specialist, South Dakota State University – Personal communication (2006).

Common Weeds in Soybean Production: Southeast Region

Morningglory spp. (8)[1]
Crabgrass spp. (6)
Prickly sida (6)
Nutsedge spp. (6)
Sicklepod (5)
Signalgrass, broadleaf (5)
Palmer amaranth (4)
Pigweed spp. (4)
Barnyard grass (3)
Florida pusely (3)
Goosegrass (3)
Johnsongrass (3)
Ragweed, common (3)
Cocklebur (2)
Florida beggarweed (2)
Hemp sesbania (2)
Horseweed (marestail) (2)
Texas millet (2)
Browntop millet (1)
Copperleaf, hophorn (1)
Cutleaf evening-primrose (1)
Groundcherry (1)
Henbit (1)
Lambsquarters (1)
Ragweed, giant (1)
Smartweed (1)
Spurge, nodding/hyssop (1)
Spurge, Prostrate (1)
Tropic croton (1)

Dicamba is effective on weeds highlighted in bold.

[1] Number provided in parenthesis is the number of states out of the eight total states in the Southeast region reporting each weed as a common weed.

Sources:
AL, AR, GA, LA, NC, SC: (Webster, et al. 2009).
MS, TN: (Webster et al. 2005).

Common Weeds in Soybean Production: Eastern Coastal Region

Foxtail spp. (6)[1]
Ragweed, common (6)
Velvetleaf (6)
Lambsquarters (5)
Pigweed spp. (5)
Cocklebur (4)
Jimson weed (4)
Morningglory spp. (4)
Panicum, fall (4)
Crabgrass spp. (3)
Nutsedge spp. (3)
Quackgrass (2)
Canada thistle (1)
Burcucumber (1)
Dandelion (1)
Goosegrass (1)
Johnson grass (1)
Nightshade, Eastern black (1)
Prickly sida (1)
Shattercane (1)
Smartweed spp. (1)

Dicamba is effective on weeds highlighted in bold.

[1] Number provided in parenthesis is the number of states out of the six total states in the Eastern Coastal region reporting each weed as a common weed. Data were not available for DE in soybean.

Sources:
DE, MD, NJ, PA: (WSSA 1992).
NY: Russell Hahn, Extension Weed Specialist, Cornell University – Personal Communication (2006).
VA: (Webster et al. 2009).

Common Weeds In Cotton Production

Common weeds in Cotton Production in the Southeast Region of the U.S.[1,2]

- Crabgrass spp. (6)
- **Morningglory spp (6)**
- **Prickly sida (5)**
- **Florida pusley (4)**
- Nutsedge spp. (4)
- **Sicklepod** (4)
- Broadleaf signalgrass (3)
- Goosegrass (3)
- **Pigweed spp (3)**
- **Common cocklebur (2)**
- **Common lambsquarters (2)**
- **Common ragweed (2)**
- **Florida beggarweed (2)**
- **Palmer amaranth (2)**
- Texas millet (2)
- Bermudagrass (1)
- Crowfootgrass (1)
- **Horseweed (marestail) (1)**
- **Jimsonweed (1)**
- Johnsongrass (1)
- **Smartweed spp. (1)**
- **Spurge spp (1)**
- Volunteer peanut (1)

Dicamba is effective on weeds highlighted in bold.

[1] Source: (Webster et al. 2009).

[2] Number provided in parenthesis is the number of states out of the six total states (AL, FL, GA, NC, SC, & VA) in the Southeast Region reporting each weed as one of the ten most common weeds.

Common weeds in Cotton Production in the Midsouth Region of the U.S.[1,2]

- **Morningglory spp (5)**
- Broadleaf signalgrass (4)
- Crabgrass spp (4)
- Nutsedge spp (4)
- **Prickly sida (4)**
- **Spurge spp (4)**
- **Pigweed spp (3)**
- **Velvetleaf (3)**
- Barnyardgrass (2)
- **Horseweed (marestail) (2)**
- Johnsongrass (2)
- **Palmer amaranth (2)**
- Bermudagrass (1)
- Browntop millet (1)
- **Common cockleburr (1)**
- **Cutleaf evening-primrose (1)**
- Goosegrass (1)
- **Hemp sesbania (1)**
- **Henbit (1)**
- Spurred anoda (1)

Dicamba is effective on weeds highlighted in bold.

[1] Source: (Webster et al. 2005; Webster et al. 2009) Webster et al., 2005 (MS & TN); Webster et al., 2009 (AR, LA, & MO).

[2] Number provided in parenthesis is the number of states out of the five total states (AR, LA, MS, MO, & TN) in the Midsouth Region reporting each weed as one of the ten most common weeds.

Common weeds in Cotton Production in the Southwest Region of the U.S.[1,2]

Johnsongrass (4)
Nutsedge spp (4)
Common cockleburr (3)
Palmer amaranth (3)
Silverleaf Nightshade (3)
Common lambsquarters (2)
Large Crabgrass (2)
Devil's claw (2)
Morningglory spp (2)
Mustard spp (2)
Pigweed spp (2)
Russian thistle (2)
Barnyardgrass (1)
Bermudagrass (1)
Bindweed, field (1)
Foxtail spp (1)
Groundcherry spp (1)
Kochia (1)
Horseweed (marestail) (1)
Shepardspurse (1)
Smartweed (1)
Smellmelon (1)
Spurred anoda (1)
Red Sprangletop (1)
Sunflower (1)
Texas blueweed (1)
Texas millet (2)
Velvetleaf (1)
Woolyleaf bursage (1)

Dicamba is effective on weeds highlighted in bold.

[1] Source: OK - (Webster et al. 2009); KS – Dr. Stewart Duncan, Kansas State University – Personal Communication 11/4/2010; NM – Dr. Jamshid Ashigh, New Mexico State University – Personal Communications 11/12/2010; TX – Dr. Wayne Keeling and Dr. Gaylon Morgan, Texas A&M University - Personal communications 11/4/2010.

[2] Number provided in parenthesis is the number of states out of the four total states (KS, OK, TX, & NM) in the Southwest Region reporting each weed as one of the ten most common weeds.

Common weeds in Cotton Production in the West Region of the U.S.[1,2]

Barnyardgrass (2)
Morningglory spp (2)
Sprangletop (2)
Bermudagrass (1)
Field Bindweed (1)
Cupgrass, southwestern (1)
Groundcherry spp (1)
Common lambsquarters (1)
Johnsongrass (1)
Junglerice (1)
Nutsedge spp (1)
Pigweed spp (1)
Black Nightshade (1)
Hairy Nightshade (1)
Silverleaf Nightshade (1)
Palmer amaranth (1)
Common Purslane (1)
Horse Purslane (1)
Volunteer corn (1)

Dicamba is effective on weeds highlighted in bold.

[1] Source: AZ – Bill McCloskey, University of Arizona – Personal Communication 11/5/2010; CA – Steven Wright, University of California - Personal Communication 11/16/2010.

[2] Number provided in parenthesis is the number of states out of the two total states (AZ & CA) in the West Region reporting each weed as one of the ten most common weed

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