UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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OFFICE OF CHEMICAL SAFETY
AND POLLUTION PREVENTION

MEMORANDUM

SUBJECT: Glufosinate Resistance Management Recommendations

FROM: Bill Chism, Ph.D., Senior Biologist
Biological Analysis Branch

Bill Chism 6/23/2016

THRU: Monisha Kaul, M.S., Acting Chief
Biological Analysis Branch
Biological and Economic Analysis Division (7503P)

Monisha Kaul

TO: Marquea King, Ph.D., Chemical Review Manager
Risk Implementation and Management Branch V
Pesticide Re-evaluation Division (7508P)

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SUMMARY

To address the spread of herbicide resistant weeds the Agency is proposing weed resistance management elements be considered during the registration review process. This is a tiered approach where the situations (i.e. the interaction of the mechanism of action, resistant weeds, and weed management strategies) with the least concern for herbicide resistant weeds will have the fewest number of resistance management elements and the situations with the highest concern will have the most resistance management elements.

In addition to the glufosinate docket, a separate docket is being established for the Agency's herbicide resistant management approach. All stakeholders are encouraged to submit comments to both dockets. Public comments received from both the chemical specific docket and the herbicide resistance management docket will be considered prior to the Agency's final decision on glufosinate.

Glufosinate is a glutamine synthase inhibitor which is a Weed Science Society of America (WSSA) Group 10 mechanism of action (MoA). This MOA is of high concern because

glufosinate is a broad spectrum post-emergence herbicide used on a wide variety of herbicide resistant and non-resistant crops to control herbicide resistant and susceptible weeds. This MOA has only one resistant weed species, Italian ryegrass, in the U.S.

The Agency is proposing here a set of herbicide resistance elements for glufosinate. This includes changes to the label language and elements on reporting, education and stewardship. Because glufosinate is used on herbicide resistant crops and is an integral part of many resistance management programs, the registrants should be required to address all eleven elements of the resistance management described herein.

RESISTANCE MANAGEMENT

The development and spread of herbicide resistant weeds in agriculture is a widespread problem that has the potential to fundamentally change production practices in US agriculture. While herbicide resistance weeds have been known since the 1950s, the number of species and their geographical extent, has been increasing rapidly. Currently there are 249 weed species worldwide with confirmed herbicide resistance and in the United States there are 155 weed species with confirmed resistance to one or more herbicides (Heap, 2016).

Management of herbicide resistant weeds, both in mitigating established herbicide resistant weeds, and in slowing or preventing the development of new herbicide resistant weeds is a complex problem without a simple solution. Coordinated efforts of growers, agricultural extension, academic researcher, scientific societies, pesticide registrants, and state and federal agencies are required to address this problem.

In September 2014, the Weed Science Society of America sponsored an international meeting, the Herbicide Resistance Summit II, hosted by the National Research Council (WSSA, 2014). This meeting was organized to facilitate a more unified understanding of the herbicide resistance issues across the country, understanding differences of viewpoints, and approaches to solutions. The meeting was attended in person or via webinar by participants from approximately 100 locations across the United States, Australia, Canada and Germany, underscoring the significance and widespread nature of this problem and its impact on agricultural productivity.

The Agency announced at this meeting that it would take a more proactive role in developing regulatory approaches for managing resistant weeds (Housenger, 2014). Shortly after this meeting, the Secretary of Agriculture announced USDA's herbicide resistance actions that were developed in collaboration with the Environmental Protection Agency (USDA, 2014).

The EPA, Office of Pesticide Programs (OPP) is proposing measures for the pesticide registrants to provide growers and users with detailed information and recommendations to slow the development and spread of herbicide resistant weeds. This is part of a more holistic, proactive approach recommended by crop consultants, commodity organizations, professional/scientific societies, researchers, and the registrants themselves. OPP's approach is measured, based on the inherent risk of weed resistance developing for a given herbicide, considering the target weeds

and the agronomic practices of the registered crops. Situations with the least concern for the development of herbicide resistant weeds will have the fewest resistance management elements and the situations with the highest concern will have additional resistance management elements. Additional details on herbicide resistance are provide in the attached appendices, as follows:

- Appendix I – Guidance for Pesticide Registrants on Pesticide Resistance Management Labeling (US EPA, 2001)
- Appendix II – Definition of Resistance and Likely Resistance
- Appendix III – Best Management Practices for Herbicide Resistant Weeds (from the Herbicide Resistance Action Committee and the Weed Science Society of America

Implementation Timeline and Opportunities for Public Comment on Herbicide Resistance Approach

OPP is proposing to implement herbicide resistance measures for existing chemicals during registration review, and to implement herbicide resistance measures for new chemicals and uses at the time of registration. In registration review, proposed herbicide resistance elements will be included in every herbicide preliminary interim decision. Comments on these chemical specific measures are welcomed.

On June 3, 2016 two Pesticide Registration Notices on resistance management were released to the public for a 60 day comment which closes on August 2, 2016. The first notice is draft guidance for pesticide registrants on herbicide resistance management labeling, education, training, and stewardship (FRL #: 9946-53 and OCSPP Docket #: OPP-2016-0226) is available online at https://www.regulations.gov/docket?D=EPA-HQ-OPP-2016-0226 (US EPA, 2016). The second notice updates guidance for registrants on resistance management labeling for all agricultural pesticides except those regulated as plant incorporated protectants (FRL #: 9946-52 and OCSPP Docket #: OPP-2016-0242) is available online at https://www.regulations.gov/docket?D=EPA-HQ-OPP-2016-0242 (US EPA, 2016a).

Public comments received from both the chemical specific docket and the separate HR management docket will be considered prior to the final decision on glufosinate.

Specific Herbicide Resistance Measures

Glufosinate is used on a wide variety of crops to control herbicide resistant and susceptible broadleaf and grass weeds. The emergence of herbicide resistant weeds is an increasing problem that has become a significant economic issue to growers. In many situations crop consultants and the extension recommend the use of glufosinate to control herbicide resistant weeds. Between 1998 and 2013 the total number of glufosinate treated acres has risen 4 fold from approximately 1.5 million acres to over 7 million acres (Market Research Data). Currently, there is one herbicide resistant weed in the U.S., Italian ryegrass or *Lolium perenne ssp. multiflorum* (Heap, 2016). The introduction of herbicide-tolerant crops has also increased the selective pressure for herbicide resistant weeds. Currently there are four glufosinate-resistant crops (e.g.

LibertyLink®) that have been commercialized in the United States: canola, corn, cotton, and soybean. Because glufosinate is effective on a large number of resistant weed species, millions of acres are infested with these weed species, and glufosinate is used on herbicide resistant crops it is categorized as a high concern for herbicide resistance. Glufosinate registrants should be required to address all eleven elements of the resistance management list in Table 1 below. Table 2 identifies the elements needed for each level of concern.

Table 1. Elements of a resistance management and stewardship plan

Element	Description
1	List Mechanism of Action (MOA) Group Number. • This information is critical to allow the user to rotate between effective MOA's to reduce the buildup of resistant pests. ➢ Registrant is responsible for placement on label.
2	List seasonal and annual maximum number of applications and amounts. • This information is critical to allow the user to know how many applications and amounts can be applied in order to develop an effective IPM plan for the season and the entire year. ➢ Registrant is responsible for placement on label.
3	Resistance Management language from PR Notice 2001-5, and/or Best Management Practices (appropriate to crop) from Weed Science Society of America (WSSA) & Herbicide Resistance Action Committee (HRAC), and/or HRAC proposed guidelines for herbicide labels. • This is an educational opportunity to remind users to look for and follow a resistance management plan. ➢ Registrant is responsible for placement on label.
4	User should scout before and after application. • Reminding the user to scout can help insure that the proper pesticide is applied based on the weed species and growth stage and determine if the pesticide applied provided effective control. ➢ Registrant is responsible for placement on label. ➢ User is responsible for following the recommendations.
5	Definition of Likely Resistance. • It can take up to five years to confirm herbicide resistance. By describing likely resistance users could proactively identify and attempt to control weeds in the early stages before they become widespread in their fields. ➢ Registrant is responsible for placement on label.
6	User should report lack of performance to registrant or their representative. • Reporting lack of performance can help provide the user with additional resources for the identification and control of problem weeds. In some cases lack of performance could be an early indication of likely resistance and contacting the registrant can help insure the weed is controlled before resistance becomes widespread in their fields. ➢ Registrant is responsible for placement on label. ➢ User is responsible for following the recommendations.

7	List confirmed resistant weeds in a separate table and list effective or recommended rates for these weeds with the table. • This is an educational opportunity to clearly indicate which weeds are prone to resistance and remind the users to select the correct rates for their crop and site. ➢ Registrant is responsible for placement on label.
8	Registrant report new cases of likely and confirmed resistance to EPA and users yearly. This will be in addition to any adverse effects reporting. • This will allow the information likely and confirmed resistance to be available in a timely manner to users, consultants, extension, etc. so that they are aware of and proactively address the problem. • Provide weed species, crop or site, state, and herbicide used. ➢ Registrant is responsible for reporting.
9	For sites of high concern provide growers with: □ Resistance Management Plan □ Remedial Action Plan (to control resistant weeds this season or next season) □ Educational materials on resistance management. • Plans should be locally developed and easily modified. EPA recommends that registrants work with Extension, Consultants, Crop Groups, HRAC, & USDA. • This is an educational opportunity to remind users of the importance of resistance management. ➢ Registrant is responsible for creating or providing educational materials.
10	For combination products with multiple MOA, list which herbicide is controlling which weed (a 3 way mixture may only have 1 effective MOA for some problem weeds). List minimum recommended rate if resistance is suspected. • Using a combination products with only one effective MOA can select for herbicide resistant weeds. • This will allow users to select herbicide combinations with multiple effective MOAs for the problem weeds on their fields. • Registrant is responsible for placing the list on label or otherwise providing the information.
11	Any additional specific requirements (e.g. mandatory crop rotation, unique agronomic aspects, additional training, time limited registration, etc.). • During discussions with the Agency other elements may be deemed appropriate to help reduces the spread of resistance. • The elements may be on the label, the technical use agreement for the seed trait, or as a reporting requirement. ➢ Registrant is responsible.

Footnote: Mechanism of Action Group number comes from the WSSA, definition of resistance and likely resistance, PR Notice 2001-5 and BMP language are in Appendix 1-3. Resistance elements for fungicides and insecticides.

Table 2. Herbicide Resistance Categories of Concern

Low Concern	Moderate Concern	High Concern
MOA's with no resistance weed species in the U.S.	MOA's with up to six resistant weed species in the U.S.	• Any new herbicide with a new or novel mechanism of action, or • Herbicides for which resistant crop(s) have been developed (conventionally bred or GM), or • MOA's with the most resistant weeds in U.S. (1 to 49 species).
1. MOA on Label 2. List seasonal and annual maximum number of applications and pounds 3. Resistance management language from PRN 2001-5 or BMPs 4. Scout before and after application	Elements 1 through 4 plus 5. Definition of likely and confirmed resistance 6. Farmer should report lack of performance to registrant or its agent 7. List confirmed resistant species in separate table and list effective or recommended rates for these weeds with the table 8. Registrant report new cases of likely and confirmed resistance to EPA & users yearly	Elements 1 through 8 plus 9. Provide growers with: Resistance Management Plan, Remedial Action Plan, Educational materials on resistance management 10. For combination products with multiple MOAs, list which herbicide is controlling which weed and minimum recommended rate 11. Any additional specific requirements (e.g. mandatory crop rotation, unique agronomic aspects, time limited registration, etc.).

* If new resistant weed species are found a MOA may move to higher level of concern.

REFERENCES

U.S. Environmental Protection Agency. 2001. Pesticide Registration (PR) Notice 2001-5. Guidance for Pesticide Registrants on Pesticide Resistance Management Labeling. Accessed February 2016 at http://www.epa.gov/pesticide-registration/prn-2001-5-guidance-pesticide-registrants-pesticide-resistance-management.

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Market Research Data (MRD). 2010-2014. Data collected and sold by a private market research firm. Data collected on pesticide use for about 60 crops by annual surveys of agricultural users in the continental United States. Survey methodology provides statistically valid results, typically at the state level.

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APPENDIX I. Guidance for Pesticide Registrants on Pesticide Resistance Management Labeling (EPA, 2001)

Herbicides

1. The following general resistance management labelling statements are recommended for herbicide products containing only a single active ingredient or only active ingredients from the same group:

   a. "For resistance management, (name of product) is a Group (mode of action group number) herbicide. Any weed population may contain or develop plants naturally resistant to (name of product) and other Group (mode of action group number) herbicides. The resistant biotypes may dominate the weed population if these herbicides are used repeatedly in the same field. Other resistance mechanisms that are not linked to this mode of action but are specific for individual chemicals, such as enhanced metabolism, may also exist. Appropriate resistance-management strategies should be followed."

   For products containing active ingredients from different groups, the statement should be modified to reflect the situation, for example:

   b. "For resistance management, please note that (name of product) is both a Group (mode of action group number) and a Group (mode of action group number) herbicide. Any weed population may contain plants naturally resistant to Group (mode of action group number) and/or Group (mode of action group number) herbicides. The resistant individuals may dominate the weed population if these herbicides are used repeatedly in the same fields."

2. The following additional resistance management labeling statements are recommended for herbicides, although each bulleted statement may not be appropriate or pertinent for every product label:

   "To delay herbicide resistance:

   a. Rotate the use of (name of product) or other Group (mode of action group number) herbicides within a growing season sequence or among growing seasons with different herbicide groups that control the same weeds in a field.

   b. Use tank mixtures with herbicides from a different group if such use is permitted; Use the less resistance-prone partner at a rate that will control the target weed(s) equally as well as the more resistance-prone partner.

   c. Adopt an integrated weed management program for herbicide use that includes scouting and historical information related to herbicide use and crop rotation, and that considers tillage (or other mechanical control methods), cultural (e.g., higher crop seeding rates;

precision fertilizer application method and timing to favor the crop and not the weeds), biological (weed-competitive crops or varieties) and other management practices.

d. Scout after herbicide application to monitor weed populations for early signs of resistance development. Indicators of possible herbicide resistance include: (1) failure to control a weed species normally controlled by the herbicide at the dose applied, especially if control is achieved on adjacent weeds; (2) a spreading patch of non-controlled plants of a particular weed species; (3) surviving plants mixed with controlled individuals of the same species. If resistance is suspected, prevent weed seed production in the affected area by an alternative herbicide from a different group or by a mechanical method such as hoeing or tillage. Prevent movement of resistant weed seeds to other fields by cleaning harvesting and tillage equipment when moving between fields, and planting clean seed.

e. If a weed pest population continues to progress after treatment with this product, discontinue use of this product, and switch to another herbicide with a different target mode of action, if available.

f. Have suspected resistant weed seeds tested by a qualified laboratory to confirm resistance and identify alternative herbicide options.

g. Contact your local extension specialist or certified crop advisors for additional pesticide resistance-management and/or integrated weed-management recommendations for specific crops and weed biotypes.

h. For further information or to report suspected resistance, contact (company representatives) at (toll free number) or at (Internet site)."

APPENDIX II. Definition of Resistance and Likely Resistance

According to the Weed Science Society of America "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 may be naturally occurring or induced by such techniques as genetic engineering or selection of variants produced by tissue culture or mutagenesis." "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." (http://weedscience.org/documents/resistancecriterion.pdf).

Indicators of likely herbicide resistance (called possible resistance in Norsworthy et al 2012, Page 39) include (1) failure to control a weed species normally controlled by the herbicide at the dose applied, especially if control is achieved on adjacent weeds; (2) a spreading patch of noncontrolled plants of a particular weed species; and (3) surviving plants mixed with controlled individuals of the same species.

APPENDIX III. Best Management Practices for Herbicide Resistant Weeds (from the Herbicide Resistance Action Committee / Weed Science Society of America list of Best Management Practices)

Crop Selection and Cultural Practices:

1. Understand the biology of the weeds present.
2. Use a diversified approach toward weed management focused on preventing weed seed production and reducing the number of weed seeds in the soil seed-bank.
3. Emphasize cultural practices that suppress weeds by using crop competitiveness.
4. Plant into weed free fields, keep fields as weed free as possible, and note areas where weeds were a problem in prior seasons.
5. Incorporate additional weed control practices whenever possible, such as mechanical cultivation, biological management practices, crop rotation, and weed-free crop seeds, as part of an integrated weed control program.
6. Do not allow weed escapes to produce seeds, roots or tubers.
7. Manage weed seed at harvest and post-harvest to prevent a buildup of the weed seed-bank.
8. Prevent field-to-field and within-field movement of weed seed or vegetative propagules.
9. Thoroughly clean plant residues from equipment before leaving fields.
10. Prevent an influx of weeds into the field by managing field borders.
11. Fields should be scouted before application to ensure herbicides and application rates will be appropriate for the weed species and weed sizes present.
12. Fields should be scouted after application to confirm herbicide effectiveness and to detect weed escapes.
13. If resistance is suspected, treat weed escapes with an alternate mode of action or use non-chemical methods to remove escapes.
14. Avoid outcrossing to weedy relatives, in crops that outcross. Control weedy relatives in surrounding field margins. Research has demonstrated that the pollen can move _____ feet.

Herbicide Selection:

1. Use a broad spectrum soil applied herbicide with a mechanism of action that differs from this product as a foundation in a weed control program.
2. A broad spectrum weed control program should consider all of the weeds present in the field. Weeds should be identified through scouting and field history.
3. Difficult to control weeds may require sequential applications of herbicides with alternative mechanisms of action.
4. Fields with difficult to control weeds should be rotated to crops that allow the use of herbicides with alternative mechanisms of action.
5. Apply full rates of this herbicide for the most difficult to control weed in the field. Applications should be made when weeds are at the correct size to minimize weed escapes.
6. Do not use more than two applications of "this herbicide" or any herbicide with the same mechanism of action within a single growing season unless mixed with another mechanism of action herbicide with overlapping spectrum for the difficult to control weeds.
7. Report any incidence of non-performance of this product against a particular weed species to the _____ representative (list contact information here).