UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C., 20460

OFFICE OF CHEMICAL SAFETY
AND POLLUTION PREVENTION

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MEMORANDUM

SUBJECT: Glyphosate: Response to Comments, Usage, and Benefits (**PC Codes**: 103601 103604, 103605, 103607, 103608, 103613, 417300)

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SUMMARY

Glyphosate is the most commonly used herbicide in the United States, in terms of area treated. It is a broad-spectrum herbicide that controls broadleaf, sedge, and grass weeds with minimal residual toxicity to crops or non-target vegetation. Glyphosate is registered for use in agriculture, including horticulture, viticulture, and silviculture, as well as non-agricultural sites including commercial, industrial, and residential areas. On average, eighty-four percent of glyphosate applied in agricultural settings, in terms of pounds, is applied to soybeans, corn, or cotton per year. These three field crops all have glyphosate-resistant varieties that have been widely adopted and glyphosate is used on a large majority of acres of these crops.

About 280 million pounds of glyphosate are applied to an average of 298 million acres of crop land annually. In addition to providing broad-spectrum control, it is also relatively inexpensive, averaging between $1 and $13 per acre across agricultural use sites. Many high value crops (e.g., tree nuts, grapes, vegetables) and large acreage field crops (e.g., soybean, cotton, corn) have a large percentage of acres treated with glyphosate, implying a large majority of growers find it useful. Glyphosate provides good margins of crop safety, particularly for crops that have been engineered to be resistant to over-the-top applications of glyphosate at late-postemergence. Across many use sites, it is simple to use (i.e., it has broad-spectrum of control, minimal reentry intervals and minimum pre-harvest intervals).

In addition to agricultural uses, glyphosate is important for noxious and invasive weed control in aquatic systems, pastures/rangelands, public lands, forestry, and rights-of-way applications. Glyphosate is the leading herbicide used to control invasive species in the United States. Glyphosate is important for rights-of-way sites because it helps protect the stability of the surface and provides an unobstructed view from undesirable vegetation. Rights-of-way applications are critical to maintaining vital infrastructure and safety for transportation, distribution of goods and services (railways and roadways) and utilities (electric and gas). Glyphosate is an effective herbicide for rights-of-way because of its low cost and broad-spectrum. Glyphosate applications help to keep water resources open for navigation and help maintain water quality, habitat restoration, and recreation.

Glyphosate is also in numerous residential products and provides broad-spectrum weed control to users that include homeowners and landscaping operations. Millions of pounds of glyphosate are applied to non-crop sites every year.

To address potential risks to non-target organisms in areas adjacent to treated areas, the Agency is considering use restrictions for spray drift management. Proposed mitigation includes restrictions on applications during temperature inversions and specification of droplet size, boom length, and spray release height. The Agency is considering increasing the allowable wind speed for aerial applications in conjunction with shorter boom length.

Restrictions due to possible temperature inversions may impact the usability of glyphosate products; however, most spray drift management measures are not expected to substantially reduce the benefit of glyphosate to users.

While resistance has been widely reported and confirmed in 17 different weed species in the United States (Heap, 2018), glyphosate remains a useful herbicide for users in agricultural and non-agricultural settings because it has a broad spectrum, is simple to use, and is often cost-effective. However, the benefit of glyphosate to users is contingent upon its effectiveness. If glyphosate-resistant biotypes are present in a field or treatment area, then the benefits of glyphosate could be reduced for those users.

BACKGROUND

FIFRA Section 3(g) mandates that the Environmental Protection Agency (EPA or the Agency) periodically review the registration of all pesticides to ensure that they do not pose unreasonable adverse effects to human health and the environment. This periodic review is necessary in light of scientific advancements, changes in policy, and changes in use patterns that may alter the conditions underpinning previous registration decisions. In determining whether effects are unreasonable, FIFRA requires that the Environmental Protection Agency consider the risks and benefits of any use of the pesticide.

The Office of Pesticide Programs (OPP) completed risk assessments for glyphosate and found potential risks to birds, mammals, and terrestrial/aquatic plants.

The Agency is considering spray drift management measures to reduce the potential for exposure to non-target organisms. Spray drift management measures include:

- Applicators must not spray during temperature inversions.
- For aerial applications, do not apply when wind speeds exceed 15 mph at the application site. If the wind speed is greater than 10 mph, the boom length must be 65% or less of the wingspan for fixed wing aircraft and 75% or less of the rotor blade diameter for helicopters. Otherwise, the boom length must be 75% or less of the wingspan for fixed-wing aircraft and 90% or less of the rotor diameter for helicopters.
- For aerial applications, the release height must be no higher than 10 feet from the top of the crop canopy or ground, unless a greater application height is required for pilot safety.
- For ground boom applications, apply with the release height no more than 4 feet above the ground or crop canopy.
- For ground and aerial applications, select a nozzle and pressure that deliver fine or coarser droplets as indicated in nozzle manufacturers' catalogues and in accordance with American Society of Agricultural & Biological Engineers Standard 572.1 (ASABE S572.1).

This memo describes the benefits of glyphosate in agricultural and non-agricultural use sites and discusses EPA's proposed mitigation measures and their possible impacts on users. The information in this assessment may be used during the risk mitigation process and development of the Proposed Interim Decision (PID) for glyphosate. This memo also summarizes public comments received by EPA after the draft human health and ecological risk assessments were published.

METHODOLOGY

The benefits of the use of a pesticide are typically measured in comparison to the next best available pest control option in terms of improved outcomes, such as yield or quality, or in decreased pest control costs, where costs are considered broadly to include not just monetary costs but also factors such as managerial effort and complexity. Given the wide range of use sites for which glyphosate is registered and the low risks of concern, this assessment is qualitative in nature. Rather than focus on specific crops and target weeds, this assessment identifies benefits to glyphosate users for several broad groups of crops and use sites.

BEAD considered the following sources of information to analyze glyphosate's benefits:

- Pesticide market research data (MRD) which provides pesticide usage information, including application rates, number of applications, and percentage of the crop treated for about 60 surveyed crops.
- Kline and Company market research data which provide pesticide usage information for many non-agricultural uses, including the residential consumer market, as well as pasture and rangeland.
- Florida Fish and Wildlife Conservation Commission which provides information on the aquatic use of glyphosate.
- U.S. Forest Service (USFS) data which provides information on invasive weed control.
- Comments from stakeholders following publication of the glyphosate draft human health and ecological risk assessments.
- Extension literature.
- Papers from the open scientific literature.

BEAD analysts first consulted agricultural pesticide usage data to identify important uses that may be associated with potential risks (i.e., those accounting for the most acres treated and/or amount of glyphosate used). These sites are arranged by groups which have similar production and weed control practices. The groups are:

- Field crops, including:
  - Genetically modified glyphosate-resistant (GR) field crops (corn, soybeans, cotton, canola, sugar beets, and alfalfa)
  - Non-glyphosate-resistant varieties of these crops and other field crops (e.g., wheat, dry beans and peas, peanuts, sunflowers)
- Orchards and vineyards (e.g., fruit and nut trees, citrus, grapes)
- Vegetables and other crops (e.g., melons, berries, fruiting vegetables, onions, asparagus)
- Pasture and rangeland
- Non-agricultural uses (e.g., rights of way, turf, aquatic sites, etc.)

For each use group, information from the relevant sources listed was used to develop a qualitative assessment of the role of glyphosate in weed management and identify the advantages glyphosate provides the user.

The next section summarizes relevant comments received, most of which describe various benefits of glyphosate. These comments provide a basis for further discussion in the subsequent sections of this document.

PUBLIC COMMENTS

Thousands of comments were received from various individuals, growers, businesses, commodity groups and other stakeholders. Comment summaries and BEAD's responses to benefits and use comments are grouped according to general benefits (that apply to nearly all glyphosate uses) and according to the broad categories of glyphosate's uses: field crops (genetically-engineered to be glyphosate-resistant [GR] and non-GR field crops), other agricultural uses, i.e., vegetables and tree crops and vines, non-agricultural uses (forestry, rights-of-way, etc.,) and residential/homeowner uses.

The substantive comments of relevance to this assessment and addressed subsequently in this memo are denoted below by use of the four-digit number that was assigned to the individual submission. For instance, the comment EPA-HQ-OPP-2009-0361-1001 is identified by the last four digits (-1001) and is associated with an individual comment submission. All received comments can be found in the docket.

Commenters by Affiliation:

a) Academic/Extension: Weed Science Society of America (-2185), LSU Ag Center (-1655).

b) Commodity Groups/ Trade Organizations:
   i. General Organizations: Agribusiness Association of Iowa (-1465), Hawaii Crop Improvement Association (-2196), Western Processors Association (-2198), South Dakota Agribusiness Association (-1625), California Women for Agriculture (-1012), Minnesota AgriGrowth Council (-1671), Agricultural Retailers Association (-1874), Northeast Agribusiness and Feed Alliance (-1879), National Council of Farmer Cooperatives (-2003), Kansas Agribusiness Retailers Association (-1616), Western Growers (-2128), Washington Friends of Farms & Forests (-1002),
   ii. Alfalfa/Forage: Nebraska Alfalfa Marketing Association (-1222), National Alfalfa and Farm Alliance (-1633), Midwest Forage Association (-1635),
   iii. Grains: North Dakota Grain Growers Association (-1674), Idaho Grain Producers Association (-1819), Virginia Grain Growers Association (-1672), National Association of Wheat Growers (-2129), Virginia Grain Producers Association (-1672),
   iv. Corn: Illinois Corn Growers Association (-1642), Iowa Corn Growers Association (-1630), National Corn Growers Association (-2009), South Dakota Corn Growers Association (-1802), Wisconsin Corn Growers Association (-2095), Indiana Corn Growers Association (-2186),
   v. Cotton: Plains Cotton Growers, Inc. (-0475), Georgia Cotton Commission (-1001), California Cotton Ginners & Growers Association (-2197), National Cotton Council (-1627),

vi. Soybean: Minnesota Soybean Growers Association (-1006), American Soybean Association (-0943), Kentucky Soybean Association (-1606), Iowa Soybean Association (-1662), Ohio Soybean Association (-1604), North Dakota Soybean Growers Association (-0951),
vii. Sugar: Western Sugar Cooperative (-0944), American Crystal Sugar Company (-2164), Beet Sugar Development Foundation (-0957), American Sugarbeet Growers Association (-1016), Amalgamated Sugar Company (-1667),
viii. Specialty Crops: Malheur County Onion Growers Association (-2163), Almond Alliance of California (-1875), Northwest Horticultural Council (-1670),

c) Non-profit organizations: Center for Food Safety (-2209)
d) Federal, State or Local Government: Nebraska Department of Agriculture (-2008), Texas Department of Agriculture (-2002, -2018), USDA-Office of Pest Management Policy (-1618)
e) Agricultural Businesses: Hemdale Farms, Inc. (-1010), Mount Vineyards (-0945), Tri County Ag, LLC (-0957), Agrineed Inc. (-1663),
f) Pesticide Registrants: Monsanto Company (-1610, -1638)
g) Farm Bureaus: Illinois Farm Bureau (-1018), American Farm Bureau Federation (-1668), Delaware Farm Bureau (-1669), Kansas Farm Bureau (-1007), Hawaii Farm Bureau (-1872), Arizona Farm Bureau Federation (-1870), Pennsylvania Farm Bureau (-2098), Illinois Farm Bureau (-1605), Idaho Farm Bureau Federation (-1624), Missouri Farm Bureau Federation (-1643), Washington Farm Bureau (-1614), New York Farm Bureau (-2191), Oregon Farm Bureau Federation (-2103)

Summary of Comments on the General Benefits and Use of Glyphosate:

The Agency received comments from a broad range of stakeholders that attested to the general benefits of glyphosate's agricultural and non-agricultural uses. The majority of these comments contained information on the diverse benefits of the use of glyphosate which, according to stakeholders, include: environmental benefits due to glyphosate's role in no-till farming and conservation tillage and reduced carbon emissions, cost-effective and broad spectrum weed control, reduction in management time and farm inputs such as labor and fuel, simplification of weed control programs, better weed control resulting in higher yields, use of fewer and less toxic herbicides, and more flexibility in timing of application.

EPA's Response:

The EPA appreciates the many comments from stakeholders that describe glyphosate's benefits for agricultural and non-agricultural uses. The Agency agrees that glyphosate has the one of the largest pest spectrums of all herbicides and is registered on more use sites than any other herbicide. This is one reason that glyphosate is the preferred option to other herbicides and weed control methods. The Agency also recognizes the crop safety that glyphosate provides. The Agency has not carried out assessments of herbicides replaced by glyphosate but agrees that it is likely that the use of glyphosate results in the replacement of other herbicides and reduces grower inputs.

Summary of Comments on the Benefits and Use of Glyphosate on Glyphosate-Resistant Field Crops

Many commenters provided input concerning the benefits of glyphosate for weed control in glyphosate-resistant (GR) field crops. There are varieties of corn, sweet corn, soybeans, cotton, sugar beets, canola and alfalfa that are resistant to glyphosate. GR varieties comprise large majorities of the acres of field corn, soybeans, cotton and sugar beets produced in the United States. An important advantage of growing GR crops is that glyphosate can be applied directly over the crop canopy without injuring the crop. Commenters also provided information related to GR alfalfa and canola.

The benefits of glyphosate in GR crops cited by commenters include:

- Simplifying weed control:
  - Glyphosate is non-selective. It controls a wide range of broadleaf weeds and grasses.
  - It allows flexibility in timing of weed control. In GR crops, because it can be applied over the canopy, glyphosate can be used at almost any time during the growing season.
  - Glyphosate reduces or eliminates the need for other weed control methods, including other herbicides, many of which pose more risk to humans or the environment.
- It is cost-effective and efficient. Glyphosate can reduce the need for other weed control measures. It can also reduce the number of tractor trips across a field needed for weed control which reduces fuel consumption and labor.
- Facilitating no-till or conservation tillage production of GR crops which reduces or eliminates reliance on tillage for weed control. This results in conserving soil moisture and maintaining soil "health" by reducing soil compaction from tractor trips over the field. No-till and conservation tillage crop production also reduces soil erosion from wind and water and conserves soil moisture.
- In addition to the general benefits to GR crops cited above, comments from sugar beet producers, processors, and related stakeholders indicated that there are specific advantages of glyphosate use on GR sugar beets:
  - Sugar beet growers grow glyphosate-resistant varieties exclusively; it is not possible to produce sugar beets without glyphosate.
  - Prior to the availability of GR sugar beets, growers typically used a weed control program that combed 13 different herbicides. This weed control system required precise timing of applications, specialized equipment, multiple cultivations, and expensive hand labor.
  - Since the introduction of GR sugar beets in 2008, yields have increased by 30 percent.

EPA's Response:

The Agency appreciates the information provided and agrees that the comments received on this topic point to important benefits of glyphosate and the reasons that its use is often preferred to other weed control practices in GR crops. The Agency cannot confirm any comments related to

quantitative benefits (e.g., yield increases) because quantitative analyses were not conducted by the Agency.

When used on crops genetically-engineered to be glyphosate-resistant, glyphosate is particularly important. Its broad spectrum of weed control (broadleaf weeds and grasses) is likely to reduce farm inputs by reducing the number of herbicides and the number of trips over the field for weed control or tillage. This, in turn, is likely to result in lower labor and fuel costs compared to other weed control systems. Moreover, the Agency agrees that there are benefits in weed control efficiency and to the environment when no-till or conservation tillage, which are facilitated by glyphosate, are part of the production systems in GR field crops. The environmental benefits of no-till or conservation tillage compared to conventional tillage include reduced potential for soil erosion and preservation of soil moisture. Gains in weed management cost and efficiency compared to conventional weed management are realized through reduced trips over the field and savings on fuel and labor.

Although the Agency agrees that the use of glyphosate on GR crops provides benefits to growers, widespread use of and over-dependence on glyphosate for weed control has led to major weed resistance problems, particularly in GR crops. Widespread weed resistance has reduced some of the benefit of glyphosate use in GR crops which detracts from the simplicity of using glyphosate alone for weed control. Resistance has increased reliance on more diverse methods of weed control. In some cases, this includes tillage. It may also include reliance on herbicides other than glyphosate, including the use of pre-emergence herbicides and adding herbicides with a different mechanism of action to tank mixes with glyphosate.

Summary of Comments on Herbicide Resistance

In addition to comments on usage and benefits, there were also comments indicating that widespread use of glyphosate has resulted in increases in weed resistance, particularly in GR crops. Commenters noted that there are 17 weed species in 38 states with documented resistance to glyphosate. Commenters also noted the widespread adoption of GR plants has contributed to the evolution of herbicide resistance. Other stakeholders mentioned that glyphosate is still effective on weeds that are resistant to other herbicides, such as acetolactate synthase inhibitors (ALS herbicides). Other commenters indicated that herbicide-resistant crop technology has led to a major increase in herbicide use in the United States.

EPA Response:
The Agency published two Pesticide Registration Notices (PRNs) which address pest resistance management. PRN 2017-1 (https://www.epa.gov/pesticide-registration/prn-2017-1-guidance-pesticide-registrants-pesticide-resistance-management) promotes mechanism of action labeling by pesticide registrants. PRN 2017-2 (https://www.epa.gov/pesticide-registration/prn-2017-2-

guidance-herbicide-resistance-management-labeling-education) provides specific guidance for managing herbicide resistance.

Whenever an herbicide is used there is a potential for that use to contribute to the evolution of herbicide resistance, particularly if a weed species or population is subjected to repeat sublethal doses. This may occur in genetically-engineered crops, conventional crops, or non-crop situations. Genetically-engineered crops can be a solution to resistance or exacerbate resistance depending on herbicide use and stewardship within those crops. In the case of glyphosate-resistant crops, over reliance on glyphosate used alone has made glyphosate resistance the worst herbicide resistance problem (Heap, 2014). Glyphosate remains a valuable tool because it is still effective on many populations of weeds including species that have shown resistance to other herbicides. To facilitate management of herbicide resistance, EPA encourages tank-mixing herbicides, promotes diversity in weed control practices, rotating different mechanisms of action, crop rotation, and encourages integrated pest management (IPM) programs. To facilitate adoption of resistance management, the Agency has for several years worked closely with stakeholder groups to promote good resistance management practices. To maintain some of the most important benefits of glyphosate, growers must use the herbicide responsibly as part of an integrated weed control strategy and be proactive in employing good resistance management practices.

In regards to herbicide resistance occurring through pollen mediated gene flow from resistant crops to weedy relatives, the United States Department of Agriculture's Animal and Plant Health Inspection Service (USDA-APHIS) evaluates this risk in addition to regulating the planting, importation, or transportation of genetically engineered plants pursuant to its authority under the Plant Protection Act (PPA). By regulation, APHIS classifies most GM plants as plant pests or potential plant pests and as "regulated articles." Under the PPA, a regulated article must receive prior approval from APHIS before it is introduced for commercial production by farmers.

Summary of Comments on the Benefits and Use of Glyphosate on Conventional Field Crops

The Agency received many comments related to the benefits of glyphosate on conventional (i.e., non-GR) field crops. The crops mentioned in this group of comments included small grains, sugarcane, sorghum, alfalfa seed production, and others.

Commenters indicated that glyphosate use in conventional field crops provides some of the same benefits identified above that are not specifically related to GR crops, i.e., where non-selective herbicides can be used without injuring the target crop. These benefits include safe and cost-effective broad-spectrum weed control, facilitating weed control in conservation tillage production systems, and flexibility in application timing where a non-selective herbicide can be used.

Some of the specific circumstances where glyphosate is used in non-GR field crops include burn-down and pre-harvest applications for small grains and other conventional field crops. It can also be used to manage cover crops and fallow ground. It has benefits in sugarcane production where it is used as ripening agent and prior to planting in a fallow period.

EPA's Response:
The Agency appreciates the information submitted and agrees that glyphosate provides benefits in non-GR crops as indicated in the comments. Most of the benefits conveyed to growers of non-GR field crops relate to glyphosate's versatility and flexibility. Glyphosate is registered for nearly all field crops and can be used in most circumstances where non-selective weed control is needed. As with its use in GR crops, to maintain its benefits in conventional field crops, glyphosate should be used as part of a diversified weed control system that includes proactive resistance management practices.

Summary of Comments on the Benefits and Use of Glyphosate on Vegetable Crops
Commenters indicated that glyphosate use in vegetable crop production provides some of the same benefits to growers identified above that are not specifically related to GR crops. It is important where non-selective herbicides can be used without injuring the target crop. These benefits include safe and cost-effective broad-spectrum weed control and flexibility in application timing where a non-selective herbicide can be used. Glyphosate use on vegetables is common for weed burn-down before seeds or transplants go into the soil. It is also used around perimeters of vegetable fields.

Some of the specific circumstances where glyphosate is used in vegetable production include burn-down applications and managing cover crops and fallow ground.

EPA's Response:
The Agency appreciates the information submitted and agrees that glyphosate provides benefits to vegetable crop producers. Most of the benefits conveyed to vegetable growers relate to glyphosate's versatility and flexibility. Glyphosate is registered for nearly all vegetable crops and can be used in most circumstances where non-selective weed control is needed, including pre-plant burn-down and weed control around field perimeters. As with its other use categories, to maintain its benefits to vegetable crop growers, glyphosate should be used as part of a diversified weed control system that includes proactive resistance management practices.

Summary of Comments on Benefits and Use of Glyphosate on Tree and Vine Crops
Commenters indicated that glyphosate use in tree and vine crop production provides some of the same benefits to growers identified above that are not specifically related to GR crops. In these crops its primary use is for weed control on orchard and vineyard floors. It is important where non-selective herbicides can be used without injuring the target crop. These benefits include safe and cost-effective broad-spectrum weed control and flexibility in application timing where a non-selective herbicide can be used.

Some of the specific comments received concerned glyphosate's use and benefits to growers of apples, pears and cherries in the Pacific Northwest. Information was also submitted concerning glyphosate use and benefits in almond production. There were also comments on the benefits of glyphosate to producers of wine grapes, including the importance of using dome sprayers to reduce drift.

EPA's Response:
The Agency appreciates the information submitted and agrees that glyphosate provides benefits to producers of orchard and vine crops. Most of the benefits conveyed to these growers relate to glyphosate's versatility and flexibility. Glyphosate is registered for nearly all orchard and vine crops and can be used in most circumstances where non-selective weed control is needed. As with its other use categories, to maintain its benefits to orchard and vine crop growers, glyphosate should be used as part of a diversified weed control system that includes proactive resistance management practices.

Summary of Comments Regarding the Usage

A number of private citizens expressed concerns that EPA did not adequately assess the large volume of glyphosate use and the large number of use sites as part of registration review. Some commenters, such as Center for Food Safety (CFS), requested that EPA update or adjust usage reports to more accurately depict the scale and trends of agricultural glyphosate usage and overall herbicide usage in the United States.

EPA's Response:

The Agency appreciates these comment regarding usage data. EPA agrees that the overall use of herbicides, in terms of pounds applied, has increased from 2005 to 2016. At various points in registration review, EPA has provided estimates of agricultural usage and non-agricultural for glyphosate. In this assessment, EPA provides an updated summary of glyphosate agricultural usage based on the available agricultural survey data (MRD 2012-2016) at the appropriate geographic and statistically significant scale. EPA also provides an estimates of non-agricultural use data from various sources. The following use reports were previously published in the glyphosate registration review docket: the 2008 *Screening Level Estimates of Agricultural Uses of the Case Glyphosate* and the 2015 *Updated Screening Level Usage Analysis (SLUA) Report for Glyphosate Case PC #s (103601, 103604, 103607, 103608, 103613, 417300)*.

Summary of Comments on Benefits and Use of Glyphosate in Non-Agricultural Scenarios (Forestry, Rights-of-way, Aquatic Uses, etc.)
The Agency received comments from many stakeholders concerning the use and importance of glyphosate in non-agricultural scenarios. Commenters indicated that glyphosate provides some of the same benefits in non-agricultural scenarios that are identified above. It is important where non-selective herbicides can be used and provides flexibility and safe and cost-effective broad-spectrum weed control.

Comments indicated that glyphosate is an important and effective herbicide in a variety of non-agricultural situations. It is useful in vegetation management along roadsides and helps makes roads safer (e.g., by improving visibility for drivers). It is also useful in weed control in parks and other public spaces such as school yards, city landscapes and nature trails. It is used to manage turf in commercial areas and golf courses. It is used widely in forest management, particularly for reforestation and to control invasive species. Glyphosate is important to landscape contractors, lawncare specialists, and to nursery and greenhouse managers. Glyphosate is also commonly used for weed control in aquatic systems where it is effective against emerged and floating weeds.

The U.S. Department of Agriculture (USDA) provided information from the U.S. Forest Service (USFS) on situations when relatively high rates of glyphosate are needed for weed control in specific non-crop scenarios. For instance, the Southern USFS region uses glyphosate at rates from 0.2 pounds acid equivalent (lbs. a.e.) per acre to 7.5 lbs. a.e. per acre. The higher end of the rate range is used on "rare" occasions. The scenarios where glyphosate is used at higher rates by the USFS in the Southern region include forest site preparation, invasive plant treatment in forests, administrative sites, rights-of-way, forest nurseries, and creation of wildlife openings (areas cleared of forest canopy and managed as wildlife feeding areas). For the Intermountain and Northern USFS regions, high rates of glyphosate are used for wipe-on, stem wick, cut stem pour application to apply glyphosate selectively and effectively. For the Pacific region, USDA provided information from the Forest Service Activity Tracking System (FACTS) from 1998-2016 showing that the average application rate of glyphosate used for site preparation or conifer release is 2.4 lbs. a.e. per acre.

EPA's response:
The Agency thanks USDA and other stakeholders for the information submitted concerning the use of glyphosate in a variety of non-agricultural scenarios. The Agency is aware of the broad range of non-agricultural use sites on which glyphosate can be used. The Agency is particularly appreciative of the USDA/USFS information concerning situations where relatively high application rates are needed. This information suggests that relatively high application rates of glyphosate are needed for some forestry and aquatic scenarios and that the application method of many of these high rate applications (e.g., 8 lbs. ae per acre) does not reflect a rate that is applied to an entire acre in some situations.

Comments on Residential Uses

Comments indicated that glyphosate is cost-effective and efficacious. Comments also indicated that residential herbicide products are limited.

EPA's Response:

The Agency thanks commenters for this information. This information reiterates that glyphosate has a broad weed control spectrum and is registered on many sites that include turf, ornamentals, and residential/industrial sites.

CHEMICAL INFORMATION

Glyphosate (N-[phosphonomethyl] glycine) is a 5-Enolpyruvyl-Shikimate-3-Phosphate (EPSP) Synthase Inhibitor (WSSA Group 9) herbicide. Glyphosate was commercialized in 1974 and use increased substantially after glyphosate-resistant crops were introduced in 1996. It is the only herbicide with this Mechanism of Action. Glyphosate is absorbed across the leaves and stems of plants and is translocated throughout the plant. It concentrates in meristematic tissue.

Glyphosate can be used as an herbicide or harvest aid. There are numerous salt, amine and ester forms of glyphosate (as noted with the PC Codes above) undergoing registration review. In this document, "glyphosate" is used to describe all forms of glyphosate undergoing review.

Glyphosate controls emerged weed species. It is applied preemergence to crops, and preemergence and early/late postemergence to the crop in GR cropping systems. It is also applied as a fall burndown application to control weeds that emerge after a crop has been harvested. Fall burndown applications help to reduce weed pressure in the following spring.

In addition to agricultural uses, glyphosate is used to control weeds and woody species in residential, non-agricultural and industrial use sites. It can be applied to foliage or cut stems/stumps.

USE AND USAGE

Glyphosate is the most used herbicide in United States' crop production in terms of acres treated (MRD, 2012-2016). There are approximately 280 million pounds of glyphosate applied to 298 million acres annually in agricultural settings (MRD, 2012-2016). Tables 1a-c present usage information for crops with the greatest usage, in terms of acres treated and pounds applied, for agricultural crops: field crops, orchards and vineyards, and vegetable crops. Table 2 presents the usage information available to the Agency for non-agricultural sites.

The highest potential ecological risks from the use of glyphosate are associated with sites with high maximum application rates, such as pastures, non-food tree crops, forestry, and non-crop uses with application rates at or above 8 lbs. acid equivalence per acre (a.e./acre). There are also potential ecological risks associated with aerial applications and multiple applications of glyphosate.

Agricultural Usage Information

Table 1a summarizes the usage of glyphosate in field crops for the years 2012-2016. Large field crops, with millions of acres planted, such as soybeans, corn, cotton, and sugar beets have the highest total area treated (TAT) and pounds applied with glyphosate (MRD, 2012-2016). The majority of glyphosate use, in terms of total acres treated, occurs late postemergence to the crop

in field crops (MRD, 2012-2016). On average, eighty-four percent of glyphosate, in terms of pounds, is applied to soybeans, corn, or cotton per year (MRD, 2012-2016). These three field crops all have glyphosate-resistant (GR) varieties that have been widely adopted. Many field crops, with and without GR varieties, have a high percentage of their acres treated with glyphosate which is an indication that growers experience benefits from use of this chemical. The field crops with the highest percentage of their acres treated with glyphosate are sugar beets, soybeans, cotton, and corn, respectively (Table 1a). With the exception of sugarcane, the average single application rate for field crops ranges from 0.72 to 1.00 lbs. a.e./acre (Table 1a). With the exception of sugarcane, the average cost per application for field crops ranges from $3-$5/acre (Table 1a).

There is also use of glyphosate as a plant growth regulator (PGR) on a few crops. However, sugarcane is the only crop with substantial use of glyphosate as a PGR, with over 50,000 pounds applied to over 254,000 acres (MRD, 2012-2016). Sugarcane has the highest average application rate and per acre cost of glyphosate as an herbicide for field crops at 1.76 lbs. a.e./acre and $9/acre (Table 1a), which are the second highest overall for all agricultural crops, right behind table grapes (MRD, 2012-2016). Glyphosate usage as a PGR has the lowest average application rate and cost at 0.20 lbs. a.e./acre and $1, respectively (Table 1a).

Table 1a. Average Annual Glyphosate Usage in Agricultural Crops- *Field Crops*, 2012-2016

Crop[1]	Total Area Treated (acres)	Pounds (lbs.) Acid Equivalent (a.e.) Applied	Single Application Rate (lbs. a.e./acre)	Number of Applica-tions	Percent Crop Treated (PCT)	Cost ($) /TAT
Barley	1,102,000	800,000	0.72	1.2	29%	$3
Canola (oilseed rape) [4]	1,237,000	835,000	0.67	1.6	57%	$3
Corn [4]	100,196,000	94,909,000	0.95	1.3	80%	$5
Cotton [3,4]	20,215,000	20,115,000	1.00	2.2	89%	$5
Dry Beans/Peas	1,762,000	1,356,000	0.76	1.3	44%	$3
Peanuts	452,000	407,000	0.90	1.1	29%	$4
Potatoes [3]	150,000	135,000	0.89	1.0	14%	$5
Rice	1,482,000	1,432,000	0.96	1.2	46%	$5
Sorghum	6,095,000	5,097,000	0.83	1.6	53%	$4
Soybeans [4]	117,400,000	113,937,000	0.97	1.6	92%	$5
Sugar Beets [4]	2,608,000	2,449,000	0.94	2.3	98%	$4
Sugarcane (H) [3]	249,000	410,000	1.76	1.2	24%	$9
Sugarcane (PGR)[3]	254,000	52,000	0.20	1.0	30%	$1
Sunflowers	1,772,000	1,413,000	0.80	1.4	74%	$3
Wheat, Spring	7,060,000	5,312,000	0.75	1.2	41%	$3
Wheat, Winter	8,373,000	6,814,000	0.81	1.1	20%	$4

Fallow[2]	16,752,000	13,263,000	0.79	1.9	64%	$3

MRD 2012-2016

1 - There were 11 crops in the MRD that showed less than 10% of the crop treated with glyphosate: alfalfa, artichoke, carrots, cauliflower, celery, garlic, lettuce, lima beans, pastureland, spinach, and tobacco. Taken together, the total average annual pounds of glyphosate used on these 11 crops was approximately 2 million lbs. or less than 1% of the total use of glyphosate on all surveyed crops. These crops are not listed in the table.

2 - Fallow land- land going coming out of production or ready to go back into production, but not crop specific and typically associated with grain production.

3- There are a few crops with recent PGR (plant growth regulator) use of glyphosate: cotton, potatoes and sugarcane. However, since sugarcane was the only one with significant and consistent use, it is included in this table. The (H) stands for herbicide use in sugarcane. To get the total use in terms of pounds or acres treated, it would be necessary to add these two sugarcane rows together.

4- Crops with substantial acreage planted with glyphosate-resistant varieties.

Many citrus fruits (e.g. grapefruit, oranges, lemons) and tree nuts (e.g. almonds, walnuts, pistachios) have the highest percentage of their acres treated with glyphosate. As with field crops, a high PCT is indicative of benefits to growers of those crops. The orchard and vineyard crops with the highest percentage of their acres treated with glyphosate are grapefruit, oranges, almonds, and grapes, respectively (Table 1b).

Most orchard/vineyard crops have average single application rates around 1.00 lb. a.e./acre (Table 1b). However, grapes (table and wine) and grapefruit have average application rates above 1.50 lbs. ae/acre (Table 1b). The average cost per application for orchard/vineyard crops ranges from $5-$13/acre (Table 1b). The average number of applications ranges from 1 to 3 applications per year (Table 1b). Generally, the average number of applications (~2) in orchard and vineyard crops is higher than for field crops or vegetables (~1) (MRD 2012-2016).

Table 2b. Average Annual Glyphosate Usage in Agricultural Crops - *Orchards and Vineyards*, 2012-2016

Crop[1]	Total Area Treated (acres)	Pounds (lbs.) Acid Equivalent (a.e.) Applied	Single Application Rate (lbs. a.e./acre)	Number of Applica-tions	Percent Crop Treated (PCT)	Cost ($) /TAT
Almonds	2,174,000	2,138,000	0.99	2.5	89%	$6
Apples	275,000	220,000	0.82	1.5	58%	$5
Apricots	13,000	10,000	0.90	1.9	62%	$5
Cherries	162,000	158,000	1.00	1.5	76%	$6
Grapefruit	205,000	313,000	1.56	3.5	93%	$7
Grapes, Raisin	263,000	346,000	1.31	1.6	74%	$8
Grapes, Table	196,000	359,000	1.84	2.0	88%	$13
Grapes, Wine	735,000	1,190,000	1.62	1.6	74%	$10
Hazelnuts	22,000	24,000	1.11	1.2	50%	$6
Lemons	121,000	173,000	1.42	2.6	78%	$10
Oranges	2,074,000	2,697,000	1.31	3.5	91%	$7
Peaches	123,000	115,000	0.95	2.1	58%	$5
Pecans	429,000	342,000	0.80	2.7	34%	$4
Pistachios	560,000	561,000	1.00	2.6	84%	$6
Plums/Prunes	150,000	145,000	1.00	2.3	81%	$6

Walnuts	602,000	590,000	0.98	2.2	82%	$6

MRD 2012-2016

The TAT and pounds applied for vegetables and fruits (i.e. those listed in Table 1c), is lower than for the previously mentioned groups of agricultural crops. This is mostly driven by the fact that the average acre and field size of these crops is lower than that of typical field or orchard/vineyard crops. As with field and orchard/vineyard crops, a high PCT is indicative of benefits to growers of these crops.

The vegetable and fruit crops with the highest percentage of their acres treated with glyphosate are asparagus, cucumbers, onions and tomatoes, respectively (Table 1c). Sweet corn and succulent beans are also vegetable crops with high TAT and pounds applied (Table 1c). The average single application rate for vegetables ranges from 0.89 to 1.73 lbs. a.e./acre (Table 1c). The average cost per application for vegetables ranges from $5-$8/acre (Table 1c). The average number of applications for each vegetable crop is less than 1.5 applications per year (Table 1c).

Table 3c. Average Annual Glyphosate Usage in Agricultural Crops - *Vegetables and Other Crops*, 2012-2016

Crop[1]	Total Area Treated (acres)	Pounds (lbs) Acid Equivalent (a.e.) Applied	Single Application Rate (lbs. a.e./acre)	Number of Applica-tions	Percent Crop Treated (PCT)	Cost ($) /TAT
Asparagus	23,000	22,000	0.99	1.5	60%	$5
Cabbage	14,000	23,000	1.55	1.2	20%	$8
Caneberries	5,000	5,000	0.89	1.7	13%	$5
Cantaloupes	8,000	14,000	1.64	1.1	13%	$8
Cucumbers	40,000	56,000	1.40	1.2	30%	$6
Onions	51,000	52,000	1.03	1.2	34%	$5
Peppers	17,000	25,000	1.47	1.1	22%	$7
Pumpkins	16,000	19,000	1.22	1.1	19%	$7
Squash	13,000	18,000	1.38	1.0	28%	$7
Strawberries	11,000	21,000	1.73	1.5	13%	$7
Succulent Beans	53,000	72,000	1.34	1.1	21%	$6
Succulent Peas	25,000	23,000	0.89	1.0	15%	$5
Sweet Corn	140,000	166,000	1.17	1.1	26%	$6
Tomatoes	134,000	158,000	1.17	1.2	34%	$7
Watermelons	25,000	27,000	1.17	1.2	17%	$6

MRD 2012-2016

1 - There were 11 crops in the MRD that showed less than 10% of the crop treated with glyphosate: alfalfa, artichoke, carrots, cauliflower, celery, garlic, lettuce, lima beans, pastureland, spinach, and tobacco. Taken together, the total average annual pounds of glyphosate used on these 11 crops was approximately 2 million lbs. or less than 1% of the total use of glyphosate on all surveyed crops. These crops are not listed in the table.

Applications Methods for Glyphosate

There are many ways of applying glyphosate; methods of application include aerial, ground, spot treatments, strip sprays, trunk sprays, etc. BEAD only has data on application methods for agricultural sites. Ground is by far the most common application method with over 90% of acres (or 284 million acres) being treated in this way (MRD, 2012-2016). Despite the variety of application methods, the average rates per method are still around 1 lbs. a.e./acre, ranging from 0.92 lbs. a.e./acre for ground to 1.39 lbs. a.e./acre for trunk sprays. (MRD, 2012-2016)

Aerial is not a common application method for agricultural users of glyphosate. This application method represents about 2% (or 5 million) of all acres treated with glyphosate (MRD, 2012-2016). The crop sites with the largest number of acres treated with aerial applications are soybeans, corn, cotton, and rice, respectively, which altogether account for over 4 million of the 5 million acres treated aerially (MRD, 2012-2016). The crops with the highest percentage of their acres treated aerially with glyphosate are rice (36%) and tomatoes (8%). The average rate for aerial applications is 0.98 lbs. a.e./acre. (MRD, 2012-2016).

Application Rates for Glyphosate

With the high PCT, acres treated, and pounds applied with glyphosate for many crops (Tables 1a-c), glyphosate use is prevalent nationwide. The benefits of glyphosate are described in subsequent sections of this memo. In addition to benefits, there are also ecological risks, primarily driven by repeated applications at maximum crop cycle rates and for non-agricultural use sites or spot treatments where the maximum annual rate or single application rate is high. Typically, the maximum labeled single application rate for most uses is lower than 8.00 lbs. a.e./acre. Generally, the label maximum is 3.75 a.e./acre or less for ground applications (inclusive of most GR crops such as corn, cotton, and sugar beets) and 1.55 a.e./acre or less for aerial applications. As noted earlier, the average rates as shown in Tables 1a-c are typically around 1.00 lbs. a.e./acre. Approximately 90% of ground applications to agricultural sites occur at or below 2.00 lb. a.e./acre and around 90% of aerial applications of glyphosate to agricultural use sites occur at or below 1.25 lb. a.e./A (MRD, 2012-2016).

Non-Agricultural Usage Information

Approximately 24 million pounds of glyphosate were reported as being used in 2011 on a variety of non-agricultural sites (Kline, 2012a and b). Glyphosate is usually one of the top chemical control options for these sites. Glyphosate was the most used herbicide in terms of pounds in the consumer market (e.g. homeowners) (Kline, 2012a). The consumer market, turf, and forestry sites had the highest use of glyphosate in terms of pounds applied (Table 2). Glyphosate was the most used herbicide for roadways in terms of acre-treatments and the Agency received comments supporting the benefits of this use pattern (Kline, 2012b). It was the second most used herbicide, in terms of acre-treatments, for electric utilities and pipelines, forestry, and railroad use sites (Kline, 2012b). In 2011, glyphosate accounted for 7% of all herbicide acre-treatments for control of aquatic vegetation (Kline, 2012b). The Florida Fish and Wildlife commission applied over 40,000 pounds of glyphosate in aquatic settings in 2017 (FWC, 2017). Glyphosate was the fourth most-used active

ingredient, in terms of acres treated, applied by the United States Forest Service to control invasive weeds in 2013 (USFS, 2013). Nationally, glyphosate is the leading active ingredient applied by federal entities for the control of invasive species (Wagner et al., 2017).

Table 2. Annual Glyphosate Usage for Non-Crop Sites, 2011

Use Site	Pounds Applied (Lbs. a.e.)	Acre Treatments
Aquatic	128,900	40,000
Consumer Market [1]	5,000,000	-
Electric Utilities and Pipelines (Rights of Way)	2,070,200	654,000
Forestry	3,646,900	757,000
Nursery Greenhouse	2,800,000	-
Railroads (Rights of Way)	528,000	293,000
Range and Pasture	1,479,000	1,498,000
Roadways	3,271,000	1,833,000
Turf [2]	4,920,000	-
Total	**23,844,000**	**-**

Kline 2012a and Kline 2012b

[1] This site includes use by homeowners.

[2] This site "turf" includes institutional turf (e.g. cemeteries and parks) (59%), lawn care operators (20%), landscape professionals (12%), golf courses (7%), and turf (2%).

BEAD does not have detailed application rate data for the sites listed in Table 2.

According to comments from the United States Department of Agriculture (USDA), application to these use sites with higher rates (e.g. aquatic, forestry, rights of way) are generally done via handheld, wick, wipe-on, brush-on, and other equipment that are unlikely to contribute to non-target exposure.

BENEFITS OF GLYPHOSATE

Glyphosate is a relatively inexpensive herbicide for agricultural applications (MRD, 2012-2016) that provides control of numerous broadleaf weeds, sedges, and grasses. In addition to the broad-spectrum of pests controlled, it has few use restrictions and can be used immediately before planting in many crops and in non-agricultural sites. Generally, in the absence of glyphosate, users would need to change to active ingredients that have more stringent use restrictions, narrower control spectrums, or mechanical methods. Some of these methods may not be as cost-effective.

Field Crops

Glyphosate is used at various crop timings in a large variety of field crops throughout the United States. Glyphosate can be applied for post-harvest fall burndown, preplant burndown, at plant weed control, over-the-top weed control (in GR crops), directed spot treatments, between row

weed control, and as a harvest aid. A majority of canola, corn, cotton, sorghum, and soybean acres (over 50 percent of acres treated by crop [Table 1]) are treated at least once each year; while other crops such as barley, rice, peanuts, and wheat also have substantial percentages (>20 percent) of acres treated each year (MRD, 2012-2016). The average single application rate for most of these crops does not exceed 1.0 lbs. per acre. The average number of applications in most field crops is between 1 and 2 applications, with two exceptions: cotton and sugar beets. Cotton is treated 2.2 times, on average, and sugar beet is treated 2.3 times, on average (MRD, 2012-2016).

Glyphosate-Resistant Field Crops

Current glyphosate-resistant field crops include soybean, corn, cotton, canola, alfalfa, and sugar beet. Many of these crops, such as corn, cotton, soybean, and sugar beet, have exceptionally high percentages of their acreage treated with glyphosate (approximately 90 percent of acres treated in each crop [Table 1]). GR canola is also available, and canola also has a high PCT (57 percent) (MRD, 2012-2016). Genetically-engineered (transgenic) glyphosate-resistant (GR) varieties of these crops can be sprayed over-the-top with minimal or no crop phytotoxicity, and glyphosate may also be used as a pre-plant burndown in many of these crops. For example, the Iowa Corn and Soybean Production guide (Owen, 2019) recommends 14 postemergence herbicide products in soybean. Only three of the active ingredients in these products control broadleaf and grass species: glyphosate, imazamox, and imazethapyr. Of these three active ingredients, only glyphosate has an excellent crop safety rating (for GR varieties) (Owen, 2019). The widespread use of glyphosate in GR systems is attributed to simplicity and cost efficiency (Powles, 2008). Without access to glyphosate, growers of GR field crops would convert to other herbicides with corresponding resistant crop varieties (if available) or change to other chemical or mechanical practices to control weeds. Given that glyphosate is relatively inexpensive at $3 to $5 per acre (Table 1a), these alternative methods of control could lead to increases in cost for these users of glyphosate.

GR alfalfa is also available; however, average PCT for alfalfa is less than 5 percent (MRD, 2012-2016).

Non-glyphosate Resistant Field Crops

Glyphosate is also used in field crops that are not glyphosate-resistant for early season weed control (burndown), termination of cover crops, and as a harvest aid. For example, glyphosate is used as an herbicide on high percentages of barley, peanut, rice, sorghum, sunflower, spring wheat, and winter wheat acres (PCTs ranging from 29 percent to 74 percent) (MRD, 2012-2016). Glyphosate controls a broad spectrum of weeds and has a short plant-back interval; therefore, growers can apply a burndown application and plant a sensitive crop within a few days or weeks. These characteristics of glyphosate also support no-till or strip-till production. The adoption of cover crops varies widely by geographic region and crop, but if a grower planted a cover crop, glyphosate may also be used to terminate the cover crop before planting the subsequent crop. When used as a harvest aid, glyphosate can control green weeds and accelerates uniform maturity in cereals such as wheat, corn, barley, oats, and sorghum.

Non-GR corn, cotton, and soybean, which make up small percentages of national acreages, are also treated with glyphosate for burndown prior to planting. On average, GR corn, cotton and

soybean receive more applications of glyphosate than non-GR corn, cotton, and soybean (MRD, 2012-2016). For example, GR cotton receives an average of 2 applications while non-GR cotton receives 1 application on average (MRD, 2012-2016). Average rates in non-GR corn, cotton, and soybean are similar to GR corn, cotton and soybean (approximately 1.0 lb. per acre) (MRD, 2012-2016). Without access to glyphosate or with restriction(s) that severely limit the use parameters of glyphosate, growers of non-GR field crops would change to other chemical or mechanical practices to control weeds. Given that glyphosate is relatively inexpensive, at $3 to $5 per acre (Table 1a), these alternative methods of control could lead to increases in cost for these users of glyphosate. Depending on the crop, other broad-spectrum burndown herbicides for non-GR varieties could include paraquat and glufosinate and broadleaf specific herbicides such as 2,4-D, or dicamba combined with other active ingredients. In other cases, no-till growers may resort to tillage.

Orchards and Vineyards

Weeds impact production in orchards and vineyards by competing with trees and vines, inhibiting irrigation, and acting as habitat for a variety of insect pests (Mitchem, 2016; Washington State University, undated). Orchard floor management helps to control erosion, limit rodent populations, and increase harvest efficiency. Generally, the orchard floor is divided into two areas: the area directly beneath the trees and the area between trees rows which may be planted in a cover crop or sod. Depending on the crop, glyphosate can be used to manage plants in the row-middles, to manage weeds in the row, or to establish a vegetation free orchard floor for crop harvest.

Glyphosate is used in the establishment of orchards or vineyards and used to control weeds once established. Glyphosate may also be used for chemical mowing or wiping. Chemical mowing is the application of sub-lethal rates of an herbicide to reduce the number of times a sod strip needs to be mowed throughout the season. Chemical wiping is an application method through which taller weeds are contacted with glyphosate without disturbing desirable sod (University of Florida, 2018). Glyphosate is the only nonselective postemergence systemic herbicide recommended for use in citrus (University of Florida, 2016). It is the most diverse herbicide in orchard floor management because it may be used for under tree weed control, chemical wiping, chemical mowing, and spot treatment. Non-selective chemical control of weeds could be achieved with paraquat or glufosinate or a combination of broadleaf and grass products (University of Florida, 2016.)

Orchard crops and vineyards have very high percentages of acres treated with glyphosate (Table 1b). Almonds, walnuts, pistachios, and plums/prunes all have over 80 percent of their acres treated with glyphosate. Oranges and grapefruit each have over 90 percent of their acres treated. Table grapes, wine grapes, and raisin grapes have over 80 percent of their acres treated, as well. Generally, orchards and vineyards receive more applications than field crops with most of these perennial cropping systems averaging 2 to 3.5 applications. For example, oranges receive an average of 3.5 applications and table grapes receive an average of 2 applications. The average single application rate in tree nuts and stone fruit is approximately 1.0 lbs. per acre, while average single application rates in grapes and citrus are approximately 1.5 lbs. per acre (Table 1b).

Glyphosate is typically the leading herbicide in orchard floor management because of its broad-spectrum, versatility of use, and cost. For example, glyphosate is the leading herbicide applied in

tree nuts (almonds, hazelnuts, pecans, and pistachios, walnut), vineyards, and in citrus, in terms of TAT (MRD, 2012-2016). The next four leading active ingredients in tree nuts are oxyfluorfen, saflufenacil, paraquat and indaziflam (MRD, 2012-2016). Of these, saflufenacil, oxyfluorfen, and paraquat are recommended for control of emerged weeds (UC-IPM, 2017). Paraquat is a restricted use product; certain oxyfluorfen formulations have restricted use periods in California due to air quality concerns (CDPR, 2015); and all three herbicides have longer re-entry intervals (REIs) than glyphosate (UC-IPM, 2017).

Glyphosate is also the leading herbicide in citrus (grapefruit, lemons, and oranges), in terms of TAT (MRD, 2012-2016). The next four leading herbicides are diuron, indaziflam, 2,4-D, and saflufenacil (MRD, 2012-2016). Indaziflam and diuron are preemergence, residual herbicides, while 2,4-D and saflufenacil can be applied to control emerged weeds but only control broadleaf weeds (University of Florida, 2018). Diuron and indaziflam can be tank mixed with postemergence herbicides to control of weeds that have not yet germinated; however, there are many options for preemergence herbicides in orchards. Glyphosate is non-selective; therefore, it can fulfill the need to control both grasses and broadleaf weeds after they have emerged. In addition, glyphosate has other advantages in that its use is not typically restricted (e.g. due to being a restricted-use product (RUP), like paraquat, or having state level restrictions, like oxyfluorfen). It has short REIs so growers and their workers can re-enter fields more quickly. This reduces interference with necessary in-field activities like scouting. Other broad-spectrum, postemergence herbicides recommended for orchards include paraquat and carfentrazone, both of which are contact and require good coverage to be effective (University of Florida, 2016).

For weed management in vineyards, glyphosate is the leading herbicide, followed by oxyfluorfen, paraquat, glufosinate, and carfentrazone-ethyl (in terms of TAT) (MRD, 2012-2016). Carfentrazone only controls broadleaf weeds and paraquat, glufosinate, and oxyfluorfen all have longer REIs than glyphosate (UC-IPM, 2016a).

Without access to glyphosate or with restriction(s) that severely limit the use parameters of glyphosate, growers of orchard and vineyard crops would change to other chemical or mechanical practices to help with orchard/vineyard establishment, to chemically mow or wipe, and/or to control weeds. Given that glyphosate is relatively inexpensive, $5 to $13 per acre for orchard/vineyard crops, these alternative methods could lead to increases in cost for these users of glyphosate. In addition, some alternative chemical methods of control have additional restrictions, (e.g. such as being partially off-labelled in some states, needing special certifications for use [i.e. RUP] or having longer REIs) that may restrict their use.

Vegetables and Other Crops

Many vegetables and other crops (listed in Table 1c.) have substantial portions of their acreage treated each year with glyphosate. One of the major uses of glyphosate is as a burndown herbicide application. Burndown applications are made post-harvest to prevent weed seed production or before planting, so that a grower can plant into a vegetation-free field to eliminate early season weed competition for the crop as it emerges. The majority of glyphosate applied in vegetables, in terms of TAT, is applied at pre-plant or pre-transplant (approximately 75 percent of total acres treated) (MRD, 2012-2016). Glyphosate is the leading herbicide active ingredient applied to

vegetables and cucurbits pre-plant or pre-transplant (MRD, 2012-2016). The next five-leading active ingredients for this timing include metolachlor-S, trifluralin, pendimethalin, oxyfluorfen, and imazethapyr (MRD, 2012-2016). These five alternatives are used primarily when glyphosate use is not appropriate, e.g., when growers make herbicide applications to prevent weed seed germination or when glyphosate use would result in crop damage.

There is a GR sweet corn variety available and twenty-five percent of sweet corn acres are treated with glyphosate (MRD, 2012-2016). However, like other vegetables, most glyphosate is used prior to planting (MRD, 2012-2016) for burndown. Glyphosate is also used from planting to emergence in vegetables, as 15 percent of glyphosate TAT in vegetables occurs during this period (MRD, 2012-2016). Glyphosate is also labeled for shielded or hooded sprayer applications in row middles and wiper application in row middles.

In cole crops, artichokes, asparagus, and leafy vegetables, glyphosate is the fifth-leading herbicide used, in terms of total acres treated (MRD, 2012-2016). The majority of acres treated with glyphosate occur pre-plant or pre-transplant or after planting until emergence (MRD, 2012-2016). The four herbicides with more acres treated for all timings are pronamide, bensulide, oxyfluorfen, and DCPA (MRD, 2012-2016). Pronamide, bensulide, and DCPA are all used to prevent weeds from emerging. While oxyfluorfen is used after the crop and weeds emerge. Glyphosate is the second-leading foliar active ingredient used in cole crops (MRD, 2012-2016). In cucurbits, the top five leading herbicides, in terms of TAT, are ethalfluralin, clomazone, glyphosate, halosulfuron, and trifluralin (MRD, 2012-2016).

Overall, glyphosate is the predominate herbicide used at burndown in vegetable production because it is effective on a wide range of weed species, affordable, easy-to-use, and does not have residual phytotoxicity. Glyphosate is also used from planting to emergence in vegetables.

Although it may not be the market-leading or first-choice herbicide option in all crops, it is a top option for growers for reasons similar to those of the burndown vegetable users (e.g. affordable, broad-spectrum). Without access to glyphosate or with restriction(s) that severely limit the use parameters of glyphosate, growers of some vegetable and fruit crops would change to other chemical or mechanical practices to control weeds or for burndown applications. Given that glyphosate is relatively inexpensive, $5 to $8 per acre for these crops, these alternative methods could lead to increases in cost for these users of glyphosate, especially for burndown.

NON-CROP SITES

Pasture and Rangelands

Western rangelands are disturbed environments that are vulnerable to encroachment of invasive weeds. DiTomaso (2010) estimates that encroaching vegetation leads to a loss of $5 billion annually in the United States. The loss was attributed to lower yields and quality of forage resulting in slowed weight gain of cattle, illnesses and deaths associated with toxic plants, increased production costs, reduced quality of animal products (e.g., meat, hides), and reducing the value of land. However, Duncan et. al. (2004) mentions that the economic impacts are often poorly documented and do not account for “non-market costs such as those to society and the environment (e.g., changes in fire frequency, wildlife habitat, aesthetics, biodiversity).”

Duncan et al. (2004) reviewed 16 invasive plants that were selected based on their infestation level and perceived environmental or economic impact. These 16 plants infest more than 120 million acres of land in the United States. Most of the weeds impact the community structure of the ecosystem by one of several means (e.g., reducing forage and wildlife habitat, displacing native species, altering the soil) (DiTomaso, 2010).). Glyphosate controls 13 of the 16 invasive weeds (musk thistle [*Carduus nutans*], Russian knapweed [*Acroptilon repens*], diffuse knapweed [*Centaurea diffusa*], spotted knapweed [*Centaurea maculosa*], yellow starthistle [*Centaurea solstitialis*], Canada thistle [*Cirsium arvense*], leafy spurge [*Euphorbia esula*], purple loosestrife [*Lythrum salicaria*], saltcedar [*Tamarix ramosissima*], medusahead [*Taeniatherum caput-medusae*], perennial pepperweed [*Lepidium latifolium*], *Sericea lespedeza* [lespedeza]).

Rights-of-Way

Rights-of-way vegetation control can be broken into 4 major categories: roadside, electrical lines, pipelines and railroads, which cover more than 20 million acres of land in the United States (NRCA, 2006). Well maintained rights-of-way are important to the economy because they are critical to the distribution of goods and services. Safety is also a major driver for vegetation control. Vegetation control along roadsides increases visibility, enhances drainage, prevents erosion and degradation of road surfaces, prevents the spread of invasive species, and reduces the potential for fires and snow drift. Weed control provides railroads with many of the same benefits roadside weed control including good visibility for drivers, engineers and inspector, drainage, erosion and fire control, protection of railroad, and safe work areas in rail yards. Vegetation management for electric utilities and pipelines provides workers safe surfaces while working, makes doing inspections easier, and prevents overgrowth of vegetation from interfering with infrastructures. Glyphosate applications can control vegetation under a wide variety of mixed species and site conditions.

Forestry

Land managers use forestry herbicides to increase forest productivity and achieve management goals. Silvicultural objectives include: forest stand improvement, precommercial thinning, site preparation, release operations, and invasive plant control (Penn State University, 2016). Glyphosate provides forest and timber managers with a versatile and cost-effective tool to control unwanted vegetation (Oregon State University, 2014). The Forest Service uses glyphosate primarily for conifer release, site preparation, and noxious weed control (USDA Forest Service, 2011). Other management objectives for which glyphosate is used by the Forest Service include, wildlife habitat improvement, grassland restoration, and reduction of fuels for fire management (USDA Forest Service, 2011). Application rates in forestry settings are generally higher than most agricultural applications due to target species being woody species or species that are difficult to control. For example, from 2000-2004 the average application rate across all Forest Service regions from was 2.07 lbs. ae per acre, while some regions such as the Pacific Southwest have average rates as high a 3.75 lbs. a.e. per acre (USDA Forest Service, 2011). Conifer release treatments had the one of the highest average rates per acre, at 3.21 lbs. a.e. per acre (USDA Forest Service, 2011).

Aquatic Systems

In aquatic systems, invasive weeds can alter the plant and animal species richness and abundance have cascading ecological effects by depleting oxygen levels in water and altering food webs (Hussner et al. 2017). Additionally, aquatic weeds can hinder commerce and navigation, degrade water for recreational activities (e.g., water sports, fishing), decrease property values, clog hydropower dams (and thereby reducing generation of power) and surface water intakes, and reduce water flow in irrigation and drainage systems (e.g., Hussner et al. 2017).

Glyphosate is an important herbicide for aquatic weed managers because it controls a broad spectrum of annual and perennial broadleaf weeds and grasses, trees, and certain floating plants. The Florida Fish and Wildlife Conservation Commission reported use of glyphosate for emergent species such as *Typha* species (bulrush and cattail), floating species such as *Nymphoides cristata* (Crested floating heart), and for woody species such as *Salix spp.* (willow), among other nussiance aquatic species (FWC, 2017). Unlike triclopyr and imazapyr (other systemic aquatic herbicides that control emergent vegetation), glyphosate does not have irrigation water use restrictions. Some of the most invasive floating and emerged weeds controlled by glyphosate are waterfern (*Azolla filiculoides*), water hyacinth (*Eichhornia crassipes*), floating pennywart (*Hydrocotyle ranunculoides*), giant salvinia (*Salvinia molesta*), and water primrose (*Ludwigia spp.*) (Hussner et al. 2017, and references within).

Residential Uses

There are numerous products containing glyphosate that are available for residential uses. Glyphosate is the market leader for the consumer herbicide market (Kline 2012a). Additionally, this market segment was the largest non-agricultural use in terms of pounds (Table 2).

Glyphosate accounted for roughly 40% of consumer herbicides pounds sold in 2011 (5.1 million as shown in Table 2), followed by 2,4 D with about 20% (2.3 million pounds), and MCPA with 10% (1.3 million pounds) (Kline, 2012a). Glyphosate is the most widely used active ingredient in nonselective herbicides and accounts for almost 70% of total active ingredient pounds sold (Kline, 2012a). According to the consumer market for pesticides report, "Consumer interest in glyphosate-based nonselective vegetation control herbicides continues to be strong due to their effectiveness, their reputation for safety, the increasing popularity of spot-treatment of weeds, and stronger promotion for edging, maintenance of paved areas, and other applications." (Kline, 2012a) Additionally, glyphosate is usually listed as an herbicide control option for homeowners in university extension recommendations and other sources in the open literature geared towards educating homeowners about pesticides (Langeland 2003, McCullough et al, 2015, and UMD, undated). Typically, glyphosate is described in their documents or websites as an herbicide that is "non-selective and giv[es] broad-spectrum control of many annual weeds, perennial weeds, woody brush and trees" (McCullough et al, 2015).

Turf

Turf refers to grass grown for production (seed or sod), golf courses, athletic fields, etc. The turf category in Table 2 also includes use by professional groundskeepers in residential areas. The turf category was also the second largest non-agricultural use in terms of pounds (Table 2). Weed control may impact yield and/or seed/turf quality, or it may be primarily driven by aesthetics. Most perennial grass weeds cannot be controlled with selective herbicides without damage to the turf.

Glyphosate may be used prior to planting turf for site preparation or for spot treatment control of perennial grasses and sedges in existing lawns (UC-IPM, 2016). Spot treatment with a nonselective herbicide such as glyphosate is an effective way to control perennial grasses without leaving harmful soil residuals which slow down the growth of replacement plants or turfgrass. Glyphosate may also be used to control broadleaf weeds and grasses when applied to dormant desirable turf (Penn State, 2018).

ADDITIONAL BENEFITS OF GLYPHOSATE: GENERAL CONTROL OF INVASIVE SPECIES

Invasive plant species are detrimental to the economy and environment of the United States. Impacts from invasive species include:

- Direct competition with native plant species can result in the decline of threatened and endangered species;
- Reductions in plant diversity;
- Degradation of wildlife habitat;
- Reductions in agricultural land quality;
- Degradation of water quality;
- And decreased opportunities for recreation (USDA-Forest Service, undated; Invasive Species Advisory Committee, 2006).

Wagner et al. (2016) compiled information from numerous federal sources to determine herbicide usage for invasive species control and found that, from 2007-2011, approximately 2.5 million acres of wildland were sprayed with an assortment of sixty-five herbicides. The leading sites for application included grasslands, road maintenance, and forest sites. Nationally, glyphosate was leading active ingredient in terms of amount applied and area treated (Wagner et al., 2016). The next most-used active ingredients, in terms of total area treated, were triclopyr, imazapyr, and clopyralid. Glyphosate's popularity in invasive species management may be attributed to its broad spectrum, low mobility and half-life in soil, and low toxicity for wildlife when compared to alternatives (Duke and Powles, 2008). Further, glyphosate may be more affordable than other active ingredients. Controlling woody species may require high application rates of glyphosate and rely on application methods such as stem injection, wiping, and stump treatments.

GLYPHOSATE RESISTANCE

Over the last 20 years, herbicide resistance has increased at a rate of 13 new unique cases annually at a global level (Heap, 2018). Currently, there is a total of 79 unique cases of weed species that are resistant to one or more different herbicide modes of action (MOA) in the United States. There are 35 weed species that are resistant to more than one MOA and there are 17 weeds that have at least one case of multiple resistance (i.e., the population of weeds is resistant to multiple herbicides across different MOA). Even though industry is working on developing new herbicides, there are no herbicides with a new MOA that will be available in the near future (Sparks and Lorsbach 2016). Herbicide resistant weeds have become a significant financial, production, and pest management issue for many herbicide users in the United States.

There are 17 weed species in the United Stated that have developed resistance to glyphosate (Heap, 2018). The first glyphosate-resistant species in the United States (ryegrass) appeared in California in 1998 (Heap, 2018). Glyphosate-resistant weed populations appeared quickly after the deregulation and adoption of GR crops, and they were also found in perennial cropping systems such as orchards (Duke and Powles, 2008). Herbicide-resistance technology allows multiple applications of the same active ingredient for longer periods of time (e.g., corn soybean glyphosate-resistant crop rotation), which substantially increases selection pressure. Glyphosate resistance first appeared in Roundup Ready (RR) soybeans in 2001. In 2005, glyphosate resistant Palmer amaranth appeared in numerous southern states (Heap, 2018). Of these glyphosate resistant weeds, many are difficult-to-control or common in agricultural systems and non-crop systems (Van Wychen, 2016; 2017).

Glyphosate resistance can decrease the benefits of glyphosate to users if resistance is so prevalent that: 1) a grower must resort to mechanical removal of glyphosate-resistant biotypes (i.e. tilling or chopping) 2) a grower must tank mix other active ingredients with glyphosate in order to control glyphosate-resistant biotypes, 3) a grower must change active ingredients in order to control glyphosate resistant biotypes, or 4) a grower must grow another less profitable crop.

IMPACTS OF POSSIBLE PROPOSED SPRAY DRIFT MITIGATION

While there are no human health risks of concern associated with glyphosate use, there are environmental risks of concern. There are risks to birds, non-target plants, and mammals associated with the use of glyphosate. The Agency is considering implementing mitigation to reduce these risks.

Temperature Inversions

The Agency is considering adding label language preventing applications during temperature inversions. This requirement could reduce the amount of time users have to apply glyphosate. Users may switch to other products that do not have this restriction if they encounter temperature inversions.

Release Height

The Agency is considering a maximum release height of 10 feet for aerial applications, with exceptions for reasons of pilot safety, and a release height of 4 feet or less for ground boom applications.

EPA does not anticipate that these releases heights will impact the use of glyphosate because applications at these heights are standard practice.

Droplet Size

The Agency is considering requiring a fine or coarser droplet size for all ground and aerial broadcast applications.

EPA does not anticipate that applying fine or coarser droplets will affect the efficacy of glyphosate when glyphosate is used alone since it is systemic. Extension specialists estimate that more than 80% of applicators apply herbicides in tank mixes (Sprague 2018, Steckel 2018) because it allows growers to control herbicide resistant weeds, broadens the spectrum of weeds controlled, delays the development of resistant weeds, saves time and resources with one trip across the field (Sprague, 2018) and reduce rates (Culpepper and York 2018). Glyphosate is a compound that is frequently tank mixed with other herbicides. Because the proposed language provides flexibility with droplet size for tank mixed partners, BEAD does not expect there would be concerns for tank mixes with other herbicides. However, since glyphosate is commonly applied as a burndown treatment, insecticides may be included in the tank mix. Insecticides are generally considered to provide better efficacy with smaller droplets such as fine droplets. BEAD does not know if requiring fine droplets will impact the efficacy of insecticides tank mixed with glyphosate because some insecticides could be more effective at droplet sizes smaller than fine (such as very fine or extremely fine). If reduced efficacy occurred, BEAD would expect growers to respond by increasing the application rates (if allowed by the label), increasing the number of applications, increasing the application rates of tank mix partners, making additional applications, or switch to a different active ingredient.

Wind Speed

The Agency is considering 15 mph maximum wind speed for ground and aerial applications. For aerial applications, the Agency is considering the following language:

> Do not apply when wind speeds exceed 15 mph at the application site. If the wind speed is greater than 10 mph, the boom length must be 65% or less of the wingspan for fixed wing aircraft and 75% or less of the rotor blade diameter for helicopters. Otherwise, the boom length must be 75% or less of the wingspan for fixed-wing aircraft and 90% or less of the rotor diameter for helicopters.

Most labels currently have restrictions of 10 mph for maximum wind speed. This language should provide more flexibility to applicators who are willing to change the boom length in conditions above 10 mph.

CONCLUSIONS

Glyphosate is a broad-spectrum herbicide that is applied on an average to 298 million acres of crop land annually, making it the most commonly used herbicide on agricultural sites in the United States. It is also the most commonly used herbicide by pounds in the consumer or residential use market and for the control of invasive weeds. It controls most broadleaves, sedges, and grasses and is labeled for use on most agricultural and non-agricultural use sites. It is also relatively inexpensive in agricultural settings, ranging $1 per acre to $13 per acre across all agricultural use sites.

Glyphosate can be applied for post-harvest fall burndown, preplant burndown, at plant weed control, over-the-top weed control (in GR crops), directed spot treatments, between row weed control, and as a harvest aid. Approximately one-half of agricultural acres are treated with applications that are applied late postemergence (to the crop). Removal of weeds at late

postemergence is important to reduce competition nutrient, sunlight, and water, and to eradicate habitat for insect pests. Pre-plant applications of glyphosate are also important to growers who practice conservation tillage, so that they can continue this practice. Other benefits of glyphosate include few use restrictions and minimum residual phytotoxicity, so desirable vegetation can be planted soon after applications occur.

Glyphosate is used to control weeds in non-agricultural and industrial use sites. Glyphosate is important for noxious weed control in aquatic systems, pastures/rangelands and right-of-way applications. Glyphosate is the top active ingredient used to control invasive species in the United States.

There are currently 17 weed species that are resistant to glyphosate in the United States. Glyphosate resistance can reduce the benefit of glyphosate to users if resistance is so prevalent that they must change to alternative weed control options that could be more expensive or less effective. Despite widespread resistance, glyphosate remains a valuable tool for controlling both herbicide resistant and non-herbicide resistant weeds.

Potential spray drift management measures being considered include changes to boom length, wind speed, droplet size and release height for aerial applications. The Agency is also considering restricting applications during temperature inversions. Restrictions during temperature inversions may impact the usability of glyphosate products; however, most spray drift management measures are not expected to substantially reduce the benefit of glyphosate to users.

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