Issues in Weed Management for 2006

Update on Glyphosate-Resistant Weeds and Weed Population Shifts

Micheal D. K. Owen, professor and extension weed scientist, Iowa State University

Introduction

Given that more than 90 percent of the soybeans in Iowa are glyphosate-resistant varieties with the concurrent use of glyphosate products, and that recent interest in glyphosate-resistant corn is likely to result in an increasing number of crop acres where glyphosate will follow glyphosate, it is important to understand the level of selection pressure from this weed management plan that will be imposed upon the weed community. Changes in agroecosystems attributable to glyphosate-based systems are already being observed. Notably, recent announcements of glyphosate-resistant weeds suggest that weed populations are reacting to the selection pressure more quickly than anticipated. The implications of current glyphosate-based production systems on weed communities and resultant economics need to be understood if sound management systems are to be developed and this important technology preserved.

Understanding selection pressure

Selection pressure is the sum of all crop production practices that are imparted on a field. Decisions such as planting date, tillage, crop rotation, fertilization, weed management program, and crop variety or hybrid are directly or indirectly a component of the overall selection pressure that influences the ecological balance of organisms that exists within an agroecosystem. With regard to weeds, all of the aforementioned factors influence the weed community, but the primary factors that impact selection pressure are tillage and herbicide program.

Weed communities adapt to the tillage regime. For example, prior to the widespread adoption of conservation tillage programs, larger seeded annual broadleaf weeds such as velvetleaf and common cocklebur were predominant problems. However, conservation tillage "selected" for weeds that can germinate early and from shallow depths. Thus, common lambsquarters and common waterhemp became the predominant problems.

Similarly, herbicides select for weeds that are not effectively controlled. The evolution of ALS (acetolactate synthase enzyme)-resistant biotypes of common waterhemp became widespread due to the repeated use of ALS-inhibiting herbicides. Note, however, that the herbicide does not "cause" the trait to occur in the unselected weed population. The trait for herbicide resistance is there due to the natural genetic variability within weed populations.

However, weeds do not have to evolve herbicide resistance to become an economic problem. Weed population shifts are a slower and more complicated example of a response to selection pressure. For example, woolly cupgrass has become a major problem throughout the Midwest over the last 10 to 15 years, but herbicide-resistant populations have not yet been identified. The reason is that woolly cupgrass demonstrates considerable tolerance to most soil-applied herbicides, is extremely well adapted to conservation tillage, has a high level of seed production, and is more competitive than most other weeds. Thus, given the overall ecological advantage that woolly cupgrass demonstrates, a population will eventually become the dominant weed in the community without the need for evolved herbicide resistance.

The key to managing a weed community reflects an understanding of the selection pressure that is imparted on a field. The better the management practices, the greater the selection pressure that is

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imparted. Essentially, the better the weed control and the narrower the focus of the weed control tactics (i.e., the singular use of one herbicide repeatedly over time), the greater the likelihood that a change in the weed community, either evolved herbicide resistance or weed population shifts, will occur. These changes are inevitable unless due consideration is given to developing a diverse weed management program.

Common waterhemp and glyphosate resistance

A recent press release announced that isolated populations of common waterhemp in Missouri had evolved resistance to glyphosate. While the data to support the announcement are not complete and based primarily on greenhouse efficacy data, the announcement comes as no surprise. In discussions with the University of Missouri personnel, the situation they describe is not unlike that which is relatively common in Iowa. The difference in Missouri is the relative selection pressure on the two fields that were included in the press release. These fields have been in continuous soybean production for a number of years and have undergone nine years of glyphosate selection pressure. The level of resistance is similar to what we have reported in Iowa. Our data demonstrated clearly that the genetically heritable trait for glyphosate resistance exists within common waterhemp populations but at a very low frequency. Given the selection pressure that is anticipated with the consistent use of glyphosate on glyphosate-resistant soybean and corn rotations, the frequency of glyphosate-resistant waterhemp will likely increase in Iowa unless diversity of weed management tactics is employed.

Palmer amaranth and glyphosate resistance

Other press releases this fall, three issued almost simultaneously from Georgia, North Carolina, and Tennessee, described Palmer amaranth populations that evolved resistance to glyphosate. Again, the data are not complete and heritability studies have only begun, but given the history of evolved herbicide resistance in Palmer amaranth populations, the announcements come as no great surprise. While Palmer amaranth is not a common weed in Iowa, the significance of the information is that evolved resistance to glyphosate is being discovered frequently and over a broad geographic and crop production range. Palmer amaranth is described as the most aggressive and competitive of the pigweed species. Palmer pigweed populations are increasing in Illinois, Missouri, and Kansas and have been reported to demonstrate resistance to PPO (protoporphyrinogen oxidase)- and ALS-inhibiting herbicides' glyphosate resistance independently. Thus, producers in Iowa should be aware of this potential new weed problem.

Common ragweed resistant to glyphosate

The University of Missouri announced a population of common ragweed that evolved resistance to glyphosate. The glyphosate-resistant common ragweed population is in one isolated soybean field and limited to specific areas within the field. There is little published data that describes the genetic heritability or biochemical mechanisms of the alleged glyphosate-resistant common ragweed biotype. It is unlikely, based on the cursory information available, that glyphosate-resistant common ragweed will become a serious agronomic problem in Iowa.

Horseweed resistant to glyphosate

Evolved glyphosate resistance to horseweed (also commonly known as marestail) has spread widely and rapidly across the eastern Corn Belt. The first population of glyphosate-resistant horseweed was identified three years after the adoption of glyphosate-resistant soybean and the concurrent use of glyphosate as the sole herbicide. This narrow focus using only glyphosate resulted in considerable selection pressure and the resistance evolved rapidly. Our data demonstrate that the genetic trait for glyphosate resistance is controlled by a single semi-dominate gene. Given the incredibly high seed production, the fact that the seeds are wind-dispersed, and the adaptation of horseweed to conservation tillage programs, it is obvious why glyphosate-resistant horseweed is a major concern for agriculture. While no glyphosate-resistant horseweed populations have been identified in Iowa, there is no reason to believe they do not exist and will likely increase in the near future.

Suspected giant ragweed resistance to glyphosate

There is anecdotal evidence to suggest that glyphosate resistance may be evolving in Ohio and Indiana. However, the existence of glyphosate-resistant giant ragweed has not been confirmed. Be aware that giant ragweed is difficult to manage consistently regardless of whether or not glyphosate-resistant populations evolve.

Suspected common lambsquarters resistance to glyphosate

The importance of common lambsquarters as an economic problem has increased considerably during the last 10 years. Recent adoption of glyphosate technology has resulted in suspect populations of common lambsquarters in Indiana, Ohio, and elsewhere that may have evolved resistance to glyphosate. Common lambsquarters is difficult to control with glyphosate regardless of the existence of resistance. Thus, multiple tactics should be employed for the most consistent management of common lambsquarters infestations.

Morning glory resistance to glyphosate

While annual morning glories are not major problems throughout Iowa, populations are increasing in southern and eastern Iowa. Morning glories demonstrate heritable tolerance to glyphosate and are suspected to evolve resistance to glyphosate in the southern Soybean Belt.

Weed population shifts

As indicated, weed population shifts are a long-term response to multiple selection pressure imparted on the agroecosystem. However, the selective factors are more complex than illustrated in the evolution of herbicide-resistant biotypes, and the speed at which population shifts occur is typically slower than the change that occurs when herbicide-resistant populations evolve. To that end, when a weed population shift occurs, it may require more changes in management practice than the changes required for an evolved herbicide-resistant weed population. A recent, albeit relatively isolated, weed population shift that has surfaced in response to the adoption of glyphosate technology is occurrence of Asiatic dayflower. Asiatic dayflower is naturally tolerant to glyphosate, almost irrespective to the application rate. Due to the widespread adoption of glyphosate technology, Asiatic dayflower problems are increasing in Iowa and elsewhere in the Midwest. While not yet of serious proportion, the infestations appear to be growing at an increasing rate. It is clear that increased diversity in weed management tactics must be implemented to keep this weed as a rare and scattered problem.

Conclusions

It is clear that while rare, evolved glyphosate resistance in several different weed species has become more common and is problematic at a growing rate. Given the widespread adoption of glyphosate-resistant soybean and cotton, and the anticipated increase in glyphosate-resistant corn, glyphosate will be applied consistently on fields every year. The level of selection pressure imparted on a field by this management strategy will inevitably result in weeds that are not controlled effectively by glyphosate.

Understanding Glyphosate to Increase Performance

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Introduction

Excellent, broad spectrum weed control is a primary reason for the popularity of glyphosate and Roundup Ready® crops. However, growers experience poor weed control with glyphosate on occasions. This inconsistency is generally caused by application or weather-related factors. Review these factors to learn how glyphosate can be managed to minimize fluctuations in performance.

Glyphosate formulations

The active ingredient, glyphosate, is the compound that actually kills weeds. The Roundup Ultra® label states that the active ingredient is "Glyphosate, N-(phosphonomethyl) glycine, in the form of its isopropylamine salt." The term "glyphosate" is the common name of the chemical, whereas "N-(phosphonomethyl) glycine" is the chemical name that provides information about its chemical structure.

Regardless of the product purchased, the active ingredient is the same. Glyphosate products vary in the type of salt and proprietary products included in the formulated products. These components create a product that is convenient to handle, mixes well with other agricultural products, and facilitates movement into plants. Differences in product performance are due to the types and amounts of proprietary compounds included in the formulation. Manufacturers are not required to reveal these components, and they are listed as inert ingredients on the label.

Several newer formulations contain a higher concentration of glyphosate or different salt than that of the original Roundup® formulations (Table 1). The glyphosate concentration is stated in terms of pounds acid equivalent (a.e.) per gallon on the ingredient statement of the label. Acid equivalent takes into consideration only the portion of the formulation (the parent acid glyphosate) that kills weeds. Many labels also state the quantity of active ingredient, which includes both the glyphosate and salt present in the formulation. This number should not be used to compare formulations.

Components of a Glyphosate Product

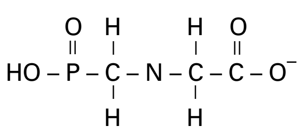
Parent Acid	Salt	Proprietary Components
	Isopropylamine Ammonium Potassium	Listed as inert ingredients, include surfactants, defoamers, etc. Manufacturers are not required to provide information on these components.
Role: Ingredient that actually kills plants	**Role:** Creates a stable product that is convenient to handle and mixes well with other products	**Role:** Enhance penetration of glyphosate into plant, make product convenient to handle

Table 1. Composition of several glyphosate formulations.

Formulation	Salt	Active Ingredient/Gal	Acid Equivalent/Gal	Product to Apply 0.75 lb a.e./Acre
Roundup Original Glyphomax GlyStar Plus, etc.	Isopropylamine	4 lbs	3 lbs	32 oz
Roundup UltraMax	Isopropylamine	5 lbs	3.68 lbs	26 oz
Roundup UltraMax II Roundup WeatherMax	Potassium	5.5 lbs	4.5 lbs	21.3 oz
Touchdown	Diammonium	3.7 lbs	3 lbs	32 oz
Touchdown HiTech	Potassium	6.2 lbs	5 lbs	19.2 oz

When comparing the performance or value of different products, compare formulations based on acid equivalent rather than product rate. The following formula is a simple way to determine glyphosate cost so any formulation can be compared fairly.

$$\text{Cost (\$) per lb of glyphosate} = \frac{\text{Price (\$)/gallon}}{\text{Lb a.e./gallon}}$$

Glyphosate products primarily differ in the surfactants found in the formulated product and the concentration of active ingredient. Surfactants increase the retention of spray droplets on weed leaves and glyphosate absorption into the leaves. Although the blend and amount of surfactants vary among the many glyphosate brands, performance of these products is similar under most conditions. Research at Purdue University found no significant differences in the performance of six glyphosate formulations (Table 2). Similar results have been found at other universities throughout the Midwest. Differences in performance among products occasionally occur, especially when below-labeled rates are used. However, these differences are inconsistent and do not support any one product being superior to others.

Table 2. Performance of several glyphosate formulations applied at 0.75 lb a.e./acre (equivalent to 32 oz of original Roundup®).*

Formulation	Giant Foxtail	Ivyleaf Morning Glory	Velvetleaf
Clearout 41 Plus	97	86	99
Glyphomax Plus	98	86	99
Roundup WeatherMax	98	80	99
Touchdown Total	97	84	99
Touchdown 4	98	84	99
Roundup Original	96	83	97

*Bauman, T., M. White, D. Hilger, and C. Dyer. 2003. Purdue University.

Weed species and size

A frequent cause for control failures with glyphosate is failure to use the appropriate rate for the specific weed species or their size. Each weed species differs in sensitivity to glyphosate, and the rate required to control weeds generally increases with weed size. The rate of Roundup WeatherMax® required to control waterhemp nearly doubled between early and late postemergence applications (Table 3). The rate used on a field should be based on the species and size of weed found within the area to be sprayed.

Table 3. Influence of glyphosate application timing on control of three weed species.*

	Roundup WeatherMax® Required to Achieve 90% Control (Oz/Acre) (Weed Height at Application)		
	Application Timing		
Species	Early	Mid	Late
Ivyleaf morning glory	37 (4″)	50 (8″)	>60 (12″)
Velvetleaf	28 (5″)	34 (10″)	40 (21″)
Waterhemp	16 (4″)	28 (9″)	30 (14″)

*Knezevic, S. 2004. University of Nebraska.

Certain weeds are naturally tolerant to glyphosate, and acceptable control is unlikely regardless of application timing or rate. Examples of weeds that are difficult to control with glyphosate include yellow nutsedge, wild buckwheat, and Asiatic dayflower. Including alternative herbicides in weed management programs will provide more consistent control of glyphosate-tolerant weeds than attempting to rely solely on glyphosate.

Spray additives

All glyphosate brands recommend adding ammonium sulfate (AMS) under certain conditions (see water quality), but recommendations for surfactants vary widely among glyphosate products. Recommendations differ due to the amount and type of surfactant included in the formulated product. Follow the product's recommendations for additional surfactants to optimize performance. Most studies have shown little benefit to adding extra surfactant to "fully loaded" formulations that do not specify the need for additional surfactant.

Selecting the optimum surfactant for glyphosate is complicated by the fact that manufacturers of surfactants and other spray additives are not required to provide information on the product's active ingredients. Thus, it is difficult to compare the numerous products available for this use. The risk of obtaining a poor quality surfactant can be minimized by obtaining products with a high concentration of active ingredients (typically greater than 80 percent), avoiding products making unrealistic claims, and purchasing spray additives from the location where the herbicide was obtained.

Water quality

Whether the water used as the spray solution for glyphosate comes from a well or a rural water association, it may contain large amounts of dissolved salts. Water hardness is a measure of how much salt is contained in the water. The harder the water, the higher the salt concentration. Salts dissolved in water may reduce the effectiveness of glyphosate, particularly calcium and magnesium salts. These salts have a positive charge and may associate with the negatively charged glyphosate molecule, replacing the isopropylamine or other salt used in the formulated product. Glyphosate bound with calcium or magnesium salts is absorbed less by plants than the formulated salt of glyphosate, thus reducing glyphosate activity.

Although specific recommendations vary, all glyphosate labels recommend the addition of AMS. The role of AMS as an additive with glyphosate is considerably different than the function of the non-ionic surfactants. Whereas surfactants are active primarily on the leaf surface and improve absorption of the herbicide into plants, AMS is primarily active within the spray tank. AMS should always be added to the tank prior to glyphosate to prevent the formation of inactive complexes between glyphosate and antagonistic cations.

Several products are currently marketed as alternatives to AMS to reduce the antagonistic effects of hard water. Although these products may be more convenient to use than AMS, most studies have shown they are less effective.

Spray volume

The Roundup WeatherMax® label recommends the use of 5 to 20 gallons of water per acre, whereas the Touchdown HiTech® label suggests a volume of 3 to 40 gallons. Research has documented increased glyphosate performance when applied in water volumes below 10 gpa compared to 20 gpa or higher. There are two primary factors responsible for this response. First, as spray gallonage increases, the ratio of antagonistic salts to glyphosate increases. Thus, the potential for calcium or magnesium salts to inactivate glyphosate increases as spray volume increases.

The second factor that may reduce glyphosate performance at high spray volumes is a simple dilution effect. As spray volume increases, the ratio of formulated glyphosate to water decreases (Figure 1). The reduction in concentration of both the active ingredient and surfactant in the spray solution may reduce performance under certain situations.

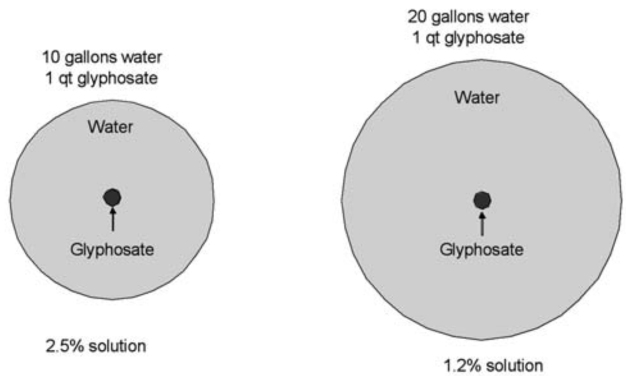


Figure 1. Relationship between spray volume and glyphosate concentration

Several factors should be considered when selecting a spray volume to apply glyphosate, including herbicide activity, target coverage, and drift potential. As carrier volume is decreased there may be an increased risk for spray drift and insufficient coverage of weeds. Relatively small spray droplets are required to achieve uniform coverage at spray volumes less than 10 gpa. Small droplets increase the likelihood of spray drift.

As spray volume is reduced, variability in deposition of spray droplets increases, and the likelihood that individual weeds may not intercept a lethal dose of the herbicide is greater. The variability in spray deposition increases as the density of the plant canopy increases. For most agronomic situations, 10 to 15 gpa spray volumes minimize negative effects on performance while allowing adequate coverage of weeds present in corn and soybeans. Higher volumes (15 to 20 gpa) may be beneficial in situations with dense weed infestations, well-developed crop canopies, or large weeds.

Spray nozzle type

Several new types of spray nozzles reduce the number of droplets that may drift. The mobility of glyphosate within plants reduces the importance of spray coverage in comparison to other herbicides. Thus, nozzle selection should primarily be based on managing spray droplet size and drift potential rather than optimizing spray coverage and glyphosate performance.

Environment

Plants respond continuously to the environment to protect themselves from stressful conditions (drought, heat, cold). For example, during dry or hot weather, plants conserve water through changes in both the composition and thickness of the cuticle on the leaf surface. These changes influence herbicide absorption and performance. Most herbicide labels contain vague statements regarding environmental influences on herbicide performance. The Touchdown HiTech® label states: “Touchdown requires actively growing green plant tissue to function.” Most growing seasons contain short periods of time when extremes in temperature or moisture essentially cease active plant growth; herbicide applications made during these periods may provide ineffective control.

Managing fluctuations in herbicide efficacy due to changes in weather is one of the most difficult challenges for those of us involved in weed control. Attempts to develop tools to determine the optimum herbicide rate or spray additive based on prevailing weather conditions have largely been unsuccessful. Increasing the rate of glyphosate may help overcome the effects of adverse weather conditions that occur preceding or at the time of application. Postponing application until more favorable conditions are present is another option if crop and/or weed size allow delayed action.

Time of day

Soon after the introduction of Roundup Ready® soybeans, control problems with glyphosate applications made in the evening were observed. Subsequent research confirmed that the activity of glyphosate can decline with applications made early in the morning or in the evening (Figure 2). In certain weed species, this response is partially due to day-to-night leaf movements. Leaves of velvetleaf and many other plants hang vertically after the sun has set and then raise parallel to the soil surface during the day. Changes in leaf orientation can influence how much herbicide spray is intercepted by a weed.

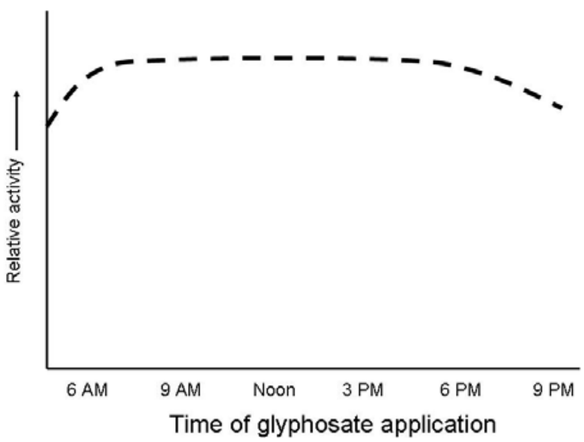


Figure 2. Time-of-day influence on glyphosate activity

Reductions in glyphosate activity when applied in the evening or morning are most likely to occur with difficult-to-control weeds or with marginal herbicide rates for the specific situation. The time-of-day influence may be overcome by increasing the glyphosate rate. However, there are no concrete guidelines to determine when and how much to increase rates to overcome this effect. If fields vary in weed size among fields, try to schedule fields with the smaller, more sensitive weeds during early morning or evening hours.

Rainfall

Glyphosate must penetrate the leaf surface in order to be effective. While absorption occurs relatively quickly, rain after an application can wash glyphosate off the leaf before it has a chance to enter the leaf. The rain-free period required to prevent reduced activity is influenced by the susceptibility of the target weed and the glyphosate rate. Small weeds of a sensitive species will require less of a rain-free period than large or difficult-to-control weeds. A 30-minute rain-free period may be adequate under ideal conditions. When spraying larger weeds, however, several hours between application and rain may be required to avoid reduced activity. Differences in the rainfastness among different glyphosate products are generally small. Additional surfactant appears to have marginal benefits on the rain-free requirement.

Dew

A wide range of views on the influence of dew on herbicide performance exists among growers. Some state that they see the best herbicide performance when a light dew covers the foliage of weeds, whereas others believe the presence of dew greatly reduces weed control. The few controlled studies investigating this factor have not found a consistent response to dew. A recent study reported reductions in glyphosate activity only with heavy dew and high spray volumes (48 gpa) where the spray solution triggered runoff from plant leaves.

Dust and tire tracks

Weed escapes in the tire tracks of the sprayer is a fairly common occurrence in glyphosate-treated fields. These failures are likely due to mechanical damage to weeds caused by the tire traffic or interception of the spray solution by dust. Glyphosate binds very tightly to soil particles; thus, any herbicide that comes in contact with dust in the air or on the leaf surface will be inactivated. Attempts to overcome these effects by mounting booms on the front of sprayers, mounting extra nozzles behind the rear wheels, or placing larger nozzles in line with wheel tracks have been inconsistent in resolving this problem. Timely application to small weeds is the best way to limit this problem.

Summary

Glyphosate's performance is affected by many factors, several that the applicator has little or no control over. The primary cause of control failures is delayed applications allowing weeds to reach sizes more difficult to kill consistently. The rate of glyphosate required to obtain effective control is directly related to weed size. Timely application to small weeds provides the most consistent control and also protects crop yield potential. Glyphosate rates should be based on the most difficult-to-control species found in the field. While many factors influence glyphosate activity, timely application and using the proper rate for the specific situation minimizes their effects and reduces the likelihood of control failures.

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Corn Herbicide Effectiveness Ratings[1]

Weed response to selected herbicides (E = excellent G = good F = fair P = poor)

	Grasses						Broadleaves									Perennials		
	Crop tolerance	Crabgrass	Fall panicum	Foxtail	Woolly cupgrass	Shattercane	*Amaranthus* spp.[2]	Black nightshade	Cocklebur[2]	Common ragweed	Giant ragweed[2]	Lambsquarters	Smartweed	Sunflower[2]	Velvetleaf	Canada thistle	Quackgrass	Yellow nutsedge
Preplant/Preemergence																		
Atrazine	E	F	P	F	P	P	E	G	G	E	F–G	E	E	G	G	P	F	F
Axiom, Define, Dual II Magnum, Frontier, Outlook	E	E	E	E	F	F	F–G	G	P	P	P	P	P	P	P	P	P	G
Balance Pro	F–G	G	F–G	G	G–E	F–G	G–E	F	P–F	F–G	P	G	G–E	F	G–E	P	P	G
Callisto	E	P	P	P	P	P	G–E	G–E	F–G	F–G	F	E	F–G	G–E	E	P	P	P
Degree, Harness, Surpass, or Topnotch	E	E	E	E	F–G	F–G	G	G	P	P	P	P–F	P–F	P	P	P	P	G
Hornet WDG	G	P	P	P	P	P	F–G	P	G	G	G	G	G–E	G–E	G	P	P	P
Pendimax, Prowl	F–G	G–E	G–E	G–E	G	G	G	P	P	P	P	G–E	F	P	P–F	P	P	P
Pursuit[3]	E	F–G	F	F–G	P–F	G	F–E	G–E	F	G	F	P	G–E	F–G	G	P	P	P
Python	G	P	P	P	P	P	E	F	F	F	P	F	G–E	F–G	E	P	P	P
Postemergence																		
Accent, Steadfast	G–E	P	G	G–E	G–E	E	G	P	F	P	P	P	G	P	F	F	G	F
Aim	G	P	P	P	P	P	F–G	G	P	P	E	G	P	P	E	P	P	P
Atrazine	G	F	P	F	P	P	E	E	E	E	G	E	E	E	E	F*	F	G
Basagran	E	P	P	P	P	P	P	P	E	E	F	P	E	G	G–E	G*	P	G*
Basis	F	F	F–G	G	F	G	G	P	F	F	P	G–E	G–E	G–E	G	P	G	P
Basis Gold or Accent Gold	G	P	G	G–E	F–G	E	G	F–G	E	G–E	G	G	E	F–G	F–G	P	P	P
Banvel, Clarity, etc.	F–G	P	P	P	P	P	G–E	G	E	G–E	E	G	E	G	F–G	G*	P	P
Beacon	G	P	F–G	P–F	P	E	E	G	G	G	E	P	G	G	F–G	F–G*	G	F
Buctril	G	P	P	P	P	P	G	G–E	E	E	G	G–E	G–E	E	G	P	P	P
Callisto	G–E	P	P	P	P	P	E	E	G–E	F	G	G	E	G–E	E	P	P	P
Distinct	F–G	P	F	F	P	F	G–E	G	E	G–E	G	G	E	G	G	G*	P	P
Equip	F–G	P	G	G–E	F–G	E	G	E	E	E	G	G	E	E	G–E	G*	G	P
Glyphosate (Roundup, etc.)[3]	E	E	E	G–E	E	E	G–E	F–G	E	E	G–E	G	E	E	G	G	G–E	F
Hornet WDG	G	P	P	P	P	P	E	F	E	E	G	F	G–E	E	G–E	G	P	P
Liberty[3]	E	E	G	G–E	E	E	G	E	E	E	G	G	E	E	E	F–G	G	F
Lightning[3]	G–E	G	G	E	G	E	F–G	E	E	G	F–G	G–E	E	E	E	G	F	F
NorthStar	G	P	F–G	F	P	E	F–G	G	E	E	E	G	E	E	G	F–G	G	F
Option	G	P	G	G–E	F–G	E	G	E	F	F	P	P	P	G	G	P	G	P
Permit	G	P	P	P	P	P	E	P	G–E	G–E	G	P	G–E	E	E	P	P	G
Pursuit[3]	G–E	G	G	F–G	F	E	F–G	E	G–E	G	F	P–F	E	G	G–E	F	P	P
Resource	G–E	P	P	P	P	P	G	P	F	F–G	P	F	P	P	E	P	P	P
Yukon	F–G	P	P	P	P	P	G	G	G–E	G–E	G	G	G–E	E	E	P	P	G
2,4-D	F	P	P	P	P	P	G	F	E	G	G–E	G	F	G	G	F*	P	P

[1] Ratings in this table are based on full label rates. Premix products containing ingredients marketed as single a.i. products may not be listed in this table.
[2] ALS-resistant biotypes of these weeds have been identified in Iowa. These biotypes may not be controlled by all ALS herbicides.
[3] Use only on designated resistant hybrids.
*Degree of perennial weed control is often a result of repeated application.

This table should be used only as a guide. Ratings of herbicides may be higher or lower than indicated depending on soil characteristics, managerial factors, environmental variables, and rates applied. The evaluations for herbicides applied to the soil reflect appropriate mechanical weed control practices.

Soybean Herbicide Effectiveness Ratings[1]

Weed response to selected herbicides (E = excellent G = good F = fair P = poor)

	Grasses						Broadleaves									Perennials		
Preplant/Preemergence	Crop tolerance	Crabgrass	Fall panicum	Foxtail	Woolly cupgrass	Shattercane	*Amaranthus* spp.[2]	Black nightshade	Cocklebur[2]	Common ragweed	Giant ragweed[2]	Lambsquarters	Smartweed	Sunflower[2]	Velvetleaf	Canada thistle	Quackgrass	Yellow nutsedge
Authority/Spartan	G	P	P	P	P	P	E	E	F	F	F	G–E	F	P	F–G	P	P	F–G
Command	E	G–E	G–E	E	F	F	P	F	F	G	P	G–E	G	F	E	P	P	P
Dual II Magnum, Intrro, Frontier	E	E	E	E	F	F	F–G	G	P	P	P	P	P	P	P	P	P	P
FirstRate/Amplify	G–E	P	P	P	P	P	F–G	P	G	G–E	G–E	G	G–E	G	F–G	P	P	F–G
Pendimax/Prowl/Sonalan/Treflan	G–E	E	E	E	E	G–E	G	P	P	P	P	G	F	P	P	P	P	P
Pursuit	G	F–G	F	F–G	P–F	G	F–E	G–E	F	G	F	P	G–E	F–G	G	P	P	P
Python	E	P	P	P	P	P	E	F	F	F	P	F–G	G–E	F	E	P	P	P
Sencor	F–G	P	P	P–F	P	P	E	F	F	E	P	E	E	F–G	G–E	P	P	P–F
Valor SX	F–G	P	P	P	P	P	G–E	E	F	G	F	E	F	P	F	P	P	P
Postemergence																		
Assure II, Fusilade DX, Fusion, Poast Plus, Select, etc.	E	E	E	E	E	E	P	P	P	P	P	P	P	P	P	P	G–E*	P
Basagran	E	P	P	P	P	P	P–F	P–F	E	E	F	P	E	G	G–E	G*	P	G*
Blazer	F–G	P	P	F	P	F	E	G	F	G	F	F	E	F	F	F	P	P
Classic	G	P	P	P	P	P	E	P	E	G–E	F	P	G–E	E	G–E	F	P	G–E
Cobra/Phoenix	F–G	F	P	P	P	P	E	G	G–E	E	F–G	F	G	G	F	F	P	P
FirstRate/Amplify	G	P	P	P	P	P	P	P	G–E	E	E	P	G	E	G	P	P	P
Glyphosate (Roundup, etc.)[3]	E	E	G–E	E	E	E	G–E	F–G	E	E	G–E	G	E	E	G	G	G–E	F
Harmony GT	F	P	P	P	P	P	E	P	F	F	P	G–E	G–E	G–E	G	P	P	P
Pursuit	G	G	G	F–G	F	E	F–G	E	G–E	G	F	P–F	E	G	G–E	F	P	P
Raptor	G	G–E	G–E	G–E	G	E	F–G	E	G–E	G	G	G	E	E	G–E	F	F	F
Reflex/Flexstar	F–G	P	P	P	P	P	E	F–G	F	G	G	F	G–E	F	F	P–F	P	P
Resource	G–E	P	P	P	P	P	G	P	F	F–G	P	F	P	P	E	P	P	P

[1] Ratings in this table are based on full label rates. Premix products containing ingredients marketed as single a.i. products may not be listed in this table.
[2] ALS-resistant biotypes of these weeds have been identified in Iowa. These biotypes may not be controlled by all ALS herbicides.
[3] Use only on designated resistant hybrids.
*Degree of perennial weed control is often a result of repeated application.

This table should be used only as a guide. Ratings of herbicides may be higher or lower than indicated depending on soil characteristics, managerial factors, environmental variables, and rates applied. The evaluations for herbicides applied to the soil reflect appropriate mechanical weed control practices.