2019 Herbicide Guide for Iowa Corn and Soybean Production

Weed Science Update

The ever-evolving weed landscape

Bob Hartzler, professor in agronomy and extension weed specialist at Iowa State University

Palmer amaranth (*Amaranthus palmeri*) – It has been five years since Palmer amaranth was first identified in Iowa, with the species now having been reported in 54 counties. The majority of introductions occurred during 2016 due to the planting of native seed mixes contaminated with Palmer amaranth seed. The good news is that most of those introductions did not appear to create permanent infestations of Palmer amaranth. There were fewer reports of new detections in 2018 than in 2017; it is not known if that is because of fewer new infestations, or if people have let their guard down and aren't as observant as in the past. While there is no evidence that Palmer amaranth is spreading rapidly in Iowa, there are enough infestations that no field is safe from being invaded by the weed. Continued vigilance is needed to detect new infestations early and take appropriate measures to prevent new, permanent infestations.

Asiatic copperleaf (*Acalypha australis*) – This weed was first found in a seed corn field near Waterloo in 2016. What drew our attention to this infestation was that the only known occurrences of the plant in North America were a few small infestations within New York City. This fall another another seed corn field near Humboldt was found to be heavily infested (different seed company than the first detection). The plant appears to be released following seed corn harvest. It is unclear how it got to Iowa, or how big of a threat it poses to Iowa crops. It is an annual in the Euphorbiaceae (spurge) family and is very similar in appearance to three-seeded Mercury, but they are easily differentiated by their distinct bracts (modified leaves associated with flowers). As with any new weed, early detection and eradication is the most cost effective approach.

Mile-a-minute weed (*Persicaria perfoliata*) – A landowner near Knoxville contacted the Iowa State University Extension and Outreach Marion County office suspecting that he had found mile-a-minute weed on his property. This is an invasive annual in the Polygonaceae (smartweed) family that has been a problem on the east coast for more than 50 years, but had not moved west of Ohio or Kentucky. The landowner is an avid gardener, and the mile-a-minute weed infested a small area on the edge of his managed landscape and a woodland. It is suspected that the plant was introduced via ornamentals purchased from nurseries on the east coast. Mile-a-minute weed should not pose a threat to crop fields, but we recommend keeping an eye out for it or any other unusual plants.

Herbicide resistance

Herbicide resistance continues to increase in Iowa and surrounding states. However, I am not aware of any new unique resistant biotypes being discovered in the state during 2018. Missouri researchers identified a waterhemp biotype that is resistant to six different herbicide groups (Groups 2, 4, 5, 9, 14, and 27). Waterhemp resistant to 2,4-D has been found in Illinois, Missouri, and Nebraska, so it is most likely present somewhere in Iowa. The Nebraska 2,4-D population was selected following repeated applications of 2,4-D used in combination with metolachlor and atrazine in a little bluestem seed production field. The Missouri field had been in continuous soybean production where 2,4-D was used for burndown for numerous years. The Nebraska population demonstrated a low level of cross-resistance to dicamba (3X), this was not observed in the other populations. The appearance of these 2,4-D resistant populations under relatively minor selection pressure should serve as a warning that

Contents

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good stewardship is needed to protect the value of 2,4-D and dicamba.

A particular concern is the increase in weeds with metabolism-based resistance, rather than target site-based resistance. Metabolism-based resistance can provide resistance to more than one herbicide group, and weeds with metabolism-based resistance often evolve resistance to additional herbicides more rapidly than weeds with other resistance mechanisms. Metabolism-based resistance has been identified in waterhemp for both Group 5 (triazine) and Group 27 (HPPD inhibitors) herbicides. The first triazine-resistant (TR) waterhemp biotypes had an altered target site as the resistance mechanism. This trait is maternally inherited, which results in the resistance only being spread by seed, not by pollen. This reduced the rate that TR spread across the landscape. More recently, TR waterhemp with metabolism-based resistance has been identified. Nebraska recently reported 31 percent of waterhemp populations in the eastern part of the state were resistant to 3X rates of atrazine applied both pre or postemergence. Four of these populations were evaluated to determine the resistance mechanism, with all being found to have metabolism-based resistance rather than target-site. Interestingly, whereas target-site TR provides cross resistance to metribuzin, waterhemp with metabolism-based TR can still be controlled with metribuzin. The presence of waterhemp with metabolism-based resistance is likely to increase the rate that resistance evolves to herbicides currently being used to manage this weed (i.e. Group 4, 10, and 15 herbicides).

Resistance is not a new problem, but the appearance of new resistant biotypes is occurring at an increasing rate. Thus, everyone involved in crop production must reconsider how weed management is viewed. Both attitudes and approaches to weed management need to change. Weed management can no longer be viewed as a short-term endeavor intended to protect crop yields. The objective needs to shift towards minimizing the number of weed seeds in the weed seed bank. This is accomplished by setting a goal of zero weed escapes. At the scale of our production system, it is unrealistic to achieve perfect weed control, but tolerating low to moderate densities of weeds because they don't affect yield or slow harvest can no longer be accepted.

Efficient use of herbicides will be the foundation of weed management, but as Mike Owen, retired University Professor in agronomy at Iowa State, liked to say, "we aren't going to spray our way out of this problem." Using multiple, effective sites of action can slow resistance evolution, but won't win the battle alone. Although it isn't always easy, it is important to determine what resistant biotypes likely are present in individual fields. Reviewing both herbicide use history and recent herbicide performance can help determine what herbicide groups weeds are resistant to. Efficient use of herbicides involves factors such as the use of full rates, optimum application timing, and proper sprayer set up (nozzle selection, carrier volume, and spray additives). Altering other practices to enhance weed management is not as simple as changing herbicides, but creating a less favorable environment for weeds is critical. Consider what practices will be simplest to incorporate into your system to provide the crop a competitive advantage in your fields.

Dicamba

2018 was year two for the use of registered dicamba products on dicamba-resistant (RR2 Xtend) soybean. Numerous changes were made to labels prior to the 2018 season in response to problems with off-target movement during 2017. Notable changes included making the products restricted-use, limiting applications to daylight hours, and increased record keeping requirements. The initial labels for products registered on Xtend soybean were two-year probationary labels, and the new labels expire on Dec. 20, 2020. The Environmental Protection Agency (EPA) is requiring registrants to conduct additional experiments to determine factors that influence volatility and off-target movement.

How well the changes implemented during 2018 mitigated the problem varies with who you ask. In both 2017 and 2018 the total number of pesticide misuse complaints to the Iowa Department of Agriculture and Land Stewardship (IDALS) was more than twice the average number from 2012-16 (Table 1). The increase was almost entirely due to problems with growth regulator herbicides. Bayer/Monsanto reported a 77 percent reduction in off-target complaints during 2018 compared to 2017, whereas dicamba complaints to IDALS were down approximately 50 percent. While off-target calls to ISU Extension and Outreach field agronomists varied based on location, when averaged across the state our field agronomists reported a similar number of dicamba drift calls in 2018 as in 2017.

In 2017, 88 of the 117 dicamba investigations were associated with postemergence dicamba applications on dicamba-resistant soybean. Complaints were fairly evenly divided among Engenia and Xtendimax with

Vapor Grip Technology, and also between commercial, certified private, and uncertified private applicators. A breakdown of 2018 complaints had not been released at the time of writing this article.

Table 1. Pesticide misuse cases handled by IDALS

Year	Total	Complaints	Total Group 4	Dicamba
2012	120	-	-	
2013	122	-	-	
2014	89	-	-	
2015	108	-	-	
2016	102	23	16	
2017	211	131	117	
2018	231	129	57	

On October 31, 2018, the EPA made the long-awaited announcement regarding dicamba registration for the 2019 growing season. Opinions regarding the EPA's actions will surely be as varied as people's views of the technology. Following are pertinent changes on the dicamba labels:

1. People under the supervision of a certified applicator can no longer make applications;
2. Applications are allowed only from one hour after sunrise to two hours before sunset (previously the restriction was between sunrise and sunset);
3. Applications are restricted to 45 days after planting or prior to R1 stage of soybean, whichever comes first (previously the restriction was up to and including the R1 stage);
4. Do not apply if rain within 24 hours may result in soil runoff (previously the label stated not to apply if rain is expected to occur within 24 hours);
5. The label clarifies what constitutes sensitive areas and where downwind buffers are required – the vegetation along roads is now considered part of the road;
6. There is a new restriction regarding use in counties with endangered species, the specifics have not been posted at this time, but this probably won't impact applications in most of Iowa;
7. Dicamba specific training will be required again for all applicators using the registered products on dicamba soybean.

There are still reservations about the ability to use this product in soybean with an acceptable level of risk to sensitive vegetation. Restrictions related to wind speed, rainfall, and hours during the day provide few hours that are appropriate (legal) for application. The label changes for 2019 do little to reduce the risk for volatility, and experience indicates that volatilization has played a significant role in off-target movement. Preemergence applications of dicamba greatly reduce the likelihood of injury compared to postemergence applications, and this is our recommendation for the technology. However, we recognize preemergence applications reduce the value of dicamba on weeds with prolonged emergence, such as waterhemp. The potential for off-target movement increases as postemergence applications are delayed. When using the new dicamba products postemergence, the goal should be to complete applications by the V2–V3 stage of soybean. Combining dicamba with a Group 15 herbicide (Dual, Warrant, Zidua, etc.) will prolong activity on late-emerging waterhemp until the crop canopy closes.

Miscellaneous

The status of both Enlist (2,4-D resistant corn and soybean) and the GT27 (glyphosate and isoxaflutole resistant soybean) systems is still unclear at time of writing this article. Both the Enlist traits and the herbicides registered for use with them are approved by the USDA and EPA, but Corteva is limiting the launch awaiting export approval. The GT27 trait is approved both in the U.S. and in export markets, but the Group 27 herbicide developed for use with them is still waiting approval from the EPA.

Syngenta is developing a premix of dicamba and S-metolachlor for use in dicamba-resistant soybean. It is currently pending registration from the EPA. It will be marketed as Tavium plus VaporGrip Technology. AMVAC has introduced Impact Z, a premix of topramezone and atrazine. The maximum rate (10.7 ounces/Acre) provides 0.33 pounds atrazine per acre. Belchim is in the process of registering pryidate (Tough) for postemergence use in corn. Pyridate previously was registered by Syngenta, but registration was voluntarily withdrawn about 15 years ago. Pyridate is a Group 6 herbicide (photosystem II inhibitor) that is active on broadleaf weeds.

New weed scientist

Iowa State is fortunate to have hired an experienced weed scientist to replace Mike Owen. Prashant Jha is currently an associate professor with Montana State University, based at the Southern Agricultural Research Center near Huntley. He received his Ph.D. at Clemson University, working with Palmer amaranth. He has both research and extension responsibilities in Montana, and his appointment at Iowa State will be 60 percent extension and 40 percent research. Jha has a widely recognized research program, with a major focus on herbicide-resistant kochia, Montana's equivalent to the Midwest's waterhemp. Earlier this year he was named Outstanding Early Career Weed Scientist by the Weed Science Society of America.

Designing Resilient Herbicide Programs

Bob Hartzler, professor in agronomy and extension weed specialist at Iowa State University

For most growers, adjusting herbicide programs will be the most important strategy managing herbicide resistance. There are numerous approaches that can provide effective control while reducing the risk of selecting resistant weed biotypes. This article will provide a brief overview of the types of herbicide strategies that can be used in corn and soybean production.

Resilient programs rely on multiple herbicide groups that are effective against important weeds present in the field. Knowledge of the individual herbicides included in the program is essential in achieving success. The rate a herbicide is applied is critical in determining its effectiveness. Ensure that the individual components of a program are used at rates that will control target weeds. Other factors that determine the effectiveness of a herbicide program include: 1) the nature of the weed infestation in the field, including species present, density of weeds, and existing herbicide resistances; 2) soil characteristics of the field; 3) ability to spray the field in a timely fashion (i.e. availability of sprayer, number of acres managed, etc.); and 4) opportunity for implementing non-chemical tactics.

The following provides a brief description of basic herbicide strategies, highlighting their benefits and risks.

Total preemergence program

- ***Advantages***
  - Offers the opportunity for a one-pass program. *Not appropriate for most fields.*
- ***Disadvantages***
  - Inability of most herbicides to sustain effective control until the crop canopy develops.
  - Reliance on timely rainfall to activate herbicides before weeds begin germination. Only appropriate for fields with low to moderate densities of annual weeds.
- Not appropriate for fields with high weed densities or significant populations of large-seeded broadleaves (e.g. giant ragweed, cocklebur, morningglories) or perennial weeds. The prolonged emergence pattern of waterhemp decreases likelihood of success in fields with moderate to high densities of this weed. Early planting results in need for extended longevity of control due to slow emergence, reducing likelihood of success. Greater likelihood of success in corn than in soybean due to characteristics of available herbicides.
- *Approaches:* This type of program typically relies on a combination of herbicides to provide broad-spectrum weed control. The herbicides must be persistent and be used at full-rates in order to extend control late into the season. Split applications of the preemergence program often are used in conservation tillage systems. Typically, 50-60 percent of the product is applied several weeks ahead of planting to control weeds that emerge prior to planting and reduce the need for timely rainfall, and the remainder is applied at or shortly after planting. This strategy can extend the activity of the herbicide later into the season than if it all was applied early.

Total postemergence program

- ***Advantages***
  - Eliminates need to spray fields during planting season, therefore reducing labor load.
- ***Disadvantages***
  - Risk of significant yield loss due to early-season competition if first application is delayed.
  - Many total post programs place high selection pressure on weeds for herbicide resistance.
- Only appropriate for fields with low weed densities in order to reduce the risk of early-season competition. Best suited for growers with own sprayer so that they have more control of when fields get sprayed.
- *Approaches:* Two approaches typically are used for total post programs. The introduction of Roundup Ready crops led to the popularity of sequential applications made 2-3 weeks apart. The other strategy is to include a residual herbicide with an early postemergence application. Halex GT is an example of the second strategy, it is a premix of glyphosate, S-metolachlor, and mesotrione. Glyphosate and mesotrione would control weeds that are present at the time of the postemergence application, while the S-metolachlor and mesotrione components would control weeds that emerge after the application. A risk with this approach is that the application is typically made during periods of peak weed emergence. Lack of rain to activate the preemergence herbicide within 5-7 days of application can result in weed escapes early in the season.

Sequential preemergence plus postemergence program

- *Advantages*
  - Provides most consistent control across a broad range of environmental conditions.
  - Preemergence component protects yield from early-season competition.
  - Easily incorporates multiple herbicide groups, therefore reducing selection pressure.
- *Disadvantages*
  - Requires multiple applications and the associated costs.
- Appropriate for any weed infestation, takes advantage of the benefits of both preemergence and postemergence herbicides.
- *Approaches:* There is considerable flexibility in these programs based on the nature of the weed infestation. In fields with low to moderate grass infestations, the preemergence component can target the grasses while the focus of the postemergence component would be the broadleaf weeds. Programs providing redundant control of target weeds with the PRE and POST components will provide the most consistent weed control and best management of herbicide resistance. Addition of residual herbicides (e.g. Warrant, Zidua) with the postemergence application can extend residual control until after the crop canopy closes.

Burndown programs for no-till

In no-till, it is essential to control emerged weeds prior to crop emergence. Delaying the burndown application until after planting results in significant risk if weather or other factors result in growing weeds being present when the crop emerges. The type of strategy used is dictated largely by the presence of winter annual and perennial weeds.

Glyphosate is the andard for burndown herbicides due to its broad-spectrum activity on annual and perennial weeds. Long-term control of most perennial weeds is reduced with preplant applications due to insufficient weed growth to result in translocation to underground structures. Activity of glyphosate on dandelion and some winter annuals can be very slow during cool temperatures in the spring, and fall applications may provide better control of these weeds in fields with heavy infestations. The addition of 2,4-D ester to glyphosate will improve control of marestail (horseweed), giant ragweed, and many mustard species.

2,4-D ester is most often used in combination with other herbicides to improve activity on emerged broadleaf weeds, specifically marestail, giant ragweed, and mustards. While 2,4-D has limited soil activity due to rapid microbial degradation, applications made prior to planting corn or soybean can cause significant injury. Ester formulations have less stringent restrictions on preplant applications than amines due to the shorter half-life and lower soil availability of ester products. In soybean, applications of up to 0.5 pounds ae/Acre must be applied at least seven days prior to planting. Restrictions for preplant applications for corn vary among labels, but an example would be seven days prior to planting for up to 0.5 pounds ae/Acre and 14 days for 0.5-1.0 pounds ae/Acre.

Liberty and **paraquat** are burndown options for fields where preplant weed infestations are limited to small annual weeds. Both products are contact herbicides and excellent coverage is required for good control. Best control is achieved when applied during warm, sunny conditions. The addition of 2,4-D to both of these products can improve control of broadleaf weeds, whereas addition of a group 5 herbicide (triazines) improves activity of paraquat.

Residual herbicides with foliar activity. Many products used for preemergence control have foliar activity (e.g. herbicide groups 2, 5, 14, and 27). In fields with low to moderate infestations of small annual weeds at planting these herbicides may have sufficient activity at planting to control the emerged weeds. The potential for omitting specific burndown herbicides (i.e. glyphosate) is dependent upon early-spring applications before annuals reach sizes that are tolerant of these herbicides. Saflufenacil (Kixor products) has good activity on small marestail. It may be substituted for 2,4-D in burndown programs where it is preferred not to delay planting following the burndown application.

Non-herbicidal strategies

While herbicides will remain the primary tactic used to manage weeds for most growers, it is essential to evaluate opportunities to include non-chemical tactics into the production system. The suitability of these tactics varies widely among operations, but inclusion of any alternative strategy can greatly improve performance of herbicides and delay the onset of herbicide resistance.

Mechanical control

Both preplant and postplant tillage significantly affect weed communities. A primary effect of seedbed preparation tillage is its influence on weed seed distribution within the seedbank. Due to waterhemp's small seed, tillage can bury a significant amount of the seed at a depth where it will not germinate. This can reduce the population that emerges after planting and simplify weed control during that season. This practice may be especially useful in years following control failures where high numbers of weed seed were produced and deposited on the soil surface. However, burying seed within the profile puts them into 'long-term storage' since seeds are much longer-lived when buried deep in the profile. If this strategy is used repeatedly its benefit is diminished since buried seeds will be brought back to the surface where they can germinate.

Rotary hoeing and inter-row cultivation remain viable practices in today's production systems. Rotary hoeing is beneficial when preemergence herbicides are not activated by rainfall. Rotary hoeing needs to be conducted prior to weed emergence (white-root stage) for greatest effectiveness. Due to waterhemp's prolonged emergence pattern the rotary hoe will not make significant contributions to full-season waterhemp control. However, using a rotary hoe to eliminate the first flush of early-emerging weeds can allow the postemergence application to be delayed, therefore improving waterhemp management.

Cultivation remains a highly effective tool to control weeds in crops planted in wide-row spacings. Because of increases in farm size, it is unrealistic to expect cultivation to be used as it was in the past. However, many growers could use cultivation on problem fields or areas within fields where weeds have escaped the chemical control program. As with other field operations, auto-steer has eliminated much of the drudgery of this practice, allows faster operating speeds, and reduces the potential for crop injury.

Narrow-row spacing

The best weed control tactic is a competitive crop canopy. Row spacings of 15 inches or less reduce the time needed to achieve canopy coverage of the interrow area, therefore suppressing emergence and growth of weeds later in the season. Increasing soybean seeding rates above the recommended population of 100,000 plants per acre at harvest when in narrow rows can enhance soybean suppression of weeds.

Cover crops

Cover crops have been promoted for weed suppression in other parts of the country. While cover crops provide numerous benefits in Iowa production systems, the state's relatively short growing season limits the amount of biomass that a cover crop accumulates by normal planting dates. Cereal rye produces more residue than most other species, and thus contributes more to weed management than others. Practices that increase cover crop biomass (early planting of cover crops, delayed termination in the spring) will improve weed control.

Summary

Weeds are the universal pest in that every field has an economic infestation every year. Our current system of large farms and narrow-profit margins limits flexibility in the types of tactics and dollars that can be invested in weed management. This also makes it difficult to factor in long-term weed management considerations such as herbicide resistance. However, the increasing rate that herbicide resistance is evolving in Iowa is a serious threat to future productivity. Taking the time to critically evaluate herbicide programs to determine the effectiveness of individual components is the first step in developing weed management programs that will provide effective control and protect the value of the herbicides are system is reliant on.

Acknowledgement: This article was adapted from material in the 2014 Ohio and Indiana Weed Control Guide.

Corn Herbicide Effectiveness Ratings[1]

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

Herbicide	Herbicide Group Number	Crop tolerance	Grasses: Crabgrass	Fall panicum	Foxtail	Woolly cupgrass	Shattercane [2]	Broadleaves: Waterhemp [2,4,5,6,7,8]	Black nightshade	Cocklebur [2]	Common ragweed	Giant ragweed [2,4,8]	Lambsquarter	Smartweed	Sunflower [2]	Velvetleaf	Perennials: Canada thistle	Quackgrass	Yellow nutsedge
Preplant/Preemergence																			
Atrazine	5	E	F	P	F	P	P	E	G	G	E	F-G	E	E	G	G	P	F	F
Balance Flexx (isoxaflutole)	27	E	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
Breakfree, Harness, Surpass (acetochlor)	15	E	E	E	E	F-G	F-G	G	G	P	P	P	P-F	P-F	P	P	P	P	G
Callisto (mesotrione)	27	E	P	P	P	P	P	G-E	G-E	F-G	F-G	F	E	F-G	G-E	E	P	P	P
Dual II Magnum, Outlook, Zidua (S-metolachlor, flumetsulam, pyroxasulfone)	15	E	E	E	E	F	F	F-G	G	P	P	P	P	P	P	P	P	P	G
Hornet WDG (flumetsulam, clopyralid)	2, 4	G	P	P	P	P	P	G-E	F-G	G	G	G	G	G-E	G-E	G	P	P	P
Linex, Lorox (linuron)	7	G	P-F	P-F	P	P	P	G-E	F	F	G	P-F	G-E	G-E	F	F	P	P	P
Pendimax, Prowl (pendimethalin)	3	F-G	G-E	G-E	G-E	G	G	G	P	P	P	P	G-E	F	P	P-F	P	P	P
Python (flumetsulam)	2	G	P	P	P	P	P	E	F-G	F	G	F	F-G	G-E	F-G	G-E	P	P	P
Sharpen (saflufenacil)	14	G	P	P	P	P	P	G-E	G-E	G	G	G	G-E	G	G-E	G-E	P	P	G
Postemergence																			
Accent Q, Steadfast Q (nicosulfuron, rimsulfuron)	2	G-E	P	G	G-E	G-E	E	G	P	F	P	P	P	G	P	F	F	G	F
Aim (carfentrazone)	14	G	P	P	P	P	P	F-G	G	P	P	F	G	P	P	E	P	P	P
Armezon, Impact (topramezone)	27	G-E	F-G	F	G	F	F	G-E	G-E	G-E	G	G	G	G	E	E	P	P	P
Atrazine	5	G	F	P	F	P	P	E	E	E	E	G	E	E	E	E	F*	F	G
Basagran (bentazon)	6	E	P	P	P	P	P	P	P	E	E	F	P	E	G	G-E	G*	P	G*
Basis, Basis Blend (rimsulfuron, thifensulfuron)	2	F	F	F-G	G	F	G	G	P	F	F	P	G-E	G-E	G-E	G	P	G	P
Banvel, Clarity, DiFlexx, Xtendimax with VGT, Eng	4	F-G	P	P	P	P	P	G-E	G	E	G-E	E	G	E	G	F-G	G*	P	P
Beacon (primisulfuron)	2	G	P	F-G	P-F	P	E	E	G	G	G	E	P	G	G	F-G	F-G*	G	F
Buctril (bromoxynil)	6	G	P	P	P	P	P	G	G-E	E	E	G	G-E	G-E	E	G	P	P	P
Callisto (mesotrione)	27	G-E	P	P	P	P	P	E	E	G-E	F	G	G	E	G-E	E	P	P	P
Enlist One3 (2, 4-D)	4	E	P	P	P	P	P	G-E	G	E	E	E	E	F-G		G-E	F-G	P	P
Glyphosate (Roundup, etc.)[3]	9	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 (flumetsulam, clopyralid)	2, 4	G	P	P	P	P	P	G-E	F	E	E	G-E	F	G-E	E	G-E	G	P	P
Liberty[3] (glufosinate)	10	E	E	G	G-E	E	E	G	E	E	E	G	G	E	E	E	F-G	G	P
Laudis (tembotrione)	27	G-E	F-G	F	G-E	F-G	F-G	E	G-E	G-E	G	G	G	G	E	E	P	P	P
Permit, Halomax, etc. (halosufuron)	2	G	P	P	P	P	P	E	P	G-E	G-E	G	P	G-E	E	E	P	P	G
Resolve (rimsulfuron)	2	F	F	F-G	G	F	G	G	P	F	F	P	G-E	G	P	F-G	F	G	F
Resource (flumiclorac)	14	G-E	P	P	P	P	P	G	P	F	F-G	P	F	P	P	E	P	P	P
Status (dicamba, diflufenzopyr)	4, 19	F-G	P	F	F	P	F	G-E	G	E	G-E	G	G	E	G	G	G*	P	P

[1] Ratings are based on full label rates. **Premix products containing ingredients marketed as single active ingredient 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.
[4] Glyphosate-resistant biotypes of these weeds have been identified in Iowa. These biotypes may not be controlled by glyphosate.
[5] PPO-resistant biotypes of waterhemp have been identified in Iowa. These biotypes may not be controlled by PPO inhibitor herbicides.
[6] HPPD-resistant biotypes of waterhemp have been identified in Iowa. These biotypes may not be controlled by HPPD herbicides.
[7] PSII-resistant biotypes of waterhemp have been identificed in Iowa. These biotypes may not be controlled by PSII herbicides.
[8] Biotypes of this weed with resistance to multiple sites of herbicide action have been identified in Iowa.
* Degree of perennial weed control is often a result of repeated application.

This chart 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	Herbicide Group Number	Crop tolerance	Grasses					Broadleaves									Perennials		
			Crabgrass	Fall panicum	Foxtail	Woolly cupgrass	Shattercane [2]	Waterhemp [2, 4, 5, 6, 7, 8]	Black nightshade	Cocklebur [2]	Common ragweed	Giant ragweed [2, 4, 8]	Lambsquarter	Smartweed	Sunflower [2]	Velvetleaf	Canada thistle	Quackgrass	Yellow nutsedge
Preplant/Preemergence																			
Authority/Spartan (sulfentrazone)	14	G	P-F	P	P-F	P	P	E	E	F	F	F	G-E	F	P	F-G	P	P	F-G
Dual II Magnum, Warrant, Zidua (*S*-metolachlor, acetochlor, pyroxasulfone)	15	E	E	E	E	F	F	F-G	G	P	P	P	P	P	P	P	P	P	P
Command (clomazone)	13	E	G-E	G-E	E	F	F	P	F	F	G	P	G-E	G	F	E	P	P	P
Engenia, FeXapan, Xtendimax w/ VGT (dicamba)	4	E[9]	P	P	P	P	P	F	G	G	G	G-E	G	G	G	F-G	G*	P	P
FirstRate, Amplify (cloransulam)	2	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
Linex, Lorox (linuron)	7	F	P-F	P-F	P	P	P	G-E	F	F	G	P-F	G-E	G-E	F	F	P	P	P
Prowl, Treflan, etc (pendimethalin, trifluralin)	3	G-E	E	E	E	E	G-E	G	P	P	P	P	G	F	P	P	P	P	P
Pursuit (imazethapyr)	2	G	F-G	F	F-G	P-F	G	F-E	G-E	F	G	F	G	G-E	F-G	G	P	P	P
Python (flumetsulam)	2	E	P	P	P	P	P	E	F	F	F	P	F-G	G-E	F	E	P	P	P
Metribuzin, Sencor, TriCor, etc	5	F-G	P	P	P-F	P	P	E	F	F	E	P	E	E	F-G	G-E	P	P	P-F
Sharpen (saflufenacil)	14	G	P	P	P	P	P	F	F	F	F	F	F	F	F	F	P	P	P
Valor SX, Rowel (flumioxazin)	14	F-G	P	P	P	P	P	G-E	E	P	G	F	G-E	F	P	F	P	P	P
Postemergence																			
Assure II, Fusilade DX, Fusion, Poast Plus, Select, (quizalofop, fluazifop, sethoxydim, clethodim)	1	E	E	E	E	E	E	P	P	P	P	P	P	P	P	P	P	G-E*	P
Basagran (bentazon)	6	E	P	P	P	P	P	P-F	P-F	E	E	F	P	E	G	G-E	G*	P	G*
Blazer (acifluroden)	14	F-G	P	P	F	P	F	E	G	F	G	F	F	E	F	F	F	P	P
Classic (clorimuron)	2	G	P	P	P	P	P	E	P	E	G-E	F	P	G-E	E	G-E	F	P	G-E
Cobra/Phoenix (lactofen)	14	F-G	F	P	P	P	P	E	G	G-E	E	F-G	F	G	G	F	F	P	P
Engenia, FeXapan, Xtendimax with VGT (dicamba)[3]	4	E[9]	P	P	P	P	P	G-E	G	E	G-E	E	G	E	G	F-G	G*	P	P
FirstRate/Amplify (cloransulam)	2	G	P	P	P	P	P	P	P	G-E	E	E	P	G	E	G	P	P	P
Glyphosate (Roundup, etc.)[3]	9	E	E	G-E	E	E	E	G-E	F-G	E	E	G-E	G	E	E	G	G	G-E	F
Harmony (thifensulfuron)	2	F	P	P	P	P	P	E	P	F	F	P	G-E	G-E	G-E	G	P	P	P
Liberty[3] (glufosinate)	10	E	E	G	G-E	E	E	G	E	E	E	G	G	E	E	E	F-G	G	F
Pursuit (imazethapyr)	2	G	G	G	F-G	F	E	F-G	E	G-E	G	F	P-F	E	G	G-E	F	P	P
Raptor (imazamox)	2	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 (fomesafen)	14	F-G	P	P	P	P	P	E	F-G	F	G	G	F	G-E	F	F	P-F	P	P
Resource (flumiclorac)	14	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 active ingredient products may not be included in this table.**

[2] ALS-resistant biotypes have been identified in Iowa. These biotypes may not be controlled by all ALS products.

[3] Use only on appropriate resistant varieties.

[4] Glyphosate-resistant biotypes of these weeds have been identified in Iowa. These biotypes may not be controlled by glyphosate.

[5] PPO-resistant biotypes of common waterhemp have been identified in Iowa. These biotypes may not be controlled by PPO inhibitor herbicides.

[6] HPPD-resistant biotypes of common waterhemp have been identified in Iowa. These biotypes may not be controlled by HPPD herbicides.

[7] PSII-resistant biotypes of these weeds have been identifed in Iowa. These biotypes may not be controlled by PSII inhibitor herbicides.

[8] Biotypes of this weed with resistance to multiple sites of herbicide action have been identified in Iowa.

[9] Diamba-tolerant soybean cultivars only.

* Degree of perennial weed control is often a result of repeated application.

This chart 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.

Grazing and Haying Restrictions for Herbicides Used in Grass Pastures

				Beef and Non-Lactating Animals			Lactating Dairy Animals	
Herbicide	**Active Ingredient**	**HG**	**Rate/Acre**	**Grazing**	**Hay harvest**	**Removal before slaughter**	**Grazing**	**Hay harvest**
2, 4-D	2, 4-D	4	1.5 to 2.0 pounds ae	0	7 days	0	0	7 days
Clarity and many others	dicamba	4	Up to 1 pint	0	0	30 days	7 days	37 days
			1 - 2 pints	0	0	30 days	21 days	51 days
			2 - 4 pints	0	0	30 days	40 days	70 days
			4 - 16 pints	0	0	30 days	60 days	90 days
Chaparral	aminopyralid + metsulfuron methyl	4, 2	1 - 3.3 ounces	0	0	0	0	0
Cimarron Max (co-pack)	metsulfuron methyl + dicamba + 2,4-D	2, 4, 4	0.25-1 ounce A + 1-4 pints B	0	0	30 days	7 days	37 days
Cimarron X-Tra	metsulfuron methyl + chlorsulfuron	2, 2	0.1 - 1.0 ounce	0	0	0	0	0
Crossbow	triclopyr + 2,4-D	4, 4	1 - 6 quarts	0	14 days	3 days	Growing season	Growing season
Curtail	clopyralid + 2,4-D	4, 4						
Escort XP	metsulfuron methyl	2, 2	Up to 1.7 ounces	0	0	0	0	0
ForeFront HL	aminopyralid + 2,4-D	4, 4	1.2 - 2.1 pints	0	7 days	0	0	7 days
Grazon P&D	picloram + 2,4-D	4, 4	3 - 4 pints	0	30 days	3 days	7 days	30 days
Milestone	aminopyralid	4	3 - 7 ounces	0	0	0	0	0
Overdrive	dicamba + diflufenzopyr	4, 19	4 - 8 ounces	0	0	0	0	0
PastureGard HL	triclopyr + fluroxypyr	4, 4	1 - 1.5 pints	0	14 days	3 days	1 year	1 year
Rave	dicamba + triasulfuron	4, 2	2 - 5 ounces	0	37 days	30 days	7 days	37 days
Redeem R&P	triclopyr + clopyralid	4, 4	1.5 - 4 pints	0	14 days	3 days	Growing season	Growing season
Remedy Ultra	triclopyr	4, 19	1 - 2 quarts	0	14 days	3 days	Growing season	Growing season
Surmount	picloram + fluroxypyr	4, 4	1.5 - 6 pints	0	7	3	14	7
Tordon 22K	picloram	4	< 2 pints	0	0	3	14	14
			> 2 pints	0	14	3	14	14
Weedmaster	dicamba + 2,4-D	4, 4	1 - 4 pints	0	7 days	30 days	7 days	7 days

Herbicide Package Mixes

The following table provides information concerning the active ingredients found in prepackage mixes, the amount of active ingredients applied with a typical use rate, and the equivalent rates of the individual products.

Corn Herbicide Premixes or Co-packs and Equivalents

Herbicide	Group	Components (active ingredient/gallon or % active ingredient)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Acuron	15	2.14 pounds S-metolachlor	3.0 quarts	1.6 pounds S-metolachlor	27.0 ounces Dual II Magnum
	5	1.0 pound atrazine		0.75 pounds atrazine	1.5 pints atrazine 4L
	27	0.24 pounds mesotrione		0.18 pounds mesotrione	5.8 ounces Callisto
	27	0.06 pounds bicyclopyrone		0.045 pounds bicyclopyrone	N/A
Acuron Flexi	27	0.08 pounds bycylopyrone	2.25 quarts	0.72 ounces bicyclopyrone	N/A
	27	0.32 pounds mesotrione		0.18 pounds mesotrione	5.8 ounces Callisto
	15	2.86 pounds S-metolachlor		1.61 pounds S-metolachlor	27.0 ounces Dual II Magnum
Alluvex WSG	2	16.7% rimsulfuron	1.5 ounces	0.25 ounces rimsulfuron	0.5 ounces Harmony SG
	2	16.7% thifensulfuron		0.25 ounces thifensulfuron	1.0 ounces Resolve SG
Anthem	15	2.087 pounds pyroxaslufone	10.0 ounces	0.16 pounds pyroxasulfone	3.0 ounces Zidua
	14	0.063 pounds fluthiacet-methyl		0.08 oz fluthiacet-methyl	0.7 ounces Cadet
Anthem Maxx	15	4.174 pounds pyroxasulfone	5.0 ounces	0.16 ounces pyroxasulfone	3.0 ounces Zidua
	14	0.126 pounds fluthiacet-methyl		0.08 ounces fluthiacet	0.7 ounces Cadet
Anthem ATZ	5	4.0 pounds atrazine	2.0 pints	1.0 pound atrazine	2.0 pints atrazine 4L
	15	0.485 pounds pyroxasulfone		0.12 pounds pyroxasulfone	2.25 ounces Zidua
	14	0.014 pounds fluthiacet		0.06 ounces fluthiacet	0.6 ounces Cadet
Armezon Pro	15	5.25 pounds dimethenamid-P	20.0 ounces	0.82 pounds dimethenamid-P	17.5 ounces Outlook
	27	0.1 pounds topramezone		0.26 ounces topramezone	0.73 ounces Armezon
Basis Blend	2	20.0% rimsulfuron	0.825 ounces	0.167 ounces rimsulfuron	0.67 ounces Resolve
	2	10.0% thifensulfuron		0.083 ounces thifensulfuron	0.16 ounces Harmony
Bicep II MAGNUM, Cinch ATZ, Medal II AT, Charger Max ATZ	15	2.4 pounds S-metolachlor	2.1 quarts	1.26 pounds S-metolachlor	21.0 ounces Dual II MAGNUM
	5	3.1 pounds atrazine		1.63 pounds atrazine	52.0 ounces Aatrex 4L
Bicep Lite II MAGNUM, Cinch ATZ Lite, Charger Max ATZ Lite	15	3.33 pounds S-metolachlor	1.5 quarts	1.25 pounds S-metolachlor	21.0 ounces Dual II MAGNUM
	5	2.67 pounds atrazine		1.00 pound atrazine	32.0 ounces atrazine 4L
Breakfree NXT ATZ	15	3.1 pounds acetochlor	2.7 quarts	2.1 pounds acetochlor	2.4 pints Breakfree NXT
	5	2.5 pounds atrazine		1.7 pounds atrazine	3.4 pints atrazine 4L
Breakfree NXT Lite	15	4.3 pounds acetochlor	2.0 quarts	2.2 pounds acetochlor	2.5 pints Breakfree NXT
	5	1.7 pounds atrazine		0.85 pounds atrazine	1.7 pints atrazine 4L
Callisto GT	9	3.8 pounds glyphosate	2.0 pints	0.95 pounds glyphosate	27.0 ounces/Acre of 4.5 pounds ae/gallon glyphosate
	27	0.38 pounds mesotrione		0.095 pounds mesotrione	3.04 ounces Callisto

Corn Herbicide Package Mixes (continued)

Herbicide	Group	Components (active ingredient/gallon or % active ingredient)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Callisto Xtra	27	0.5 pounds mesotrione	24.0 fluid ounces	0.09 pounds mesotrione	3.0 ounces Callisto
	5	3.2 pounds atrazine		0.6 pounds atrazine	1.2 pints Aatrex 4L
Capreno	2	0.57 pounds thiencarbazone	3.0 ounces	0.01 pounds thiencarbazone	NA
	27	2.88 pounds tembotrione		0.068 pounds tembotrione	2.5 ounces Laudis
Corvus	27	1.88 pounds isoxaflutole	5.6 ounces	1.3 ounces isoxaflutole	5.1 ounces Balance Flexx
	2	0.75 pounds thiencarbazone		0.5 ounces thiencarbazone	
Crusher 50 WDF	2	25.0% rimsulfuron	1.0 ounce	0.25 ounces rimsulfuron	1.0 ounce Resolve SG
	2	25.0% thifensulfuron		0.25 ounces thifensulfuron	0.5 ounces Harmony SG
Degree Xtra	15	2.7 pounds acetochlor	3.0 quarts	2.0 pounds acetochlor	36.6 ounces Harness 7E
	5	1.34 pounds atrazine		1.0 pound atrazine	1.0 quart atrazine 4L
DiFlexx Duo	27	0.27 pounds tembotrione	32.0 ounces	0.067 pounds tembotrione	2.5 ounces Laudis
	4	1.86 pounds dicamba		0.31 pounds dicamba	10.0 ounces DiFlexx
Distinct 70WDG	19	21.4% diflufenzopyr	6.0 ounces	1.3 ounces diflufenzopyr	1.3 ounces diflufenzopyr
	4	55.0% dicamba		3.3 ounces dicamba	6.0 ounces Banvel
Enlist Duo	4	24.4% 2,4-D choline salt	4.75 pints	0.95 pounds ae 2,4-D	30.4 ounces 2,4-D 4A
	9	22.1% glyphosate DMA		1.0 pounds ae glyphosate	32.0 ounces Durango DMA
Expert 4.9SC	15	1.74 pounds S-metolachlor	3.0 quarts	1.3 pounds S-metolachlor	1.4 pounds Dual II Mag.
	5	2.14 pounds atrazine		1.61 pounds atrazine	1.6 quarts Aatrex 4L
	9	0.74 pounds ae glyphosate		0.55 pounds ae glyphosate	1.5 pints Glyphosate 3L
Fierce	14	33.5% flumioxazin	3.0 ounces	1.0 ounces flumioxazin	2.0 ounces Valor
	15	42.5% pyroxasulfone		1.28 ounces pyroxasulfone	1.5 ounces Zidua
FulTime NXT	15	2.7 pounds acetochlor	3.0 quarts	2.0 pounds acetochlor	2.5 pints Surpass 6.4EC
	5	1.34 pounds atrazine		1.0 pound atrazine	2.0 pints atrazine 4L
Halex GT	15	2.09 pounds S-metolachlor	3.6 pints	0.94 pounds S-metolachlor	1.0 pint Dual II Magnum
	27	0.209 pounds mesotrione		1.44 ounces mesotrione	3.0 ounces Callisto
	9	2.09 pounds glyphosate		0.94 pounds glyphosate ae	1.5 pints Touchdown HiTech
Harness MAX	15	3.52 pounds acetochlor	75.0 fluid ounces	2.05 pounds acetochlor	2.3 pints Harness
	27	0.33 pounds mesotrione		0.188 pounds mesotrione	6.0 ounces Callisto
Harness Xtra, Confidence Xtra	15	4.3 pounds acetochlor	2.3 quarts	2.5 pounds acetochlor	2.9 pints Harness 7E
Keystone LA NXT	5	1.7 pounds atrazine		0.98 pounds atrazine	1.0 quart atrazine 4L
Harness Xtra 5.6L, Confidence Xtra 5.6	15	3.1 pounds acetochlor	3.0 quarts	2.325 pounds acetochlor	42.5 ounces Harness 7E
Keystone NXT	5	2.5 pounds atrazine		1.875 pounds atrazine	1.9 quarts atrazine 4L

Corn Herbicide Package Mixes (continued)

Herbicide	Group	Components (active ingredient/gallon or % active ingredient)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Hornet WDG	2	18.5% flumetsulam	5.0 ounces	0.924 ounces flumetsulam	1.15 ounces Python WDG
	4	60.0% clopyralid		0.195 pounds clopyralid	6.68 ounces Stinger 3S
Impact Z	27	0.26 pounds topramezone	10.7 ounces	0.35 ounces topramezone	1 ounces Impact
	5	4 pounds atrazine		0.33 pounds atrazine	0.3 quarts atrazine 4L
Integrity	14	6.24% saflufenacil	13.0 ounces	0.058 pounds saflufenacil	2.6 ounces Sharpen
	15	55.04% dimethenamid		0.5 pounds dimethenamid	10.9 ounces Outlook
Instigate	2	4.17% rimsulfuron	6.0 ounces	0.25 ounces rimsulfuron	1.5 ounces Resolve
	27	41.67% mesotrione		2.5 ounces mesotrione	5.0 ounces Callisto
Lexar EZ	15	1.74 pounds S-metolachlor	3.5 quarts	1.52 pounds S-metolachlor	1.6 pints Dual II Mag.
	5	1.74 pounds atrazine		1.52 pounds atrazine	3.0 pints Aatrex 4L
	27	0.224 pounds mesotrione		0.196 pounds mesotrione	6.27 ounces Callisto
Lumax EZ	27	0.268 pounds mesotrione	3.0 quarts	0.2 pounds mesotrione	6.0 ounces Callisto
	15	2.68 pounds S-metolachlor		2.0 pounds S-metolachlor	2.0 pints Dual II MAGNUM
	5	1.0 pound atrazine		0.75 pounds atrazine	0.75 quarts Aatrex 4L
NorthStar	2	7.5% primisulfuron	5.0 ounces	0.375 ounces primisulfuron	0.5 ounces Beacon 75SG
	4	43.9% dicamba		2.20 ounces dicamba	4.4 ounces Banvel 4L
Optill	14	17.8% saflufenacil	2.0 ounces	0.35 ounces saflufenacil	1.0 ounces Sharpen
	2	50.2% imazethapyr		1.0 ounces imazethapyr	4.0 ounces Pursuit
Panoflex 50 WSG	2	40.0% tribenuron	0.5 ounces	0.2 ounces tribenuron	0.2 ounces tribenuron
	2	10.0% thifensulfuron		0.05 ounces thifensulfuron	0.1 ounces Harmony SG
Prequel 45.0% DF	2	15.0% rimsulfuron	2.0 ounces	0.3 ounces rimsulfuron	1.2 ounces Resolve SG
	27	30.0% isoxaflutole		0.59 ounces isoxaflutole	1.2 ounces Balance Pro
Priority	14	12.3% carfentrazone	1.0 ounces	0.13 ounces carfentrazone	0.5 ounces Aim
	2	50.0% halosulfuron		0.51 ounces halosulfuron	0.68 ounces Permit
Realm Q	2	7.5% rimsulfuron	4.0 ounces	0.3 ounces rimsulfuron	1.2 ounces Resolve SG
	27	31.25% mesotrione		1.25 ounces mesotrione	2.5 ounces Callisto
Resicore	15	2.8 pounds acetochlor	2.5 quarts	1.75 pounds acetochlor	2.0 pints Surpass NXT
	27	0.3 pounds mesotrione		0.188 pounds mesotrione	6.0 ounces Callisto
	4	0.19 pounds clopyralid		0.119 pounds clopyralid	5.0 ounces Stinger
Resolve Q	2	18.4% rimsulfuron	1.25 ounces	0.23 ounces rimsulfuron	0.9 ounces Resolve DF
	2	4.0% thifensulfuron		0.05 ounces thifensulfuron	0.1 ounces Harmony SG
Revulin Q	27	36.8% mesotrione	4.0 ounces	1.5 ounces mesotrione	3.0 ounces Callisto
	2	14.4% nicosulfuron		0.58 ounces nicosulfuron	1.1 ounces Accent Q

Corn Herbicide Package Mixes (continued)

Herbicide	Group	Components (active ingredient/gallon or % active ingredient)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Scorch	4	1.0 pound gal dicamba	1.5 pints	0.187 pounds dicamba	0.37 pints Clarity
	4	3.02 pounds 2,4-D		0.57 pounds 2,4-D	1.1 pints 2,4-D LVE 4
	4	0.75 pounds fluroxypyr		0.14 pounds fluroxypyr	0.4 pints Starane Ultra
Sequence	9	2.25 pounds glyphosate	4.0 pints	1.12 pounds glyphosate	32.0 ounces/Acre of 4.5 pounds ae/gallon glyphosate
	15	3.0 pounds S-metolachlor		1.5 pounds S-metolachlor	26.0 ounces Dual II MAGNUM
Solstice	27	3.78 pounds mesotrione	3.15 ounces	1.49 ounces mesotrione	3.0 ounces Callisto
	14	0.22 pounds fluthiacet-methyl		0.08 ounces fluthiacet-m	0.75 ounces Cadet
Spirit 57WG	2	14.25% prosulfuron	1.0 ounces	0.1425 ounces prosulfuron	0.25 ounces Peak 57WG
	2	42.75% primisulfuron		0.4275 ounces primisulfuron	0.57 ounces Beacon 75SG
Spitfire	4	0.5 pounds dicamba acid	2.0 pints	0.12 pounds ae dicamba	3.8 ounces Banvel
	4	3.07 pounds ae 2,4-D ester		0.77 pounds ae 2,4-D	26.0 ounces 2,4-D 4E
Status 56WDG	19	17.1% diflufenzopyr	5.0 ounces	0.05 pounds diflufenzopyr	0.05 pounds diflufenzopyr
	4	44.0% dicamba		0.125 pounds dicamba	4.0 ounces Banvel
Steadfast Q	2	25.2% nicosulfuron	1.5 ounces	0.37 ounces nicosulfuron	0.68 ounces Accent Q
	2	12.5% rimsulfuron		0.19 ounces rimsulfuron	0.76 ounces Resolve DF
Surestart II/Tripleflex II, Trisidual	15	3.75 pounds acetochlor	2.0 pints	0.94 pounds acetochlor	1.2 pints Surpass 6.4E
	4	0.38 pounds clopyralid		1.5 ounces clopyralid	4.1 ounces Stinger 3S
	2	0.12 pounds flumetsulam		0.48 ounces flumetsulam	0.6 ounces Python WDG
Verdict	14	6.24% saflufenacil	14.0ounces	0.992 ounces saflufenacil	2.8 ounces Sharpen
	15	55.04% dimethenamid-P		0.547 pounds dimethenamid-P	11.7 ounces Outlook
WideMatch 1.5EC	4	0.75 pounds fluroxypyr	1.3 pints	0.125 pounds fluroxypyr	10.6 ounces Starane 1.5E
	4	0.75 pounds clopyralid		0.125 pounds clopyralid	5.3 ounces Stinger 3S
Yukon	2	12.5% halosulfuron	4.0 ounces	0.5 ounces halosulfuron	0.66 ounces Permit
	4	55% dicamba		0.125 pounds dicamba	4.0 ounces Banvel

Soybean Herbicide Package Mixes or Co-packs and Equivalents

Herbicide	Group	Components (active ingredient/gallon or % active ingredient)	If you apply (per acre)	You have applied (active ingredient)	An equivalent tank mix of (product)
Afforia	14	40.8% flumioxazin	3.0 ounces	1.22 ounces flumioxazin	2.4 ounces Valor SX
	2	5.0% thifensulfuron		0.15 ounces thifensulfuron	0.3 ounces Harmony
	2	5.0% tribenuron		0.15 ounces tribenuron	0.3 ounces Express
Anthem Maxx	15	4.174 pounds pyroxasulfone	5.0 ounces	0.16 ounces pyroxasulfone	3.0 ounces Zidua
	14	0.126 pounds fluthiacet methyl		0.08 ounces fluthiacet	0.7 ounces Cadet

Soybean Herbicide Package Mixes (continued)

Herbicide	Group	Components (active ingredient/gallon or % active ingredient)	If you apply (per acre)	You have applied (active ingredient)	An equivalent tank mix of (product)
Authority Assist	14	33.3% sulfentrazone	10.0 ounces	3.3 ounces sulfentrazone	5.6 ounces Authority 75DF
	2	6.67% imazethapyr		0.67 ounces imazethapyr	3.4 ounces Pursuit AS
Authority Elite, BroadAxe XC	14	7.55% sulfentrazone	25.0 ounces	2.24 ounces sulfentrazone	3.0 ounces Authority 75DF
	15	68.25% S-metolachlor		1.26 pounds S-metolachlor	1.3 pints Dual II MAGNUM
Authority First/Sonic	14	62.1% sulfentrazone	8.0 ounces	0.31 pounds sufentrazone	6.6 ounces Authority 75DF
	2	7.96% cloransulam-methyl		0.64 ounces cloransulam-methyl	0.76 ounces FirstRate
Authority MAXX	14	62.12% sulfentrazone	7.0 ounces	4.3 ounces sulfentrazone	5.7 ounces Authority 75DF
	2	3.88% chlorimuron		0.28 ounces chlorimuron	1.1 ounces Classic 25DF
Authority MTZ	14	18.0% sulfentrazone	16.0 ounces	0.18 pounds sulfentrazone	3.8 ounces Authority 75DF
	5	27.0% metribuzin		0.27 pounds metribuzin	0.36 pounds Metribuzin 75DF
Authority XL	14	62.2% sulfentrazone	8.0 ounces	5.0 ounces sulfentrazone	6.6 ounces Authority 75DF
	2	7.8% chlorimuron		0.6 ounces chlorimuron	2.4 ounces Classic
Boundary 7.8EC, Presidual	15	5.2 pounds S-metolachlor	2.1 pints	1.4 pounds S-metolachlor	1.5 pints Dual II MAG.
	5	1.25 pounds metribuzin		0.3 pounds metribuzin	0.4 pounds Metribuzin 75DF
Canopy 75DF	2	10.7% chlorimuron-ethyl	6.0 ounces	0.5 ounces chlorimuron	2.0 ounces Classic 25DF
	5	64.3% metribuzin		3 ounces metribuzin	0.25 pounds Metribuzin 75DF
Canopy EX	2	22.7% chlorimuron	1.5 ounces	0.34 ounces chlorimuron	1.36 ounces Classic
	2	6.8% tribenuron		0.10 ounces tribenuron	0.10 ounces tribenuron
Cheetah Max	10	2.0 pounds glufosinate	34 ounces	0.53 pounds glufosinate	29.0 fluid ounces Liberty
	14	1.0 pound fomesafen		0.27 pounds fomesafen	18.0 ounces Flexstar
Crusher	2	25.0% rimsulfuron	1.0 ounces	0.25 ounces rimsulfuron	1.0 ounces Resolve DF
	2	25.0% thifensulfuron		0.25 ounces thifensulfuron	0.5 ounces Harmony SG
Enlist Duo	4	1.6 pounds ae 2,4-D choline salt	4.0 pints	0.8 pounds ae 2,4-D	26.0 ounces 2,4-D 4A
	9	1.7 pounds ae glyphosate		0.85 pounds ae glyphosate	24.0 ounces Roundup WMax
Enlite 47.9DG	14	36.2% flumioxazin	2.8 ounces	1.0 ounces flumioxazin	2.0 ounces Valor
	2	8.8% thifensulfuron		0.25 ounces thifensulfuron	0.5 ounces Harmony SG
	2	2.8% chlorimuron ethyl		0.08 ounces chlorimuron ethyl	0.32 ounces Classic 25 DF
Envive 41.3DG	14	29.2% flumioxazin	3.5 ounces	1.0 ounces flumioxazin	2.0 ounces Valor
	2	2.9% thifensulfuron		0.10 ounces thifensulfuron	0.2 ounces Harmony SG
	2	9.2% chlorimuron ethyl		0.32 ounces chlorimuron ethyl	1.3 ounces Classic 25DF
Extreme	2	1.8% imazethapyr	3.0 pints	1.02 ounces imazethapyr	1.44 ounces Pursuit DG
	9	22.0% glyphosate		0.75 pounds glyphosate	24.0 ounces Roundup

Soybean Herbicide Package Mixes (continued)

Herbicide	Group	Components (active ingredient/gallon or % active ingredient)	If you apply (per acre)	You have applied (active ingredient)	An equivalent tank mix of (product)
Fierce 76.0% WDG	14	33.5 % flumioxazin	3.0 ounces	1.0 ounce flumioxazin	2.0 ounces Valor
	15	42.5% pyroxasulfone		1.28 ounces pyroxasulfone	1.5 ounces Zidua
Fierce XLT	14	24.57% flumioxazin	4.0 ounces	1.0 ounces flumioxazin	2.0 ounces Valor
	15	31.17% pyroxasulfone		1.28 ounces pyroxasulfone	1.5 ounces Zidua
	2	6.67% chlorimuron		0.25 ounces chlorimuron	1.0 ounce Classic DF
Flexstar GT 3.5	14	0.56 pounds fomesafen	3.5 pints	0.245 pounds fomesafen	16.0 ounces Flexstar
	9	2.26 pounds glyphosate		1.0 pound glyphosate	26.0 ounces Touchdown HiTech
Fusion 2.67E	1	2.0 pounds fluazifop	8.0 fl ounces	0.125 pounds fluazifop	8.0 fluid ounces Fusilade DX 2E
	1	0.67 pounds fenoxaprop		0.042 pounds fenoxaprop	8.0 fluid ounces Option II 0.67E
Harrow	2	50.0% rimsulfuron	0.5 ounces	0.25 ounces rimsulfuron	1.0 ounce Matrix SG
	2	25.0% thifensulfuron		0.12 ounces thifensulfuron	0.25 ounces Harmony SG
Latir	14	31.5% flumioxazin	3.2 ounces	1.0 ounce flumioxazin	2.0 ounces Valor
	2	23.5% imazethapyr		0.75 ounces imazethapyr	3.0 ounces Pursuit
Marvel	14	1.2% fluthiacet	5.0 ounces	0.075 ounces fluthiacet	0.66 ounces Cadet
	14	30.08% fomesafen		1.8 ounces fomesafen	0.5 pints Flexstar
Matador	15	4.0 pounds metolachlor	2.0 pints	1.0 pound metolachlor	1.0 pint Stalwart
	5	0.56 pounds metribuzin		2.25 ounces metribuzin	3.0 ounces Metribuzin 75DG
	2	0.13 pounds imazethapyr		2.0 ounces imazethapyr	2.0 ounces Pursuit 2AS
OpTill	14	17.8% saflufenacil	2.0 ounces	0.35 ounces saflufenacil	1.0 ounces Sharpen
	2	50.2% imazethapyr		1.0 ounce imazethapyr	4.0 ounces Pursuit AS
Panoflex 50.0% WSG	2	40.0% tribenuron	0.5 ounces	0.2 ounces tribenuron	0.2 ounces tribenuron
	2	10.0% thifensulfuron		0.05 ounces thifensulfuron	0.1 ounces Harmony SG
Panther Pro	14	0.67 pounds flumioxazin/gal	12.0 ounces	0.06 pounds flumioxazin	2.0 fluid ounces Panther SC
	2	0.56 pounds imazethapyr		0.053 pounds imazethapyr	3.2 fluid ounces Pursuit
	5	3.0 pounds metribuzin		0.28 pounds metribuzin	6.0 ounces of a metribuzin 75% WDG
Prefix	15	46.4% S-metolachlor	2.0 pints	1.09 pounds S-metolachlor	1.14 pints Dual Magnum
	14	10.2% fomesafen		0.238 pounds fomesafen	0.95 pints Reflex
Pummel	15	5.0 pounds metolachlor	2.0 pints	1.25 pounds metolachlor	1.2 pints Stalwart
	2	0.25 pounds imazethapyr		0.063 pounds imazethapyr	4.0 ounces Pursuit
Pursuit Plus 2.9E	2	0.2 pounds imazethapyr	2.5 pints	0.063 pounds imazethapyr	4.0 ounces Pursuit 2S
	3	2.7 pounds pendimethalin		0.84 pounds pendimethalin	2.00 pints Prowl 3.3E

Soybean Herbicide Package Mixes (continued)

Herbicide	Group	Components (active ingredient/gallon or % active ingredient)	If you apply (per acre)	You have applied (active ingredient)	An equivalent tank mix of (product)
Rowel FX	2	10.3% chlorimuron ethyl	5.0 ounces	0.52 ounces chlorimuron ethyl	0.21 ounces Classic
	14	30.0% flumioxazin		1.5 ounces flumioxazin	2.94 ounces Valor
Sequence 5.25L	15	3.0 pounds S-metolachlor	3.0 pints	1.13 pounds S-metolachlor	1.2 pints Dual Magnum
	9	2.25 pounds glyphosate		0.84 pounds ae glyphosate	26.0 ounces Touchdown
Sonic	14	6.21% sulfentrazone	8.0 ounces	0.361 pounds sulfentrazone	6.6 ounces Authority 75DF
	2	7.96% cloransulam-methyl		0.04 pounds cloransulam-methyl	0.76 ounces FirstRate
Statement	15	4.22 pounds metolachlor	2.0 pints	1.1 pounds metolachlor	1.1 pints Stalwart
	14	0.91 pounds fomesafen		0.23 pounds fomesafen	15.3 ounces Rhythm
Storm 4S	6	2.67 pounds bentazon	1.5 pints	0.5 pounds bentazon	1.0 pint Basagran 4S
	14	1.33 pounds acifluorfen		0.25 pounds acifluorfen	1.0 pint Blazer 2S
Surveil	14	51.0% flumioxazin	3.6 ounces	1.5 ounces flumioxazin	3.0 ounces Valor
	2	84.0% chloransulam		0.5 ounces cloransulam	0.6 ounces FirstRate
Synchrony NXT	2	21.5% chlorimuron	0.5 ounces	0.11 ounces chlorimuron	0.44 ounces Classic 25DF
	2	6.9% thifensulfuron		0.034 ounces thifensulfuron	0.068 ounces Harmony SG
Tailwind	15	5.25 pounds metolachlor	2.0 pints	1.3 pounds metolachlor	1.3 pints Stalwart 8E
	5	1.25 pounds metribuzin		0.31 pounds metribuzin	0.4 pounds Metribuzin 75DF
Torment	14	2.0 pounds fomesafen	1.0 pint	0.25 pounds fomesafen	2.1 pints Flexstar
	2	0.5 pounds imazethapyr		1 ounce imazethapyr	4.0 ounces Pursuit
Trivence WDG	2	3.9% chlorimuruon-ethyl	6.0 ounces	0.23 ounces chlorimuron	1.0 ounces Classic 25DF
	14	12.8% flumioxazin		0.77 ounces flumioxazin	1.5 ounces Valor
	5	44.6% metribuzin		2.68 ounces metribuzin	0.22 pounds Metribuzin 75DF
Valor XLT	14	30.3% flumioxazin	3.0 ounces	0.9 ounces flumioxazin	1.76 ounces Valor
	2	10.3% chlorimuron ethyl		0.3 ounces chlorimuron	1.24 ounces Classic
Varisto	6	4.0 pounds bentazon	27.0 ounces	0.84 pounds bentazon	0.84 quarts Basagran
	2	0.187 pounds imazamox		0.04 pounds imazamox	5.1 ounces Raptor
Warrant Ultra	15	2.82 pounds acetochlor	50.0 ounces	1.1 pounds acetochlor	3.0 pints Warrant
	14	0.63 pounds fomesafen		0.25 pounds fomesafen	1.0 pint Reflex
Zidua Pro	14	0.48 pounds saflufenacil	4.5 ounces	0.26 ounces saflufenacil	0.73 ounces Sharpen
	2	1.33 pounds imazethapyr		0.75 ounces imazethapyr	3.0 ounces Pursuit
	15	2.28 pounds pyroxasulfone		1.28 ounces pyroxasulfone	1.5 ounces Zidua

Herbicide Sites of Action

Herbicides kill plants by binding to a specific protein and inhibiting that protein's function. This protein is referred to as the herbicide site of action. Utilizing herbicide programs that include several different sites of action is a key step in managing herbicide-resistant weeds.

A numbering system has been developed that makes it easier for farmers to evaluate their herbicide program in terms of site of action diversity. Each herbicide site of action is assigned a group number (Table 1), and this group number is typically found on the first page of most herbicide labels. Simply including multiple sites of action is not sufficient in fighting herbicide resistance in weeds, but rather the different sites of action must be effective against problem weeds such as waterhemp and giant ragweed.

Table 1. Herbicide classification by group number and site of action.

Group No.	Site of Action (mode of action)
1	ACC-ase (lipid synthesis)
2	ALS (amino acid synthesis)
3	Tubulin (cell division)
4	Auxin binding site (synthetic auxin)
5	D1 protein (Photosystem II inhibition)
6	D1 protein (Photosystem II inhibition)
7	D1 protein (Photosystem II inhibition)
9	EPSPS (shikimic acid pathway inhibition)
10	Glutamine synthetase (photosynthesis inhibition)
13	DPX synthase (carotene synthesis)
14	PPO (chlorophyll synthesis)
15	Unknown (LC fatty acid synthesis)
19	Auxin transport
22	Photosystem I
27	HPPD (carotene synthesis)

Table 2. Active ingredients and group numbers of single ingredient products.

Tradename	Herbicide Group No.	Active Ingredient
2,4-D, Enlist One/Duo, and others	4	2,4-D
Accent Q	2	nicosulfuron
Aim	14	carfentrazone
Assure II	1	quizalofop
atrazine	5	atrazine
Autumn	2	iodosulfuron
Balance Flexx	27	isoxaflutole
Banvel/Clarity/DiFlexx and others	4	dicamba
Basagran	6	bentazon
Beacon	2	primisulfuron
Buctril	6	bromoxynil
Cadet	14	fluthiacet-ethyl
Callisto	27	mesotrione
Classic	2	chorimuron
Cobra	14	lactofen
Command	13	clomazone
Dual/Cinch	15	S-metolachlor
Express	2	tribenuron
FirstRate	2	cloransulam
FlexStar/Reflex	14	fomesafen
Fusilade DX	1	fluazifop
Gramoxone SL/Parazone	22	paraquat
Harmony	2	thifensulfuron
Harness/Surpass/Breakfree/ Warrant	15	acetochlor
Impact/Armezon	27	topramezone
Laudis	27	tembotrione
Liberty	10	glufosinate
Lorox/Linex	7	linuron
Metribuzin/TriCor/Sencor	5	metribuzin
Option	2	foramsulfuron
Outlook	15	dimethenamid
Peak	2	prosulfuron
Permit	2	halosulfuron
Poast	1	sethoxydim
Prowl	3	pendimethalin
Pursuit	2	imazethapyr
Python	2	flumetsulam
Raptor	2	imazamox
Resolve/Bestow	2	rimsulfuron
Resource	14	flumiclorac
Roundup/Touchdown	9	glyphosate
Scepter	2	imazaquin
Select	1	clethodim
Sharpen	14	saflufenacil
Sonalan	3	ethalfluralin
Spartan/Authority	14	sulfentrazone
Stinger	4	clopyralid
Treflan, Thrust	3	trifluralin
UltraBlazer	14	acifluorfen
Valor/Rowel/Panther SC	14	flumioxazin
Warrant	15	acetochlor
Zidua	15	pyroxasulfone
Only sold in premix	2	thiencarbazone
Only sold in premix	19	diflufenzopyr
Only sold in premix	1	fenoxaprop
Only sold in premix	27	bicyclopyrone

Table 3. Active ingredients and group numbers of herbicide premixes.

Tradename	Herbicide Group No.	Active Ingredients
Acuron	5, 15, 27, 27	atrazine, S-metolachlor, mesotrione, bicyclopyrone
Acuron Flexi	15, 27, 27	S-metolachlor, mesotrione, bicyclopyrone
Afforia	2, 2, 14	thifensulfuron, tribenuron, flumioxazin
Alluvex	2, 2	rimsulfuron, thifensulfuron
Anthem	14, 15	fluthiacet, pyroxasulfone
Anthem ATZ	5, 14, 15	atrazine, fluthiacet, pyroxasulfone
Anthem Maxx	14, 15	fluthiacet, pyroxasulfone
Armezon Pro	15, 27	dimethenamid-P, topramezone
Authority Assist	2, 14	imazethapyr, sulfentrazone
Authority Elite	14, 15	sulfentrazone, S-metolachlor
Authority MTZ	5, 14	metribuzin, sulfentrazone
Authority XL	2, 14	chlorimuron, sulfentrazone
Autumn Super	2, 2	iodosulfuron, thiencarbazone
Basis Blend	2, 2	rimsulfuron, thifensulfuron
Bicep	5, 15	atrazine, S-metolachlor
Boundry	15, 5	S-metolachlor, metribuzin
Breakfree NXT ATZ, Breakfree NXT Lite	5, 15	atrazine, acetochlor
BroadAxe	14, 15	sulfentrazone, S-metolachlor
Callisto GT	9, 27	glyphosate, mesotrione
Callisto Xtra	5, 27	atrazine, mesotrione
Canopy	2, 5	chloriuron, metrbuzin
Canopy EX	2, 2	chlorimuron, tribenuron
Capreno	2, 27	thiencarbazone, tembotrione
Charger Max ATZ	5, 15	atrazine, S-metolachlor
Cheetah Max	10, 14	glufosinate, fomesafen
Cinch ATZ	15, 5	S-metolachlor, atrazine
Confidence Xtra	5, 25	atrazine, acetochlor
Corvus	2, 27	thiencarbazone, isoxaflutole
Crusher	2, 2	rimsulfuron, thifensulfuron
Degree Xtra	5, 15	atrazine, acetochlor
DiFlexx	4, 27	dicamba, isoxaflutole
Diflexx Duo	4, 27	dicamba, tembotrione
Enlist Duo	4, 9	2,4-D, glyphosate
Enlite	2, 2, 14	chlorimuron, thifensulfuron, flumioxazin
Envive	2, 2, 14	chloriuron, thifensulfuron, flumioxazin
Expert	5, 9, 15	atrazine, glyphosate, S-metolachlor
Extreme	2, 9	imazethapyr, glyphosate
Fierce	14, 15	flumioxazin, pyroxasulfone
Fierce XLT	2, 14, 15	chlorimuron, flumioxazin, pyroxasulfone
Flexstar GT	9, 14	glyphosate, fomesafen
FulTime NXT	5, 15	atrazine, acetochlor
Fusion	1, 1	fenoxaprop, fluazifop
Halex GT	9, 15, 27	glyphosate, S-metolachlor, mesotrione
Harness MAX	15, 27	acetochlor, mesotrione
Harness Xtra	5, 15	atrazine, acetochlor
Harrow	2, 2	rimsulfuron, thifensulfuron
Impact Z	5, 27	atrazine, topramezone
Instigate	2, 27	rimsulfuron, mesotrione
Keystone NXT, Keystone LA NXT	5, 15	atrazine, acetochlor
Latir	2, 14	imazethapyr, flumioxazin
Lexar EZ	5, 15, 27	atrazine, S-metolachlor, mesotrione
Lumax EZ	5, 15, 27	atrazine, S-metolachlor, mesotrione
Marksman	4, 5	dicamba, atrazine
Marvel	14,14	fluthiacet, fomesafen
Northstar	2, 4	primisulfuron, dicamba
Optill	2, 14	imazethapyr, saflufenacil
Panoflex	2, 2	tribenuron, thifensulfuron
Panther Pro	2, 5, 14	imazethapyr, metribuzin, flumioxazin
Permit Plus	2, 2	halosulfuron, thifensulfuron
Prefix	14, 15	fomesafen, S-metolachlor

Tradename	Herbicide Group No.	Active Ingredients
Presidual	5, 15	metribuzin, S-metolachlor
Prequel	2, 27	rimsulfuron, isoxaflutole
Priority	2, 14	halosulfuron, carfentrazone
Pummel	2, 15	Imazethapyr, metolachlor
Pursuit Plus	2, 3	imazethapyr, pendimethalin
Realm Q	2, 27	rimsulfuron, mesotrione
Require Q	2, 4	rimsulfuron, dicamba
Resicore	4, 15, 27	clopyralid, acetochlor, mesotrione
Resolve Q	2, 2	rimsulfuron, thifensulfuron
Revulin Q	2, 27	nicosulfuron, mesotrione
Rowel FX	2, 14	chlorimuron ethyl, flumioxazin
Scorch	4, 4, 4	2,4-D, dicamba, fluroxypyr
Sequence	9, 15	glyphosate, S-metolachlor
Solstice	14, 27	fluthiacet, mesotrione
Sonic	2, 14	cloransulam, sulfentrazone
Spirit	2, 2	primisulfuron, prosulfuron
Spitfire	4, 4	2,4-D, dicamba
Statement	15, 14	metolachlor, fomesafen
Status	4, 19	dicamba, diflufenzopyr
Steadfast Q	2, 2	nicosulfuron, rimsulfuron
Surpass NXT	5, 15	atrazine, acetochlor
Surestart	2, 4, 15	flumetsulam, clopyralid, acetochlor
Surveil	2,14	cloransulam, flumioxazin
Synchrony	2, 2	chlorimuron, thifensulfuron
Tailwind	5, 15	metribuzin, metolachlor
Torment	2, 14	Imazethapyr, fomesafen
TripleFLEX II	2, 4, 15	flumetsulam, clopyralid, acetochlor
Trisidual	2, 4, 15	flumetsulam, clopyralid, acetochlor
Trivence	2, 5, 14	chlorimuron, metribuzin, flumioxazin
Valor XLT	2, 14	chlorimuron, flumioxazin
Varisto	2, 6	imazamox, bentazon
Verdict	14, 15	saflufenacil, dimethenamid
Warrant Ultra	14, 15	fomesafen, acetochlor
Weedmaster	4, 4	2,4-D, dicamba
Yukon	2, 4	halosulfuron, dicamba
Zemax	15, 27	S-metolachlor, mesotrione
Zidua Pro	2, 14, 15	imazethapyr, saflufenacil, pyroxasulfone

Herbicide Site of Action and Typical Injury Symptoms

Herbicides kill plants by disrupting essential physiological processes. This normally is accomplished by the herbicide specifically binding to a single protein. The target protein is referred to as the herbicide "site of action". Herbicides in the same chemical family (e.g. triazine, phenoxy, etc.) generally have the same site of action. The mechanism by which an herbicide kills a plant is known as its "mode of action". For example, triazine herbicides interfere with photosynthesis by binding to the D1 protein which is involved in photosynthetic electron transfer. Thus, the site of action for triazines is the D1 protein, whereas the mode of action is the disruption of photosynthesis. An understanding of herbicide mode of action is essential for diagnosing crop injury or off-target herbicide injury problems, whereas knowledge of the site of action is needed for designing weed management programs with a low risk of selecting for herbicide-resistant weed populations.

The [Weed Science Society of America](http://wssa.net) (http://wssa.net) has developed a numerical system for identifying herbicide sites of action by assigning group numbers to the different sites of action. Certain sites of action (e.g., photosystem II inhibitors) have multiple numbers since different herbicides may bind at different locations on the target enzyme (e.g. photosystem II inhibitors) or different enzymes in the pathway may be targeted (e.g., carotenoid synthesis). The number following the herbicide class heading is the WSSA classification. Most manufacturers are including these herbicide groups on herbicide labels to aid development of herbicide resistance management strategies. Prepackage mixes will contain the herbicide group numbers of all active ingredients.

ACCase Inhibitors – 1

The ACCase enzyme is involved in the synthesis of fatty acids. Three herbicide families attack this enzyme although there are two commonly associated with this site of actin. Aryloxyphenoxypropanoate (referred to as "fops") and cyclohexanedione (referred to as "dims") herbicides are used postemergence, although some have limited soil activity (e.g., fluazifop). ACCase inhibitors are active only on grasses, and selectivity is due to differences in sensitivity at the site of action, rather than differences in absorption or metabolism of the herbicide. Most herbicides in this class are translocated within the phloem of grasses. The growing points of grasses are killed and rot within the stem. At sublethal rates, irregular bleaching of leaves or bands of chlorotic tissue may appear on affected leaves. Resistant weed biotypes have evolved following repeated applications of these herbicides. An altered target site of action and metabolism of these herbicides have been determined as responsible for the resistance.

ALS Inhibitors – 2

A number of chemical families interfere with acetolactate synthase (ALS), an enzyme involved in the synthesis of the essential branched chain amino acids (e.g., valine, leucine, and isoleucine). This enzyme is also called acetohydroxyacid synthase (AHAS). These amino acids are necessary for protein biosynthesis and plant growth. Generally, these herbicides are absorbed by both roots and foliage and are readily translocated in the xylem and phloem. The herbicides accumulate in meristematic regions of the plant and the herbicidal effects are first observed there. Symptoms include plant stunting, chlorosis (yellowing), and tissue necrosis (brown, dead tissue), and are evident 1 to 4 weeks after herbicide application, depending upon the herbicide dose, plant species and environmental conditions. Soybeans and other sensitive broad-leaf plants often develop reddish veins visible on the undersides of leaves. Symptoms in corn include reduced secondary root formation, stunted, "bottle-brush" roots, shortened internodes, and leaf malformations (chlorosis, window-pane appearance). However, symptoms typically are not distinct or consistent. Factors such as soil moisture, temperature, and soil compaction can enhance injury or can mimic the herbicide injury. Some ALS inhibiting herbicides have long soil residual properties and may carry over and injure sensitive rotational crops. Herbicide-resistant weed biotypes possessing an altered site of action have evolved after repeated applications of these herbicides. Resistance to the ALS inhibitor herbicides attributable to metabolism has also been identified in weeds. Some weed species have both target-site and metabolic resistances.

Microtubule Inhibitors – 3

Dinitroaniline (DNA) herbicides inhibit cell division by interfering with the formation of microtubules by inhibiting tubulin polymerization. Dinitroaniline herbicides are soil-applied and absorbed mainly by roots. Very little herbicide translocation in plants occurs, thus the primary herbicidal effect is on root development. Soybean injury from DNA herbicides is characterized by root pruning. Roots that do develop are typically thick and short. Hypocotyl swelling also occurs and the hypocotyl may be brittle and easily snapped at the ground level. The inhibited root growth causes tops of plants to be stunted. Corn injured by DNA carryover demonstrates root pruning and short, thick roots. Leaf margins may have a reddish color. Since DNAs are subject to little movement in the soil, such injury is often spotty due to localized concentrations of the herbicide. Early season stunting from DNA herbicides typically does not result in significant yield reductions.

Synthetic Auxins – 4

Several chemical families cause abnormal root and shoot growth by upsetting the plant hormone (i.e., auxin) balance. This is accomplished by the herbicides binding to the auxin receptor site. These herbicides are primarily effective on broadleaf species, however some monocots are also sensitive. Uptake can occur through seeds or roots with soil-applied treatments or leaves when applied postemergence. Synthetic auxins translocate throughout plants and accumulate in the active meristems. Corn injury may occur in the form of onion leafing, proliferation of roots, or abnormal brace root formation. Corn stalks may become brittle and breakage at the nodes following application is possible; this response usually lasts for 7-10 days following application. The potential for injury increases when applications are made over the top of the plants to corn larger than 10-12 inches in height. Soybean injury from synthetic auxin herbicides is characterized by cupping, strapping and crinkling of leaves. Soybeans are extremely sensitive to dicamba; however, early season injury resulting only in leaf malformation may not negatively affect yield potential depending on the dicamba exposure rate. Soybeans occasionally develop symptoms characteristic of auxin herbicides in the absence of these herbicides. This response is poorly understood but usually develops during periods of rapid growth, low temperatures or following stress from other postemergence herbicide applications. Some dicamba formulations have a high vapor pressure and may move off target due to volatilization.

Photosystem II Inhibitors – 5, 6, 7

Several families of herbicide bind to a protein involved in electron transfer in Photosystem II (PSII). These herbicides inhibit photosynthesis, which may result in inter-veinal yellowing (chlorosis) of plant leaves followed by necrosis (brown, dead) of leaf tissue. Highly reactive compounds formed due to inhibition of electron transfer cause the disruption of cell membranes and ultimately plant death. When PSII inhibitors are applied to the leaves, uptake occurs into the leaf but very little movement out of the leaf occurs. Injury to corn may occur as yellowing of leaf margins and tips followed by browning, whereas injury to soybean occurs as yellowing or burning of outer leaf margins. The entire leaf may turn yellow, but veins usually remain somewhat green (inter-veinal chlorosis). Lower leaves are first and most affected, and new leaves may be unaffected. Triazine (Group 5) and urea (Group 7) herbicides generally are absorbed both by roots and foliage, whereas benzothiadiazole (Group 6) and nitrile (Group 6) herbicides are absorbed primarily by plant foliage. Triazine-resistant biotypes of several weed species have been confirmed in Iowa following repeated use of triazine herbicides. Although the other PSII herbicides attack the same target site, they bind on a different part of the protein and remain effective against triazine-resistant weeds.Triazine resistance is due to an altered target site and examples of metabolic resistance also have been identified.

Photosystem I Inhibitors – 22

Herbicides in the bipyridilium family rapidly disrupt cell membranes, resulting in wilting, necrosis, and tissue death. They capture electrons moving through Photostystem I (PSI) and produce highly destructive secondary plant compounds. Very little translocation of bipyridilium herbicides occurs due to loss of membrane structure. Injury occurs only where the herbicide spray contacts the plant. Complete spray coverage is essential for weed control. The herbicide molecules carry strong positive charges that cause them to be very tightly adsorbed by soil colloids. Consequently, bipyridilium herbicides have no significant soil activity. Injury to crop plants from paraquat drift occurs in the form of spots of dead leaf tissue wherever spray droplets contact the leaves. Typically, slight drift injury to corn, soybeans, or ornamentals from a bipyridilium herbicide does not result in significant growth inhibition.

Protoporphyrinogen Oxidase (PPO) Inhibitors – 14

Group 14 herbicides inhibit an enzyme involved in synthesis of a precursor of chlorophyll; the enzyme is referred to as PPO. Plant death results from destruction of cell membranes due to formation of highly reactive compounds. There are several herbicide families that are classified as PPO inhibitors. Postemergence applied diphenyl ether herbicides (e.g., aciflurofen, lactofen) kill weed seedlings are contact herbicides with little translocation. Thorough plant coverage by the herbicide spray is required. Applying the herbicide prior to prolonged cool periods or during hot, humid conditions will result in significant crop injury. Injury symptoms range from speckling of foliage to necrosis of whole leaves. Under extreme situations, herbicide injury has resulted in the death of the terminal growing point, which produces short, bushy soybean plants. Most injury attributable to postemergence diphenyl ether herbicides is cosmetic and does not affect yields. The aryl triazolinones herbicides are absorbed both by roots and foliage. Susceptible plants emerging from soils treated with these herbicides turn necrotic and die shortly after exposure to light. Soybeans are most susceptible to injury if heavy rains occur when beans are cracking the soil surface.

Carotenoid Synthesis Inhibitors – 13, 27

Herbicides in these families inhibit the synthesis of the carotene pigments. Inhibition of the carotene pigments results in loss of chlorophyll and bleaching of foliage at sublethal doses. Plant death is due to disruption of cell membranes. Several different enzymes in the synthesis of carotenoids are targeted by herbicides. Clomazone (Command) inhibits DOXP (Group 13), whereas the other bleaching herbicides used in corn (Callisto, Balance Flexx, Laudis, Armezon, Impact) inhibit HPPD (Group 27). The HPPD inhibiting herbicides are xylem mobile and absorbed by both roots and leaves, they are used both preemergence and postemergence. Resistance to the Group 27 herbicides has evolved in waterhemp and is attributable to metabolism of the herbicide.

Enolpyruvyl Shikimate Phosphate Synthase (EPSPS) Inhibitors – 9

Glyphosate is a substituted amino acid (glycine) that inhibits the EPSPS enzyme. This enzyme is a component of the shikimic acid pathway, which is responsible for the synthesis of the essential aromatic amino acids and numerous other compounds. Glyphosate is nonselective and is tightly bound in soil, so little root uptake occurs under normal use patterns. Applications must be made to plant foliage. Translocation occurs out of leaves to all plant parts including underground storage organs of perennial weeds. Translocation is greatest when plants are actively growing. Injury symptoms are fairly slow in appearing. Leaves slowly wilt, turn brown, and die. Sub-lethal rates of glyphosate sometimes produce phenoxy-type symptoms with feathering of leaves (parallel veins) and proliferation of vegetative buds, or in some cases cause bleaching of foliage. Resistance to glyphosate has evolved in a number of important weed species (e.g., waterhemp, giant ragweed, horseweed/marestail Palmer amaranth). Several mechanisms have been identified that confer resistance to glyphosate in weeds.

Glutamine Synthetase Inhibitors – 10

Glufosinate (Liberty) inhibits the enzyme glutamine synthetase, known to incorporate ammonium in plants. Although glutamaine synthetase is not involved directly in photosynthesis, inhibition of this enzyme ultimately results in the disruption of photosynthesis. Glufosinate is relatively fast acting and provides effective weed control in 3-7 days. Symptoms appear as chlorotic lesions on the foliage followed by necrosis. There is limited translocation of glufosinate within plants. Glufosinate has no soil activity due to rapid degradation in the soil by microorganisms. Liberty is nonselective except to crops that carry the Liberty Link gene. To date, there are only two weed species with evolved resistance to glufosinate and resistance has not been identified in Iowa.

Fatty Acid and Lipid Synthesis Inhibitors – 8

The specific site of action for the thiocarbamate herbicides (e.g., EPTC, butylate) is unknown, but it is believed they may conjugate with acetyl coenzyme A and other molecules with a sulfhydryl moiety. Interference with these molecules results in the disruption of fatty acid and lipid biosynthesis, along with other related processes. Thiocarbamate herbicides are soil applied and require mechanical incorporation due to high volatility. Leaves of grasses injured by thiocarbamates do not unroll properly from the coleoptiles, resulting in twisting and knotting. Broadleaf plants develop cupped or crinkled leaves.

Very Long Chain Fatty Acid Synthesis Inhibitors (VLCFA) – 15

Several chemical families (acetamide, chloroacetamide, oxyacetamide, pyrazole and tetrazolinone) are reported to inhibit biosynthesis of very long chain fatty acids. VLCFA are believed to play important roles in maintaining membrane structure. These herbicides disrupt the germination of susceptible weed seeds but have little effect on emerged plants. They are most effective on annual grasses, but have activity on certain small-seeded annual broadleaves. Soybean injury occurs in the form of a shortened mid-vein in leaflets, resulting in crinkling and a heart-shaped appearance. Leaves of grasses, including corn, damaged by these herbicides fail to unfurl properly, and may emerge underground.

Auxin Transport Inhibitors – 19

Diflufenzopyr (Status) has a unique mode of action in that it inhibits the transport of auxin, a naturally occurring plant-growth regulator. Diflufenzopyr is sold only in combination with dicamba and is primarily active on broadleaf species, but it may suppress certain grasses under favorable conditions. Diflufenzopyr is primarily active through foliar uptake, but it can be absorbed from the soil for some residual activity. Injury symptoms are similar to other growth regulator herbicides. Status (dicamba + diflufenzopyr) includes a safener to improve crop safety.

ACCase inhibitor HG 1	
aryloxyphenoxy-propanoate	
Assure II, others	quizalofop-p-ethyl
Fusilade DX	fluazifop-p-butyl
Fusion	fluazifop-p-butyl + fenoxaprop
Hoelon	diclofop
cyclohexanediones	
Poast, Poast Plus	sethoxydim
Select, Section, Arrow, others	clethodim

ALS inhibitors HG 2	
imidazolinones	
Pursuit	imazethapyr
Raptor	imazamox
Scepter	imazaquin
sulfonanilides	
FirstRate, Amplify	chloransulam
Python	flumetsulam
sulfonylureas	
Accent	nicosulfuron
Ally, Cimarron	metsulfuron
Beacon	primisulfuron
Classic	chlorimuron
Express	tribenuron
Harmony GT	thifensulfuron
Permit, Halofax	halosulfuron

Microtubule inhibitor HG 3	
dinitroanilines	
Balan	benefin
Prowl H_20, Pendimax, Framework, Satellite, others	pendimethalin
Sonalan	ethalfluralin
Surflan	oryzalin
Treflan, Trust, others	trifluralin

Synthetic auxin HG 4	
benzoic	
Banvel, Clarity, DiFlexx, Xtendimax with Vapor Grip Technology, Engenia, Sterling Blue, FeXapan, others	dicamba
phenoxy	
many	MPCA
Enlist one	2,4-D choline
many	2,4-D
Butyrac, Butoxone	2,4-DB
pyridines	
Remedy Ultra, Pathfinder II, many others	triclopyr
Milestone	aminopyralid
Stinger, Transline	clopyralid
Streamline	aminocyclopyrachlor
Tordon	picloram

Photosystem II inhibitors HG 5, 6, 7	
benzothiadiazole	
Basagran, Broadlawn	bentazon
nitriles	
Buctril, others	bromoxynil
triazines	
AAtrex, atrazine, others	atrazine
Evik	ametryn
Metribuzin, Tricor	metribuzin
Princep	simazine
ureas	
Karmex	diuron
LInex, Lorox	linuron

Photosystem I inhibitors HG 22	
Diquat, Reward	diquat
Gramoxone SL, Parazone	paraquat

Protoporphyrinogen Oxidase (PPO) inhibitors HG 14	
aryl triazolinones	
Aim	carfentrazone
Authority, Spartan, others	sulfentrazone
diphenyl ethers	
Blazer, UltraBlazer	acifluorfen
Cobra, Phoenix	lactofen
ET, Vida	pyraflufen
Flexstar, Reflex	fomesafen
Goal	oxyfluorfen
phenylphthalimides	
Resource	flumiclorac
Valor, Rowel, Panther SC, others	flumioxazin
pyrimidinedione	
Sharpen (Kixor)	saflufenacil
other	
Cadet	fluthiacet

Enolpyruvyl shikimate phosphate synthase (EPSPS) inhibitors HG 9	
Roundup, others	glyphosate

Glutamine synthetase inhibitors HG 10	
Liberty, Cheetah	glufosinate

Hydroxyphenyl pyruvate dioxygenase (HPPD) inhibitors HG 27	
Balance Flexx	isoxaflutole
Callisto, others	mesotrione
Armezon/Impact	topramezone
Laudis	tembotrione
Bicyclopyrone	bicyclopyrone

Diterpene inhibitors HG 13	
Command	clomazone

Auxin transport inhibitors HG 19	
Distinct, Status	diflufenzopyr

Lipid synthesis inhibitors HG 15	
Harness, Surpass, Warrant	acetochlor
Dual II MAGNUM, Cinch, Medal, Charger Max, others	S-metolachlor, metolachlor
Frontier, Outlook, Commit, others	dimethenamid-P
Zidua	pyroxasulfone