2020 Herbicide Guide for Iowa Corn and Soybean Production

Metabolism-based Herbicide Resistance

The rapid increase of herbicide resistance across Iowa and the corn belt is a serious threat to the current production system. Several new herbicide-resistant biotypes in the weedy amaranths/pigweeds were announced within the last few years. First, Illinois reported two populations of waterhemp resistant to metolachlor and other Group 15 herbicides. This was followed by reports of 2,4-D resistance in common waterhemp in Illinois, Nebraska, and Missouri, and in Palmer amaranth in Arkansas and Kansas. The Kansas Palmer amaranth population was also resistant to dicamba. It is believed that all of these cases are due to the weeds' enhanced ability to degrade the herbicide.

Herbicide-resistance mechanisms

The traits that allow resistant weeds to survive herbicides are classified as either target site or non-target site mechanisms. Nearly all herbicide-resistant weeds found in the Midwest prior to the turn of the century possessed altered target sites (Table 1). Target site resistance is usually due to a slight change in the target site preventing the herbicide from binding to the site, therefore providing resistance. Altered target sites are the most common resistance mechanism for Group 1, 2, 5, and 14 herbicides.

Non-target site resistance involves metabolic processes not related to the target site. These processes prevent the herbicide from reaching the target site at toxic concentrations. Non-target site resistance mechanisms may involve reduced translocation or enhanced metabolism. Metabolism-based resistance (MBR) allows the herbicide to be detoxified before reaching the target-site. MBR is on the increase in the Midwest, and poses unique threats compared to other resistance mechanisms.

Basics of herbicide metabolism

Plants are exposed to a wide variety of toxic compounds, including herbicides, and have several mechanisms that protect them from these compounds. Both plants and animals utilize the same families of enzymes to degrade toxic compounds. Toxins are initially modified by enzymes to reduce their toxicity and facilitate movement. Animals modify toxins to allow the kidneys to remove the chemical from the blood, and then excrete the compound from the body via urine. Lacking an excretory system to remove toxins, plants typically isolate the modified herbicide in the cell vacuole, preventing the toxin from reaching the target site. Cytochrome P450 monooxygenase, glycosyl transferase, and glutathione S-transferase are the enzymes often involved in MBR in weed species.

Table 1. Resistance mechanism in waterhemp and date they were first reported.

Target site-based			Metabolism-based		
Group No.	Family	Year	Group No.	Family	Year
2	ALS	1993	5	triazine	2003
5	triazine	1994	4	auxinic	2009
14	PPO	2001	27	HPPD	2009
9	glyphosate	2005	15	acetamide	2016

Contents

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Herbicide metabolism is the most common selectivity mechanism for herbicides used in crop production. For example, corn is able to rapidly metabolize atrazine, whereas susceptible plants such as cocklebur and lambsquarters are very inefficient at degrading atrazine. Weed biotypes with MBR (e.g., Group 15, 27, and 2,4-D-resistant waterhemp) have an increased ability to degrade a herbicide compared to susceptible biotypes, therefore rendering the herbicide ineffective. The exact processes (e.g., difference in compounds metabolized by enzymes, differences in production of enzymes) responsible for increased metabolism in most weed biotypes is unknown at this time.

Why should we be concerned about metabolism-based resistance?

The concern with MBR is that an alteration in herbicide metabolism providing resistance to one herbicide group may provide cross-resistance to multiple herbicide groups. Target site-based resistance will only provide resistance to other herbicides with the same target site. A plant with an altered ALS enzyme (target site for Group 2 herbicides) can provide resistance to all Group 2 herbicides (Pursuit, Classic, First Rate, etc.), but other herbicide groups will not be affected by the change in the ALS enzyme. With MBR, changes in the enzymes that provide resistance to an herbicide may also provide resistance to completely unrelated herbicides. It has been said that weeds with MBR can evolve resistance to herbicides that have yet to be discovered.

The metolachlor-resistant waterhemp in Illinois and 2,4-D-resistant Palmer amaranth in Kansas were found in populations known to be resistant to Group 27 herbicides. Group 27 resistance in waterhemp is due to increased metabolism of the herbicide. It is possible, if not likely, that the genes responsible for Group 27 resistance in the recently discovered Group 4 and 15 resistant pigweed populations are also responsible for the new resistances. It is important to note that not all Group 27 resistant populations have resistance to these other herbicide groups. This is another complexity of MBR – it is impossible to predict whether the changes in metabolism that provide resistance to one herbicide group will affect other, unrelated herbicides. Each situation will need to be evaluated individually to determine the extent of cross or multiple resistance.

Conclusion

We have moved into an era where MBR will increase in importance. The potential for MBR to provide cross-resistance to multiple herbicide groups is a threat to our current production system. It is critical to develop herbicide programs that rely on multiple effective herbicide groups and provide full-season weed control, therefore minimizing weed seed production. However, herbicides alone cannot win this battle. Production systems must be evaluated to determine what alternative strategies can be used to supplement herbicides. While strategies such as increased crop competitiveness via narrow-row spacing, planting cover crops, or harvest weed seed control methods do not provide the “big impact” of herbicides, their contribution to reducing weed seed banks can make the difference between long-term success or failure in weed management, thereby preserving the utility of existing herbicide tools and new traits into the future.

New Products for Corn and Soybean

The following is a brief summary of new products or significant label changes for 2020. Since most active ingredients are off-patent there is an increasing number of proprietary brands with different tradenames. Performance of these products typically is equivalent to the original product, although differences in formulations may alter handling and mixing characteristics. For simplicity, we have chosen not to include the majority of these products in this guide.

Shieldex 400 SC from Summit Agro is a new HG 27 corn herbicide. Shieldex contains 3.33 lb. ai/gallon topyralate, providing postemergence broadleaf and grass control. It can be used on all types of corn. Use rates of 1-1.35 oz. per acre and can be applied up to the V6 stage of control.

Tavium plus Vapor Grip Technology is a new formulation of dicamba and s-metolachlor for use in dicamba-resistant soybean. The label rate of 56.5 oz. provides the equivalent of 0.5 lb. dicamba and 1.0 lb. metolachlor. It can be applied preplant, preemergence or postemergence up through the V4 stage of soybean or within 45 days of planting, whichever comes first.

New labels for **Zidua** and **Zidua SC** (BASF) containing pyroxasulfone (HG 15) herbicide allow post applications to be made to soybean up to the V6 growth stage. The previous label allowed applications only to the V3 stage, the new label gives growers a larger window to apply pyroxasulfone as a layered preemergence residual to help control late-emerging weeds in soybean.

Authority Edge from FMC contains sulfentrazone + pyroxasulfone (HG 14 + 15) and will be available for use in soybean in 2020. Authority Edge has the same active ingredients as Authority Supreme but has a higher ratio of sulfentrazone. It will be soil-applied with activity on both annual grasses and broadleaf weeds at 7-9 fl oz. per acre.

Products waiting EPA approval

Perpetuo from Valent contains pyroxasulfone + flumiclorac (HG 15 + 14) and will be labeled for annual grass and broadleaf control in soybean.

Tough 5EC from Belchim Crop Protection contains pyridate (HG 5) and is a contact broadleaf herbicide pending full EPA registration for use in corn.

Designing Resilient Herbicide Programs

For most growers, adjusting herbicide programs will be the most important strategy for 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 individual herbicides included in the program is essential in achieving success. The rate an 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 an 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, morning glories) 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 the 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% 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 their own sprayer so 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 associated costs.
- Appropriate for any weed infestation and 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.
- The addition of a Group 15 herbicide with the postemergence application can extend residual control until after the crop canopy closes. This is probably the best approach for maintaining full season control of waterhemp in soybean. The postemergence application should be applied approximately 21-28 days after planting, while the preemergence herbicide is still active.

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. In fields with heavy winter annual pressure or history of problems in managing these weeds in the spring, a fall application of an appropriate herbicide may be advantageous.

Glyphosate is the standard for burndown herbicides due to its broad-spectrum activity on annual and perennial weeds. Long-term control of most perennial weeds is reduced with pre-plant 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 pre-plant applications than amines due to the shorter half-life and lower soil availability of ester products. In soybean, applications of up to 0.5 lb. ae per acre must be applied at least seven days prior to planting. Restrictions for pre-plant applications for corn vary among labels, but an example would be seven days prior to planting for up to 0.5 lb. ae per acre and 14 days for 0.5-1.0 lb. ae per acre.

Liberty and **paraquat** are burndown options for fields where pre-plant 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 the 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 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 pre-plant 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 the seed 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. A rotational tillage may be a better strategy in those scenarios.

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. This strategy will also reduce selection pressure on postemergence herbicides from a resistance management standpoint.

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" or less reduce the time needed to achieve canopy coverage of the inter-row 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 and reduce late-season weed seed production from survivors under the canopy.

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 relatively short growing season limits the amount of biomass that a cover crop accumulates by normal planting dates. Cereal rye produces more biomass and residue than most other cover crop 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 and reduce selection pressure from sole reliance on herbicides.

Harvest weed seed control. Destroying weed seeds at crop harvest, thereby reducing the return of seeds to the weed seedbank, is an effective way of reducing herbicide selection pressure and the resultant evolution of herbicide-resistant weeds. Australians have developed several harvest weed seed control (HWSC) techniques, including chaff lining, baling of crop residues, narrow-windrow burning, and weed seed destructors (high impact cage mills) to fight multiple herbicide-resistant weeds. Research has shown that 80-95% of seeds from weeds like waterhemp are retained by the plant at soybean harvest. During harvest, weed seeds are concentrated in the chaff within the combine; therefore, placing those seeds within narrow windrows using chaff liners (a relatively inexpensive method) at the rear of the combine can prevent their spread in the field. Mechanical destruction of those seeds using high-impact mills also holds promise in mitigating herbicide-resistant weed seed banks in the Midwest corn-soybean production.

Summary

Weeds are the universal pest and every field has an economic level of weed infestation every year. The current system of large farms and narrow profit margins limits flexibility in the types of tactics and investments that can be made for 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. The first step in developing resilient weed management systems is taking the time to critically examine herbicide programs to insure multiple sites of action are controlling target weeds. However, herbicides alone cannot prevent the rapid adaptation of weeds to these crop protection tools. The production system of individual farms needs to be evaluated to determine alternative weed control tactics that are appropriate for the operation.

Acknowledgement: This article was adapted from material in the 2014 Ohio and Indiana Weed Control Guide, Ohio State University Extension, and Purdue Extension.

Corn Herbicide Effectiveness Ratings[1]

Weed response to selected herbicides E = excellent G = good F = fair P = poor			Grasses					Broadleaves									Perennials		
	Herbicide Group Number	Crop tolerance	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																			
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
Cinch, 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, Engenia, FeXapan, etc (dicamba)	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 One (2, 4-D)[3]	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
Shieldex (topyrlate)	27	G-E	F-G	P	G	P	G	E	E	F-G	G	G	G	F-G	E	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			Grasses					Broadleaves									Perennials		
	Herbicide Group Number	Crop tolerance	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)[3]	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 (acifluorfen)	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	P	P	P	P	P	G-E	G	E	G-E	E	G	E	G	F-G	G*	P	P
Enlist One (2,4-D)[3]	4	E	P	P	P	P	P	G-E	G	E	E	E	E	F-G	G-E	G-E	F-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
Roundup (Glyphosate)[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.

*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	1.31 pints Dual II MAGNUM
	5	3.1 pounds atrazine		1.63 pounds atrazine	3.25 pints 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	1.31 pints Dual II MAGNUM
	5	2.67 pounds atrazine		1.00 pound atrazine	32.0 ounces atrazine 4L
Breakfree NXT ATZ	15	4.3 pounds acetochlor	2.0 quarts	2.1 pounds acetochlor	2.4 pints Breakfree NXT
	5	1.7 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	1.8 pints Touchdown
	27	0.38 pounds mesotrione		1.52 ounces 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	1.44 ounces mesotrione	3.0 ounces Callisto
	5	3.2 pounds atrazine	ounces	0.6 pounds atrazine	1.2 pints Aatrex 4L
Capreno	2	0.57 pounds thiencarbazone	3.0 ounces	0.16 ounces thiencarbazone	NA
	27	2.88 pounds tembotrione		1.09 ounces 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 ounce Harmony SG
Degree Xtra	15	2.7 pounds acetochlor	3.0 quarts	2.0 pounds acetochlor	2.29 pints 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	1.6 pounds 2,4-D choline salt	4.75 pints	0.95 pounds ae 2,4-D	1.9 pints 2,4-D 4A
	9	1.7 pounds glyphosate DMA		1.0 pounds ae glyphosate	2.0 pints Durango DMA
Expert 4.9SC	15	1.74 pounds S-metolachlor	3.0 quarts	1.3 pounds S-metolachlor	1.4 pints 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	2.05 pounds acetochlor	2.3 pints Harness
	27	0.33 pounds mesotrione	ounces	0.188 pounds mesotrione	6.0 ounces Callisto
Harness Xtra, Confidence Xtra Keystone LA NXT	15	4.3 pounds acetochlor	2.3 quarts	2.5 pounds acetochlor	2.9 pints Harness 7E
	5	1.7 pounds atrazine		0.98 pounds atrazine	1.0 quart atrazine 4L
Harness Xtra 5.6L, Confidence Xtra 5.6 Keystone NXT	15	3.1 pounds acetochlor	3.0 quarts	2.325 pounds acetochlor	2.66 pints Harness 7E
	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
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	1.75 pints Touchdown
	15	3.0 pounds S-metolachlor		1.5 pounds S-metolachlor	1.63 pints 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	1.63 pints 2,4-D 4E
Status 56WDG	19	17.1% diflufenzopyr	5.0 ounces	0.8 ounces diflufenzopyr	0.8 ounces 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	0.57 pounds saflufenacil	14.0 ounces	0.06 ounces saflufenacil	0.17 ounces Sharpen
	15	5.0 pounds dimethenamid-P		0.55 ounces dimethenamid-P	0.73 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	0.21 pounds sulfentrazone	5.6 ounces Authority 75DF
	2	6.67% imazethapyr		0.67 ounces imazethapyr	3.4 ounces Pursuit AS
Authority Edge	14	2.73 pounds sulfentrazone	10.0 ounces	0.21 pounds sulfentrazone	5.6 ounces Authority 75DF
	15	1.52 pounds pyroxasulfone		0.12 pounds pyroxasulfone	2.3 ounces Zidua
Authority Elite, BroadAxe XC	14	0.7 pounds sulfentrazone	25.0 ounces	0.14 pounds sulfentrazone	0.19 pounds Authority 75DF
	15	6.3 pounds S-metolachlor		1.23 pounds S-metolachlor	0.16 gallons Dual II MAG-NUM
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 Supreme	14	20.66% sulfentrazone	10 ounces	0.13 pounds sulfentrazone	0.17 pounds Authority 75DF
	15	20.66% pyroxasulfone		0.13 pounds pyroxasulfone	2.4 ounces Zidual
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	1.81 pints Liberty
	14	1.0 pound fomesafen		0.27 pounds fomesafen	1.13 pints 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	1.63 pints 2,4-D 4A
	9	1.7 pounds ae glyphosate		0.85 pounds ae glyphosate	1.5 pints 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

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)
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	4.0 ounces Pursuit DG
	9	22.0% glyphosate		0.75 pounds glyphosate	1.5 pints Roundup
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	1.0 pint Flexstar
	9	2.26 pounds glyphosate		1.0 pound glyphosate	1.63 pints Touchdown HiTech
Fusion 2.67E	1	2.0 pounds fluazifop	8.0 fluid ounces	0.125 pounds fluazifop	8.0 fluid ounces Fusilade DX 2E
	1	0.67 pounds fenoxaprop		0.67 ounces 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 ounce 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

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)
Pummel	15	5.0 pounds metolachlor	2.0 pints	1.25 pounds metolachlor	1.2 pints Stalwart
	2	0.25 pounds imazethapyr		1.0 ounce 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
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	1.63 pints Touchdown
Sonic	14	6.21% sulfentrazone	8.0 ounces	0.361 pounds sulfentrazone	6.6 ounces Authority 75DF
	2	7.96% cloransulam-methyl		0.64 ounces 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
Tavium plus VGT	4	1.12 pounds dicamba a.e.	56.5 fluid	0.5 pounds dicamba	22.0 ounces Xtendimax with VGT
	15	2.26 pounds s-metolachlor	ounces	1.0 pounds s-metolachlor	1.0 pints Dual Magnum
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

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)
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		0.64 ounces 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)

Group No.	Site of Action (mode of action)
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/ Xtendimax/Engenia	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

Tradename	Herbicide Group No.	Active Ingredient
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
Shieldex	27	topryalate
Sonalan	3	ethalfluralin
Spartan/Authority	14	sulfentrazone
Stinger	4	clopyralid
Tough	6	pyridate
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 Edge/ Authority Extreme	14, 15	sulfentrazone, pyroxasulfone
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
Perpetuo	14, 15	flumiclorac, pyroxasulfone
Permit Plus	2, 2	halosulfuron, thifensulfuron
Prefix	14, 15	fomesafen, S-metolachlor
Presidual	5, 15	metribuzin, S-metolachlor

Tradename	Herbicide Group No.	Active Ingredients
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
Tavium plus VGT	4, 15	dicamba, s-metolochlor
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) 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