

2016 Herbicide Guide for Iowa Corn and Soybean Production

Weed Management Update for 2016

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Introduction

Many issues from the past continue to be problems. Herbicide resistance continues to evolve, diversity of weed management tactics is slowly changing, and herbicides that attach to new and novel sites of action in weeds have yet to be developed.

However, there are some perspectives that are favorable; notably an increase in the use of soil-applied herbicides that provide residual control, and the occasional sighting of a row-crop cultivator in 2015.

The problem is, in my opinion, overcoming complacency. Generally, weed management is considered “OK” across the state, and areas with Palmer amaranth have not worsened, based on the yearly road trip survey. Certainly the number of soybean fields with weeds visible above the canopy prior to harvest is increasing, but overall, there has not been a notable increase across the state in major weed management failures.

However, it is noteworthy that random surveys suggest that a high percentage of fields with weeds visible above the soybean canopy have evolved resistance to one or more herbicides. It is important to recognize that questions concerning waterhemp not responding to Group 14 (PPO)

and Group 27 (HPPD) herbicides continue to increase. Given the high use of Group 14 herbicides and the prevalence of Group 27 herbicides in seed corn production, this increase in suspected and known resistant populations is not surprising.

Overall, herbicide-resistant weed populations are slowly increasing. The conservation tillage treatments, which are commonly used in the fall and immediately prior to planting, are similar to a “reset” button that serves to dilute the annual weed seed rain and slow the annual growth in weed population density. However, once the weed seed bank achieves a level of seeds that allows the population curve to move from additive to exponential, weed population densities across the state may become unmanageable.

Most Iowa fields currently have manageable weed population densities, but how much longer that will be the case, remains to be seen. Now is the time to make adjustments in weed management programs. This includes incorporating as much diversity beyond herbicides as possible, while also paying particular attention to which herbicides are included in the program and how

and when they are used. There are no new herbicides with novel sites of action available now or in the foreseeable future.

Selected Industry Updates

BASF

New for 2016 from BASF is Armezon Pro herbicide for corn (field, sweet, seed corn, and popcorn). Armezon Pro is an EC formulation containing topramezone (Group 27) and dimethenamid-P (Group 15) (see Herbicide Package Mixes table). Armezon Pro may be applied from corn emergence up to V8 stage or 30-inch tall corn (12-inches tall for sweet corn) and provides burndown and residual control of some annual broadleaf and grass weeds. Use rate range is from 14 to 24 ounces per acre, depending on soil texture and organic matter.

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BAYER CROP SCIENCE

DiFlexx was registered for field, white, seed, and popcorn last spring and is a dicamba (Group 4) formulation with the safener, cyprosulfamide. DiFlexx is registered as preplant burndown, preemergence, and postemergence application in corn without any planting restrictions because of the safener included in the formulation. Postemergence applications can be made to corn up to the V10 stage of development. Observe the DiFlexx label recommendations for adjuvants. Use 8 to 16 oz/A with a seasonal maximum of 32 oz/A total.

Capreno (Groups 2 and 27) is now registered to be applied to V7 corn stage. Apply Capreno to field corn, silage and white corn from emergence to 20 inches tall. Do not apply corn is taller than 20 inches or has seven or more leaf collars, whichever is more restrictive. MSO was also added as an adjuvant choice.

All Bayer Crop Science labels will include new pest resistance management language. The language is generally more detailed and reflects the need to diversify weed management tactics. In addition to closely managing the weed seed bank, scouting, controlling weed escapes, rotation of crops and herbicide-tolerant traits, and herbicide sites of action are emphasized.

DuPONT

DuPont received registration approval from the U.S. Environmental Protection Agency (EPA), Revulin Q herbicide (Groups 2 and 27) early

in the first quarter of 2015. Revulin Q is a premixture of dry mesotrione, nicosulfuron, and a safener. Revulin Q is labeled for postemergence grass and broadleaf weed control in numerous types of corn including field corn grown for grain, silage or seed, yellow popcorn, and sweet corn.

Cinch herbicide (Group 15) can now be applied as part of a sequential soybean weed control program. If Cinch was applied as a preplant surface, preplant incorporated, or a preemergence treatment, a second treatment of Cinch can be applied postemergence provided that the total rate during any one crop does not exceed 2.5 pts./A. No more than 1.33 pts./A of Cinch can be applied postemergence, and the total Cinch rate applied preplant, preemergence, or postemergence to soybeans during any one crop should not exceed 2.5 pts./A (2.4 lbs. a.i./A of S-metolachlor). Postemergence applications must be made at least 90 days before harvest. Cinch does not provide any control of emerged weeds.

FMC

Anthem Maxx is a premixture of fluthiacet-methyl (Group 14) and pyroxasulfone (Group 15) and replaces Anthem. Anthem Maxx has 4.3 lbs a.i./gallon which is twice the a.i. that was in Anthem. The rates of application for Anthem Maxx will be one-half of the rates for Anthem. Anthem Maxx is registered for preplant burndown, preemergence, preplant incorporated, and postemergence application in field corn, sweetcorn, popcorn, and soybeans. Postemergence applications in corn should be

made through the V4 stage of corn development, and through the V3 leaf stages in soybeans. Weeds should be small and actively growing. Observe application restrictions listed on the Anthem Maxx label.

MONSANTO

Warrant Ultra is a premixture of encapsulated acetochlor (Group 15) and fomesafen (Group 14). This product can be applied preemergence and postemergence before soybeans reach growth stage R2, and will provide control of many annual grass and broadleaf weeds. The encapsulation of the acetochlor provides a slow release of the herbicide and increases the potential for the herbicide to remain effective for a longer period of time.

Warrant can now be applied to corn postemergence for extended residual control of some annual grass and broadleaf weeds. Warrant does not have any activity on weeds that have emerged at the time of application.

SYNGENTA

Syngenta introduced Acuron herbicide for control of annual grass and broadleaf weeds in field corn, seed corn, silage corn, sweet corn, and yellow popcorn. Acuron is a premixture of S-metolachlor (Group 15), atrazine (Group 5), mesotrione (Group 27), and bicyclopyrone (Group 27). Acuron can be applied preemergence in all corn types listed. Acuron may also be applied early postemergence in field, seed, and silage corn, but not to emerged sweet corn or yellow popcorn because of potential severe crop injury. Acuron may also be applied in split application. Postemergence applications must be made before the corn is 12 inches in height.

Most of the Syngenta proprietary herbicides the now have the herbicide group numbers indicated and revised resistance management language included in the label. Flexstar and Flexstar GT labels now include an adjuvant statement that requires adjuvant products to meet the standards of the Chemical Producers and Distributors Association certification program.

VALENT

Valent has a new premixture Fierce XLT registered for use in soybeans. Fierce XLT includes chlorimuron (Group 2), flumioxazin (Group 14), and pyroxasulfone (Group 15) and can be applied as an early preplant, preplant, or preemergence application. Preemergence applications must be made within three days after planting and prior to soybean emergence. Applications of Fierce XLT after soybeans have begun to crack or are emerged will result in severe injury. Do not apply Fierce XLT on soils with a composite pH of greater than 7.6. Do not perform any tillage operation after application or residual weed control will be reduced.

New Herbicide-Resistant Crops

DOW AGROSCIENCE

Dow continues to move forward with plans to market the Enlist corn and soybeans but are waiting on deregulation by China before full commercial availability. Enlist crops are tolerant to 2,4-D (Group 4) and glyphosate (Group 9). Enlist corn is available to a select group of farmers who can meet the stringent stewardship program developed by Dow. Enlist soybean are available only for seed production.

BASF

Dicamba-tolerant soybean cultivars are deregulated in the United States, but not yet in China. Furthermore, the herbicide that will be registered for application to the dicamba-tolerant soybean (Engenia [a low volatility formulation of dicamba]) is pending registration with the EPA. Engenia is a Group 4 herbicide.

MONSANTO

Monsanto reports that soybean cultivars with tolerance to dicamba (Group 4) are deregulated in the United States, but not yet in China. Furthermore, the herbicides that will be registered for application to the dicamba-tolerant soybeans (Roundup Xtend [a premixture of glyphosate (Group 9) and dicamba with anti-vapor drift component] and ExtendiMax [dicamba with anti-vapor drift component]) are waiting on EPA registration.

If China deregulates these genetically-engineered crop cultivars at the next opportunity (November), and if EPA follows quickly with registration of the dicamba-based herbicides, it is possible that these crop/herbicide “systems” may be commercially available in 2016. However, there is much speculation and many dominos that must fall in a timely fashion. Regardless, the new “systems” will provide many opportunities and challenges for growers and applicators if they are to be used safely and effectively. Following the stewardship requirements as stated by the companies will be paramount to the success of the technologies.

BAYER CROP SCIENCE

Bayer Crop Science continues to move forward with the Balance GT soybean that has tolerance to the Group 27 herbicide isoxaflutole, a potent HPPD inhibitor, and is

resistant to glyphosate. Pending approval in China, a 2017 commercial launch is anticipated.

SYNGENTA

Syngenta anticipates that the soybean cultivars with tolerance to mesotrione, a Group 27 herbicide, will be available in the latter part of this decade. The soybean cultivars will allow the preemergence application of mesotrione for control of important annual broadleaf weeds.

Marestail/Horseweed Management

Marestail, also known as horseweed (*Conyza canadensis*), is one of the more troublesome weeds in no-tillage crop production systems. As a seedling or small rosette, there are many soil-applied herbicides that have activity on marestail, however, burndown activity is the primary concern of most farmers who use no-tillage production systems. While marestail is described as a winter annual weed, most of the marestail in Iowa behaves more like a spring annual weed with germination in April and May. Also, after marestail “bolts” (changes from the rosette stage of development to flowering), it becomes extremely difficult to control with any postemergence herbicide application.

Adding to the difficulty of managing this weed with herbicides, populations have evolved resistance to herbicides and multiple-resistant populations have been identified. Marestail populations with resistance to glyphosate (Group 9) and ALS inhibitor herbicides (Group 2) are common in Iowa. While not reported in Iowa, marestail populations with resistance to atrazine (Group 5) have been identified. Given the prevalence of atrazine use in Iowa, the likelihood of atrazine-resistant marestail in the state is high.

Herbicides that are effective postemergence burndown applications include the auxin herbicides (Group 4), consisting of Banvel, Clarity, Status, and 2,4-D, which provide good control of small rosette-stage marestail. In addition, atrazine (Group 5) also works well on small marestail. Similarly, glyphosate (Group 9) is effective on small rosette-stage marestail, although populations with evolved resistance to glyphosate are common in Iowa. The Group 14 herbicides—Sharpen (saflufenacil), Optill (saflufenacil + imazethapyr) (Groups 2 and 14), and Verdict (saflufenacil + dimethenamid) (Groups 14 and 15)—can be effective as a burndown treatment on small rosette-stage marestail.

Tillage is an effective tactic to control marestail. If the marestail populations are high, it may be good to consider tilling the fields in order to lessen the ecological advantage that marestail has in a no-tillage crop production system. One tillage trip may be sufficient to significantly reduce the marestail populations and allow the resumption of no-tillage systems.

Palmer Amaranth

There were no new infestations of Palmer amaranth discovered in 2015. Some of the previously identified fields have been managed effectively, but others have not. It is important to remain vigilant and continue to scout for suspected infestations of Palmer amaranth, particularly in southeastern, southern, and southwestern Iowa counties; given the proximity to states with serious Palmer amaranth problems.

Conclusions

Weeds continue to remain the most important pest complex in Iowa crop production, and resistance to herbicides continues to be a significant problem that impacts effective weed management. There will not be any new herbicides with novel sites of action in the foreseeable future, and while the availability of new crop cultivars with tolerance to herbicides (e.g., Group 4) will provide farmers with options, it will be important to set expectations appropriately. These products have some benefits to provide, but also have risks that must be considered. These risks include,

but are not limited to, drift and spray tank and nurse tank contamination. It will be important to follow all of the stewardship precautions put forward by companies to minimize the issues that may occur with the new technologies.

Another consideration for the future is grower organized and managed community-based weed management programs. Community-based efforts have demonstrated considerable success in addressing significant problems (i.e., boll weevil in cotton and soil conservation/water quality), and it is suggested that weed management, particularly herbicide-resistant weed management, may benefit from a community-based efforts.

Designing Resilient Herbicide Programs

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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 the individual herbicides included in the program is essential in achieving success. The herbicide application rate is critical in determining its effectiveness, and ensuring 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, 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. Narrow row spacing provides more rapid canopy closure, reducing length of residual control needed.
- Not appropriate for fields with high weed densities, significant populations of large-seeded broadleaves (e.g., giant ragweed, cocklebur, and 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 the need for extended longevity of control due to slow emergence, reducing likelihood of success. There is a 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 to reduce the need for timely rainfall. The remainder is applied at, or shortly after, planting. This strategy can extend the activity of the herbicide later into the season than if all of it 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 are typically used for total post programs. The introduction of Roundup Ready crops led to the popularity of sequential applications, made two to three 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 five to seven 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

residual herbicides (e.g., Warrant and 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 of weeds being present when the crop emerges, as a result of weather or other factors. The type of strategy used is dictated largely by the presence of winter annual and perennial weeds.

Glyphosate is the standard for burndown herbicides because of 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 kill 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 maretail (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 maretail, giant ragweed, and mustards. While 2,4-D has limited soil activity, 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 lb. ae/A of an ester must be applied at least seven days prior to planting, whereas the restriction is 15 days for an amine formulation. Restrictions for preplant applications for corn vary among labels, but an example would be seven days prior to planting for up to 0.5 lb. ae/A and 14 days for 0.5-1.0 lb. ae/A.

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, 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) works well on small maretail. It may be substituted for 2,4-D in burndown programs, where delayed planting following the burndown application is not preferred.

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 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. Burying seed within the profile will put them into 'long-term storage' until the next tillage operation brings them back to the upper inch of the soil profile.

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 efficacy. 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.

Narrow-row spacing

The best weed control tactic is a competitive crop canopy. Row spacing of 15" 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/A at harvest 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, our relatively

short growing season limits the amount of biomass that a cover crop accumulates by normal planting dates. This limits weed suppression provided by the cover crop when planting dates for optimum crop yields are desired.

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 types of tactics and dollars that can be invested in weed management. It also makes it difficult to factor in long-term weed management considerations such as herbicide resistance. However, the rate of herbicide resistance evolution is increasing in Iowa, and 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 resilient weed management programs. This will provide effective control and protect the value of the herbicides our systems rely on.

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

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	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 NXT, etc	15	E	E	E	E	F-G	F-G	G	G	P	P	P	P-F	P-F	P	P	P	P	G
Callisto	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, etc	15	E	E	E	E	F	F	F-G	G	P	P	P	P	P	P	P	P	P	G
Hornet WDG	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	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, etc	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	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 (Kixor)	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	2	G-E	P	G	G-E	G-E	E	G	P	F	P	P	P	G	P	F	F	G	F
Aim	14	G	P	P	P	P	P	F-G	G	P	P	F	G	P	P	E	P	P	P
Armezon, Impact	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	6	E	P	P	P	P	P	P	P	E	E	F	P	E	G	G-E	G*	P	G*
Basis, Basis Blend	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, etc.	4	F-G	P	P	P	P	P	G-E	G	E	G-E	E	G	E	G	F-G	G*	P	P
Beacon	2	G	P	F-G	P-F	P	E	E	G	G	G	E	P	G	G	F-G	F-G*	G	F
Buctril	6	G	P	P	P	P	P	G	G-E	E	E	G	G-E	G-E	E	G	P	P	P
Callisto	27	G-E	P	P	P	P	P	E	E	G-E	F	G	G	E	G-E	E	P	P	P
Glyphosate (Roundup, Touchdown, 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	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	10	E	E	G	G-E	E	E	G	E	E	E	G	G	E	E	E	F-G	G	P
Laudis	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
NorthStar	2, 4	G	P	F-G	F	P	E	F-G	G	E	E	E	G	E	E	G	F-G	G	F
Permit, Halomax, etc.	2	G	P	P	P	P	P	E	P	G-E	G-E	G	P	G-E	E	E	P	P	G
Resolve	2	F	F	F-G	G	F	G	G	P	F	F	P	G-E	G	P	F-G	F	G	F
Resource	14	G-E	P	P	P	P	P	G	P	F	F-G	P	F	P	P	E	P	P	P
Status	4, 19	F-G	P	F	F	P	F	G-E	G	E	G-E	G	G	E	G	G	G*	P	P
Yukon	2, 4	F-G	P	P	P	P	P	G	G	G-E	G-E	G	G	G-E	E	E	P	P	G

¹ Ratings are based on full label rates. **Premix products containing ingredients marketed as single a.i. products may not be listed in this table.**

² ALS-resistant biotypes of these weeds have been identified in Iowa. These biotypes may not be controlled by all ALS herbicides.

³ Use only on designated resistant hybrids.

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 identified 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

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	14	G	P-F	P	P-F	P	P	E	E	F	F	F	G-E	F	P	F-G	P	P	F-G
Cinch, Dual II Magnum, Frontier, Warrant, Zidua, etc.	15	E	E	E	E	F	F	F-G	G	P	P	P	P	P	P	P	P	P	P
Command	13	E	G-E	G-E	E	F	F	P	F	F	G	P	G-E	G	F	E	P	P	P
FirstRate/Amplify	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	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
Pendimax, Prowl, Sonalan, Treflan, etc	3	G-E	E	E	E	E	G-E	G	P	P	P	P	G	F	P	P	P	P	P
Pursuit	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	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	14	G	P	P	P	P	P	F	F	F	F	F	F	F	F	F	P	P	P
Valor SX, Rowel	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, etc.	1	E	E	E	E	E	E	P	P	P	P	P	P	P	P	P	P	G-E*	P
Basagran	6	E	P	P	P	P	P	P-F	P-F	E	E	F	P	E	G	G-E	G*	P	G*
Blazer	14	F-G	P	P	F	P	F	E	G	F	G	F	F	E	F	F	F	P	P
Classic	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	14	F-G	F	P	P	P	P	E	G	G-E	E	F-G	F	G	G	F	F	P	P
FirstRate/Amplify	2	G	P	P	P	P	P	P	P	G-E	E	E	P	G	E	G	P	P	P
Glyphosate (Roundup, Touchdown) 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	2	F	P	P	P	P	P	E	P	F	F	P	G-E	G-E	G-E	G	P	P	P
Liberty ³	10	E	E	G	G-E	E	E	G	E	E	E	G	G	E	E	E	F-G	G	F
Pursuit	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	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, Rumble, Dawn, Rhythm	14	F-G	P	P	P	P	P	E	F-G	F	G	G	F	G-E	F	F	P-F	P	P
Resource	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 a.i. 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 identified 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

Herbicide	A.I.	Rate/A	Beef and Non-Lactating Animals			Lactating Dairy Animals	
			Grazing	Hay harvest	Removal before slaughter	Grazing	Hay harvest
Clarity and many others	dicamba	Up to 1 pt	0	0	30 days	7 days	37 days
		1 - 2 pt	0	0	30 days	21 days	51 days
		2 - 4 pt	0	0	30 days	40 days	70 days
		4 - 16 pt	0	0	30 days	60 days	90 days
Chaparral	aminopyralid + metsulfuron methyl	1 - 3.3 oz	0	0	0	0	0
Cimarron Max (co-pack)	metsulfuron methyl + dicamba + 2,4-D	0.25-1 oz A + 1-4 pt B	0	0	30 days	7 days	37 days
Cimarron X-Tra	metsulfuron methyl + chlorsulfuron	0.1 - 1.0 oz	0	0	0	0	0
Crossbow	triclopyr + 2,4-D	1 - 6 qt	0	14 days	3 days	Growing season	Growing season
Escort XP	metsulfuron methyl	Up to 1.7 oz	0	0	0	0	0
ForeFront HL	aminopyralid + 2,4-D	1.2 - 2.1 pt	0	7 days	0	0	7 days
Grazon P&D	picloram + 2,4-D	3 - 4 pt	0	30 days	3 days	7 days	30 days
Milestone	aminopyralid	3 - 7 oz	0	0	0	0	0
Overdrive	dicamba + diflufenzopyr	4 - 8 oz	0	0	0	0	0
PastureGard HL	triclopyr + fluroxypyr	1 - 1.5 pt	0	14 days	3 days	1 year	1 year
Rave	dicamba + triasulfuron	2 - 5 oz	0	37 days	30 days	7 days	37 days
Redeem R&P	triclopyr + clopyralid	1.5 - 4 pt	0	14 days	3 days	Growing season	Growing season
Remedy Ultra	triclopyr	1 - 2 qt	0	14 days	3 days	Growing season	Growing season
Surmount	picloram + fluroxypyr	1.5 - 6 pts	0	7	3	14	7
Tordon 22K	picloram	< 2 pts	0	0	3	14	14
		> 2 pts	0	14	3	14	14
Weedmaster	dicamba + 2,4-D	1-4 pts	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 (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Acuron	15	2.14 lb S-metolachlor	3 qt	1.6 lb S-metolachlor	27 oz Dual II Magnum
	5	1.0 lb atrazine		0.75 lb atrazine	1.5 pt atrazine 4L
	27	0.24 mesotrione		0.18 lb mesotrione	5.8 oz Callisto
	27	0.06 lb bicyclopyrone		0.045 lb bicyclopyrone	N/A
Alluvex WSG	2	16.7% rimsulfuron	1.5 oz	0.25 oz rimsulfuron	0.5 oz Harmony SG
	2	16.7% thifensulfuron		0.25 oz thifensulfuron	1.0 oz Resolve SG
Anthem	15	2.087 lb pyroxasulfone	10 oz	0.16 lb pyroxasulfone	3.0 oz Zidua
	14	0.063 lb fluthiacet-methyl		0.005 lb fluthiacet-methyl	0.7 oz Cadet
Anthem Maxx	15	4.174 lb pyroxasulfone	5 oz	0.16 oz pyroxasulfone	3.0 oz Zidua
	14	0.126 lb fluthiacet-methyl		0.005 lb fluthiacet	0.7 oz Cadet
Anthem ATZ	5	4 lb atrazine	2 pt	1 lb atrazine	2 pt atrazine 4L
	15	0.485 lb pyroxasulfone		0.12 lb pyroxasulfone	2.25 oz Zidua
	14	0.014 lb fluthiacet		0.004 lb fluthiacet	0.6 oz Cadet
Armezon Pro	15	5.25 lb dimethenamid-P	20 oz	0.82 lb dimethenamid-P	17.5 oz Outlook
	27	0.1 lb topramezone		0.016 lb topramezone	0.73 oz Armezon
Basis Blend	2	20% rimsulfuron	0.825 oz	0.167 oz rimsulfuron	0.67 Resolve
	2	10% thifensulfuron		0.083 oz thifensulfuron	0.16 oz Harmony
Bicep II MAGNUM, Cinch ATZ, Medal II AT	15	2.4 lb S-metolachlor	2.1 qt	1.26 lb S-metolachlor	21 oz Dual II MAGNUM
	5	3.1 lb atrazine		1.63 lb atrazine	52 oz Aatrex 4L
Bicep Lite II MAGNUM, Cinch ATZ Lite	15	3.33 lb S-metolachlor	1.5 qt	1.25 lb S-metolachlor	21 oz Dual II MAGNUM
	5	2.67 lb atrazine		1.00 lb atrazine	32 oz atrazine 4L
Breakfree NXT ATZ	15	3.1 lb acetochlor	2.7 qt	2.1 lb acetochlor	2.4 pt Breakfree NXT
	5	2.5 lb atrazine		1.7 lb atrazine	3.4 pt atrazine 4L
Breakfree NXT Lite	15	4.3 lb acetochlor	2.0 qt	2.2 lb acetochlor	2.5 pt Breakfree NXT
	5	1.7 lb atrazine		0.85 lb atrazine	1.7 pt atrazine 4L
Callisto GT	9	3.8 lb glyphosate	2 pt	0.95 lb glyphosate	1.8 pt Touchdown
	27	0.38 lb mesotrione		0.095 lb mesotrione	3.04 oz Callisto

Corn Herbicide Package Mixes (continued)

Herbicide	Group	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Callisto Xtra	27	0.5 lb mesotrione	24 fl oz	0.09 lb mesotrione	3.0 oz Callisto
	5	3.2 lb atrazine		0.6 lb atrazine	1.2 pt Aatrex 4L
Capreno	2	0.57 lb thiencazabone	3.0 oz	0.01 lb thiencazabone	-
	27	2.88 lb tembotrione		0.068 lb tembotrione	2.5 oz Laudis
Corvus	27	1.88 lb isoxaflutole	5.6 oz	1.3 oz isoxaflutole	5.1 oz Balance Flexx
	2	0.75 lb thiencazabone		0.5 oz thiencazabone	
Crusher 50 WDF	2	25% rimsulfuron	1 oz	0.25 oz rimsulfuron	1 oz Resolve SG
	2	25% thifensulfuron		0.25 oz thifensulfuron	0.5 oz Harmony SG
Degree Xtra	15	2.7 lb acetochlor	3 qt	2 lb acetochlor	36.6 oz Harness 7E
	5	1.34 lb atrazine		1 lb atrazine	1 qt atrazine 4L
Distinct 70WDG	19	21.4% diflufenzopyr	6 oz	1.3 oz diflufenzopyr	1.3 oz diflufenzopyr
	4	55.0% dicamba		3.3 oz dicamba	6 oz Banvel
Enlist Duo	4	24.4% 2,4-D choline salt	4.75 pt	0.95 lb ae 2,4-D	30.4 oz 2,4-D 4A
	9	22.1% glyphosate DMA		1.0 lb ae glyphosate	32 oz Durango DMA
Expert 4.9SC	15	1.74 lb S-metolachlor	3 qt	1.3 lb S-metolachlor	1.4 lb Dual II Mag.
	5	2.14 lb atrazine		1.61 lb atrazine	1.6 qt Aatrex 4L
	9	0.74 lb ae glyphosate		0.55 lb ae glyphosate	1.5 pt Glyphosate 3L
Fierce	14	33.5% flumioxazin	3 oz	1 oz flumioxazin	2 oz Valor
	15	42.5% pyroxaulfone		1.28 oz pyroxaulfone	1.5 oz Zidua
FulTime NXT	15	2.7 lb acetochlor	3 qt	2.0 lb acetochlor	2.5 pt Surpass 6.4EC
	5	1.34 lb atrazine		1.0 lb atrazine	2.0 pt atrazine 4L
Hallex GT	15	2.09 lb S-metolachlor	3.6 pt	0.94 lb S-metolachlor	1.0 pt Dual II Magnum
	27	0.209 lb mesotrione		0.09 lb mesotrione	3.0 oz Callisto
	9	2.09 lb glyphosate		0.94 lb glyphosate ae	24 oz Touchdown HiTech
Harness Xtra, Keystone LA NXT	15	4.3 lb acetochlor	2.3 qt	2.5 lb acetochlor	2.9 pt Harness 7E
	5	1.7 lb atrazine		0.98 lb atrazine	1 qt atrazine 4L
Harness Xtra 5.6L , Keystone NXT	15	3.1 lb acetochlor	3 qt	2.325 lb acetochlor	42.5 oz Harness 7E
	5	2.5 lb atrazine		1.875 lb atrazine	1.9 qt atrazine 4L
Hornet WDG	2	18.5% flumetsulam	5 oz	0.924 oz flumetsulam	1.15 oz Python WDG
	4	60% clopyralid		0.195 lb clopyralid	6.68 oz Stinger 3S

Corn Herbicide Package Mixes (continued)

Herbicide	Group	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Integrity	14	6.24% saflufenacil	13 oz	0.058 lb saflufenacil	2.6 oz Sharpen
	15	55.04% dimethenamid		0.5 lb dimethenamid	10.9 oz Outlook
Instigate	2	4.17% rimsulfuron	6.0 oz	0.25 oz rimsulfuron	1.5 oz Resolve
	27	41.67% mesotrione		2.5 oz mesotrione	5 oz Callisto
Lexar EZ	15	1.74 lb S-metolachlor	3.5 qt	1.52 lb S-metolachlor	1.6 pt Dual II Mag.
	5	1.74 lb atrazine		1.52 lb atrazine	3 pt Aatrex 4L
	27	0.224 lb mesotrione		0.196 lb mesotrione	6.27 oz Callisto
Lumax EZ	27	0.268 lb mesotrione	3 qts	0.2 lb mesotrione	6.4 oz Callisto
	15	2.68 lb S-metolachlor		2.0 lb S-metolachlor	2 pt Dual II MAGNUM
	5	1.0 lb atrazine		0.75 lb atrazine	0.75 qt Aatrex 4L
NorthStar	2	7.5% primisulfuron	5.0 oz	0.375 oz primisulfuron	0.5 oz Beacon 75SG
	4	43.9% dicamba		2.20 oz dicamba	4.0 oz Banvel 4L
Optill	14	17.8% saflufenacil	2 oz	0.35 oz saflufenacil	1 oz Sharpen
	2	50.2% imazethapyr		1 oz imazethapyr	4 oz Pursuit
Panoflex 50 WSG	2	40% tribenuron	0.5 oz	0.2 oz tribenuron	0.2 oz tribenuron
	2	10% thifensulfuron		0.05 oz thifensulfuron	0.1 oz Harmony SG
Prequel 45% DF	2	15% rimsulfuron	2 oz	0.3 oz rimsulfuron	1.2 oz Resolve SG
	27	30% isoxaflutole		0.59 oz isoxaflutole	1.2 oz Balance Pro
Priority	14	12.3% carfentrazone	1.0 oz	0.008 lb carfentrazone	0.5 oz Aim
	2	50% halosulfuron		0.032 lb halosulfuron	0.68 oz Permit
Realm Q	2	7.5% rimsulfuron	4 oz	0.3 oz rimsulfuron	1.2 oz Resolve SG
	27	31.25% mesotrione		1.25 oz mesotrione	2.5 oz Callisto
Resolve Q	2	18.4% rimsulfuron	1.25 oz	0.23 oz rimsulfuron	0.9 oz Resolve DF
	2	4.0% thifensulfuron		0.05 oz thifensulfuron	0.1 oz Harmony SG
Revolin Q	27	36.8% mesotrione	4 oz	1.5 oz mesotrione	3 oz Callisto
	2	14.4% nicosulfuron		0.58 oz nicosulfuron	1.1 oz Accent Q
Sequence	9	2.25 lbs glyphosate	4 qt	1.12 lbs glyphosate	28 oz Touchdown
	15	3 lbs S-metolachlor		1.5 lbs S-metolachlor	26 oz Dual II MAGNUM
Solstice	27	3.78 lb mesotrione	3.15 oz	0.093 lb mesotrione	3 oz Callisto
	14	0.22 lb fluthiacet-methyl		0.0053 lb fluthiacet-m	0.75 oz Cadet

Corn Herbicide Package Mixes (continued)

Herbicide	Group	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Spirit 57WG	2	14.25% prosulfuron	1 oz	0.1425 oz prosulfuron	0.25 oz Peak 57WG
	2	42.75% primisulfuron		0.4275 oz primisulfuron	0.57 oz Beacon 75SG
Spitfire	4	0.5 lb dicamba acid	2 pt	0.12 lb ae dicamba	3.8 oz Banvel
	4	3.07 lb ae 2,4-D ester		0.77 lb ae 2,4-D	26 oz 2,4-D 4E
Status 56WDG	19	17.1 % diflufenzopyr	5 oz	0.05 oz diflufenzopyr	0.05 oz diflufenzopyr
	4	44% dicamba		0.125 oz dicamba	4 oz Banvel
Steadfast Q	2	25.2% nicosulfuron	1.5 oz	0.37 oz nicosulfuron	0.68 oz Accent Q
	2	12.5% rimsulfuron		0.19 oz rimsulfuron	0.76 oz Resolve DF
Surestart II/Tripleflex II	15	3.75 lb acetochlor	2.0 pt	0.94 lb acetochlor	1.2 pt Surpass 6.4E
	4	0.38 lb clopyralid		1.5 oz clopyralid	4.1 oz Stinger 3S
	2	0.12 lb flumetsulam		0.48 oz flumetsulam	0.6 oz Python WDG
Verdict	14	6.24% saflufenacil	14 oz	0.992 oz saflufenacil	2.8 oz Sharpen
	15	55.04% dimethenamid-P		0.547 lb dimethenamid-P	11.7 oz Outlook
WideMatch 1.5EC	4	0.75 lb fluroxypyr	1.3 pt	0.125 lb fluroxypyr	10.6 oz Starane 1.5E
	4	0.75 lb clopyralid		0.125 lb clopyralid	5.3 oz Stinger 3S
Yukon	2	12.5% halosulfuron	4 oz	0.031 lb halosulfuron	0.66 oz Permit
	4	55% dicamba		0.125 lb dicamba	4.0 oz Banvel
Zemax	15	3.34 lb S-metolachlor	2 qt	1.67 lb S-metolachlor	1.7 pt Dual II Magnum
	27	0.33 lb mesotrione		0.17 lb mesotrione	5.4 oz Callisto

Soybean Herbicide Package Mixes or Co-packs and Equivalents

Herbicide	Group	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Afforia	14	40.8% flumioxazin	3 oz	1.22 oz flumioxazin	2.4 oz Valor SX
	2	5.0% thifensulfuron		0.15 oz thifensulfuron	0.3 oz Harmony
	2	5.0% tribenuron		0.15 oz tribenuron	0.3 oz Express
Anthem Maxx	15	4.174 lb pyroxasulfone	5 oz	0.16 oz pyroxasulfone	3 oz Zidua
	14	0.126 lb fluthiacet methyl		0.005 lb fluthiacet	0.7 oz Cadet
Authority Assist	14	33.3% sulfentrazone	10 oz	3.3 oz sulfentrazone	5.6 oz Authority 75DF
	2	6.67% imazethapyr		0.67 oz imazethapyr	3.4 oz Pursuit AS
Authority Elite	14	7.55% sulfentrazone	25 oz	2.24 oz sulfentrazone	3 oz Authority 75DF
	15	68.25% S-metolachlor		1.26 lb S-metolachlor	1.3 pt Dual II MAGNUM

Soybean Herbicide Package Mixes (continued)

Herbicide	Group	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Authority First/Sonic	14	6.21% sulfentrazone	8.0 oz	0.31 lb sulfentrazone	6.6 oz Authority 75DF
	2	7.96% cloransulam-methyl			
Authority MAXX	14	62.12% sulfentrazone	7 oz	4.3 oz sulfentrazone	5.7 oz Authority 75DF
	2	3.88% chlorimuron			
Authority MTZ	14	18% sulfentrazone	16 oz	0.18 lb sulfentrazone	3.8 oz Authority 75DF
	5	27% metribuzin			
Authority XL	14	62.2% sulfentrazone	8 oz	5.0 oz sulfentrazone	6.6 oz Authority 75DF
	2	7.8% chlorimuron			
Boundary 7.8EC	15	5.2 lbs S-metolachlor	2.1 pt	1.4 lb S-metolachlor	1.5 pt Dual II MAG.
	5	1.25 lbs metribuzin			
Canopy 75DF	2	10.7% chlorimuron-ethyl	6 oz	0.5 oz chlorimuron	2.0 oz Classic 25DF
	5	64.3% metribuzin			
Canopy EX	2	22.7% chlorimuron	1.5 oz	0.34 oz chlorimuron	1.36 oz Classic
	2	6.8% tribenuron			
Cheetah Max	10	2 lb glufosinate	34 oz	0.53 lb glufosinate	29 fl oz Liberty
	14	1 lb fomesafen			
Crusher	2	25% rimsulfuron	1 oz	0.25 oz rimsulfuron	1.0 oz Resolve DF
	2	25% thifensulfuron			
Enlist Duo	4	1.6 lb ae 2,4-D choline salt	4 pt	0.8 lb ae 2,4-D	26 oz 2,4-D 4A
	9	1.7 lb ae glyphosate			
Enlite 47.9DG	14	36.2% flumioxazin	2.8 oz	1.0 oz flumioxazin	2.0 oz Valor
	2	8.8% thifensulfuron			
	2	2.8% chlorimuron ethyl			
Envive 41.3DG	14	29.2% flumioxazin	3.5 oz	1.0 oz flumioxazin	2.0 oz Valor
	2	2.9% thifensulfuron			
	2	9.2% chlorimuron ethyl			
Extreme	2	1.8% imazethapyr	3 pt	0.064 lb imazethapyr	1.44 oz Pursuit DG
	9	22% glyphosate			
Fierce 76% WDG	14	33.5 % flumioxazin	3 oz	1.0 oz flumioxazin	2.0 oz Valor
	15	42.5% pyroxasulfone			

Soybean Herbicide Package Mixes (continued)

Herbicide	Group	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Fierce XLT	14	24.57% flumioxazin	4 oz	1.0 oz flumioxazin	2 oz Valor
	15	31.17% pyroxasulfone		1.28 oz pyroxasulfone	1.5 oz Zidua
	2	6.67% chlorimuron		0.25 oz chlorimuron	1 oz Classic DF
Flexstar GT 3.5	14	0.56 lb fomesafen	3.5 pt	0.245 lb fomesafen	16 oz Flexstar
	9	2.26 lb glyphosate		1.0 lb glyphosate	26 oz Touchdown HiTech
Fusion 2.67E	1	2 lb fluazifop	8 fl oz	0.125 lb fluazifop	8 fl oz Fusilade DX 2E
	1	0.67 lb fenoxaprop		0.042 lb fenoxaprop	8 fl oz Option II 0.67E
Harrow	2	50% rimsulfuron	0.5 oz	0.25 oz rimsulfuron	1 oz Matrix SG
	2	25% thifensulfuron		0.12 oz thifensulfuron	0.25 oz Harmony SG
Latir	14	31.5% flumioxazin	3.2 oz	1 oz flumioxazin	2 oz Valor
	2	23.5% imazethapyr		0.75 oz imazethapyr	3 oz Pursuit
Marvel	14	1.2% fluthiacet	5 oz	0.075 oz fluthiacet	0.66 oz Cadet
	14	30.08% fomesafen		1.8 oz fomesafen	0.5 pt Flexstar
Matador	15	4 lb metolachlor	2 pt	1 lb metolachlor	1 pt Stalwart
	5	0.56 lb metribuzin		2.25 oz metribuzin	3 oz Metribuzin 75DG
	2	0.13 lb imazethapyr		2 oz imazethapyr	2 oz Pursuit 2AS
OpTill	14	17.8% saflufenacil	2 oz	0.35 oz saflufenacil	1 oz Sharpen
	2	50.2% imazethapyr		1.0 oz imazethapyr	4 oz Pursuit AS
Panoflex 50% WSG	2	40% tribenuron	0.5 oz	0.2 oz tribenuron	0.2 oz tribenuron
	2	10% thifensulfuron		0.05 oz thifensulfuron	0.1 oz Harmony SG
Prefix	15	46.4% S-metolachlor	2 pt	1.09 lb S-metolachlor	1.14 pt Dual Magnum
	14	10.2% fomesafen		0.238 lb fomesafen	0.95 pt Reflex
Pummel	15	5.0 lb metolachlor	2 pt	1.25 lb metolachlor	1.2 pt Stalwart
	2	0.25 lb imazethapyr		0.063 lb imazethapyr	4 oz Pursuit
Pursuit Plus 2.9E	2	0.2 lb imazethapyr	2.5 pt	0.063 lb imazethapyr	4.0 oz Pursuit 2S
	3	2.7 lb pendimethalin		0.84 lb pendimethalin	2.00 pt Prowl 3.3E
Rowel FX	2	10.3% chlorimuron ethyl	5 oz	0.52 oz chlorimuron ethyl	0.21 oz Classic
	14	30% flumioxazin		1.5 oz flumioxazin	2.94 oz Valor
Sequence 5.25L	15	3.0 lb S-metolachlor	3 pt	1.13 lb S-metolachlor	1.2 pt Dual Magnum
	9	2.25 lb glyphosate		0.84 lb ae glyphosate	26 oz Touchdown

Soybean Herbicide Package Mixes (continued)

Herbicide	Group	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Sonic	14	6.21% sulfentrazone	8.0 oz	0.361 lb sulfentrazone	6.6 oz Authority 75DF
	2	7.96% cloransulam-methyl		0.04 lb cloransulam-methyl	0.76 oz FirstRate
Statement	15	4.22 lb metolachlor	2 pt	1.1 lb metolachlor	1.1 pt Stalwart
	14	0.91 lb fomesafen		0.23 lb fomesafen	15.3 oz Rhythm
Storm 4S	6	2.67 lb bentazon	1.5 pt	0.50 lb bentazon	1 pt Basagran 4S
	14	1.33 lb acifluorfen		0.25 lb acifluorfen	1 pt Blazer 2S
Surveil	14	51% flumioxazin	3.6 oz	1.5 oz flumioxazin	3.0 oz Valor
	2	84% chloransulam		0.5 oz chloransulam	0.6 oz FirstRate
Synchrony NXT	2	21.5% chlorimuron	0.5 oz	0.11 oz chlorimuron	0.44 oz Classic 25DF
	2	6.9% thifensulfuron		0.034 oz thifensulfuron	0.068 oz Harmony SG
Tailwind	15	5.25 lb metolachlor	2 pt	1.3 lb metolachlor	1.3 pt Stalwart 8E
	5	1.25 lb metribuzin		0.31 lb metribuzin	0.4 lb Metribuzin 75DF
Torment	14	2.0 lb fomesafen	1 pt	0.25 lb fomesafen	2.1 pt Flexstar
	2	0.5 lb imazethapyr		0.063 lb imazethapyr	4 oz Pursuit
Trivence WDG	2	3.9% chlorimuron-ethyl	6 oz	0.23 oz chlorimuron	1.0 oz Classic 25DF
	14	12.8% flumioxazin		0.77 oz flumioxazin	1.5 oz Valor
	5	44.6% metribuzin		2.68 oz metribuzin	0.22 lb Metribuzin 75DF
Valor XLT	14	30.3% flumioxazin	3 oz	0.056 lb flumioxazin	1.76 oz Valor
	2	10.3% chlorimuron ethyl		0.019 lb chlorimuron	1.24 oz Classic
Warrant Ultra	15	2.82 lb acetochlor	50 oz	1.1 lb acetochlor	3 pt Warrant
	14	0.63 lb fomesafen		0.25 lb fomesafen	1 pt Reflex

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

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

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

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

Tradename	Herbicide Group No.	Active Ingredients	Tradename	Herbicide Group No.	Active Ingredients
Acuron	5, 15, 27, 27	atrazine, S-metolachlor, mesotrione, bicyclopyrone	Extreme	2, 9	imazethapyr, glyphosate
Afforia	2, 2, 14	thifensulfuron, tribenuron, flumioxazin	Fierce	14, 15	flumioxazin, pyroxasulfone
Alluvex	2, 2	rimsulfuron, thifensulfuron	Fierce XLT	2, 14, 15	chlorimuron, flumioxazin, pyroxasulfone
Anthem	14, 15	fluthiacet, pyroxasulfone	Flexstar GT	9, 14	glyphosate, fomesafen
Anthem ATZ	5, 14, 15	atrazine, fluthiacet, pyroxasulfone	FulTime NXT	5, 15	atrazine, acetochlor
Anthem Maxx	14, 15	fluthiacet, pyroxasulfone	Fusion	1, 1	fenoxaprop, fluazifop
Armezon Pro	15, 27	dimethenamid-P, topramezone	Halex GT	9, 15, 27	glyphosate, S-metolachlor, mesotrione
Authority Assist	2, 14	imazethapyr, sulfentrazone	Harness Xtra	5, 15	atrazine, acetochlor
Authority Elite	14, 15	sulfentrazone, S-metolachlor	Harrow	2, 2	rimsulfuron, thifensulfuron
Authority MTZ	5, 14	metribuzin, sulfentrazone	Instigate	2, 27	rimsulfuron, mesotrione
Authority XL	2, 14	chlorimuron, sulfentrazone	Keystone NXT, Keystone LA NXT	5, 15	atrazine, acetochlor
Autumn Super	2, 2	iodosulfuron, thiencazuron	Latir	2, 14	imazethapyr, flumioxazin
Basis Blend	2, 2	rimsulfuron, thifensulfuron	Lexar EZ	5, 15, 27	atrazine, S-metolachlor, mesotrione
Bicep	5, 15	atrazine, S-metolachlor	Lumax EZ	5, 15, 27	atrazine, S-metolachlor, mesotrione
Breakfree NXT ATZ, Breakfree NXT Lite	5, 15	atrazine, acetochlor	Marksman	4, 5	dicamba, atrazine
Callisto GT	9, 27	glyphosate, mesotrione	Marvel	14, 14	fluthiacet, fomesafen
Callisto Xtra	5, 27	atrazine, mesotrione	Northstar	2, 4	primisulfuron, dicamba
Canopy	2, 5	chloriuron, metribuzin	Optill	2, 14	imazethapyr, saflufenacil
Canopy EX	2, 5	chlorimuron, tribenuron	Panoflex	2, 2	tribenuron, thifensulfuron
Capreno	2, 27	thiencazuron, tembotrione	Permit Plus	2, 2	halosulfuron, thifensulfuron
Cheetah Max	10, 14	glufosinate, fomesafen	Prefix	14, 15	fomesafen, S-metolachlor
Cinch ATZ	5, 15	S-metolachlor, atrazine	Prequel	2, 27	rimsulfuron, isoxaflutole
Corvus	2, 27	thiencazuron, isoxaflutole	Priority	2, 14	halosulfuron, carfentrazone
Crusher	2, 2	Rimsulfuron, thifensulfuron	Pummel	2, 15	Imazethapyr, metolachlor
Degree Xtra	5, 15	atrazine, acetochlor	Pursuit Plus	2, 3	imazethapyr, pendimethalin
DiFlexx	4, 27	dicamba, isoxaflutole	Realm Q	2, 27	rimsulfuron, mesotrione
Enlist Duo	4, 9	2,4-D, glyphosate	Require Q	2, 4	rimsulfuron, dicamba
Enlite	2, 2, 14	chlorimuron, thifensulfuron, flumioxazin	Resolve Q	2, 2	rimsulfuron, thifensulfuron
Envive	2, 2, 14	chloriuron, thifensulfuron, flumioxazin	Revulin Q	2, 27	nicosulfuron, mesotrione
Expert	5, 9, 15	atrazine, glyphosate, S-metolachlor	Rowel FX	2, 14	chlorimuron ethyl, flumioxazin
			Sequence	9, 15	glyphosate, S-metolachlor
			Solstice	14, 27	fluthiacet, mesotrione

Tradename	Herbicide Group No.	Active Ingredients
Sonic	2, 14	cloransulam, sulfentrazone
Spirit	2, 2	primisulfuron, prosulfuron
Spitfire	4, 4	2,4-D, dicamba
Statement	14, 15	metolachlor, fomesafen
Status	4, 19	dicamba, diflufenzopyr
Steadfast Q	2, 2	nicosulfuron, rimsulfuron
Suprass NXT	5, 25	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, formesafen
TripleFLEX II	2, 4, 15	flumetsulam, clopyralid, acetochlor
Trivence	2, 5, 14	chlorimuron, metribuzin, flumioxazin
Valor XLT	2, 14	chlorimuron, flumioxazin
Verdict	14, 15	saflufenacil, dimethenamid
Warrant Ultra	14, 15	formesafen, acetochlor
Yukon	2, 4	halosulfuron, dicamba
Zemax	15, 27	S-metolachlor, mesotrione

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 (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 action. Aryloxyphenoxypropanoate (commonly 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 to 10 days following application. The potential for injury increases when applications are made over the top of the plants to corn larger than 10 to 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 usually does not negatively affect yield potential. 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 Photosystem 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., acifluofen, 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 triazolines 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, an enzyme that incorporates ammonium in plants. Although glutamine 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 three to seven 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 ₂ O, Pendimax, Framework, Satellite, others	pendimethalin
Sonalan	ethalfluralin
Surflan	oryzalin
Treflan, Trust, others	trifluralin

Synthetic auxin HG 4

benzoic

Banvel, Clarity, DiFlexx, Sterling Blue, others	dicamba
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phenoxy

many	MPCA
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
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nitriles

Buctril, others	bromoxynil
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triazines

AAtrex, atrazine, others	atrazine
Evik	ametryn
Metribuzin, Tricor	metribuzin
Princep	simazine

ureas

Karmex	diuron
Llnex, Lorox	linuron

Photosystem I inhibitors HG 22

Diquat, Reward	diquat
Gramoxone Max	paraquat

Protoporphyrinogen Oxidase (PPO) inhibitors HG 14

aryl triazolinones

Aim	carfentrazone
Authority, Spartan	sulfentrazone

diphenyl ethers

Blazer, UltraBlazer	acifluorfen
Cobra, Phoenix	lactofen
ET, Vida	pyraflufen
Flexstar, Reflex	fomesafen
Goal	oxyfluorfen

phenylphthalimides

Resource	flumiclorac
Valor, Rowel	flumioxazin

pyrimidinedione

Sharpen (Kixor)	saflufenacil
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other

Cadet	fluthiacet
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Enolpyruvyl shikimate phosphate synthase (EPSPS) inhibitors HG 9

Roundup, Touchdown, others	glyphosate
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Glutamine synthetase inhibitors HG 10

Liberty, Cheetah	glufosinate
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Hydroxyphenyl pyruvate dioxygenase (HPPD) inhibitors HG 27

Balance Flexx	isoxaflutole
Callisto	mesotrione
Armezon/Impact	topramezone
Laudis	tembotrione
bicyclopyrone	bicyclopyrone

Diterpene inhibitors HG 13

Command	clomazone
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Auxin transport inhibitors HG 19

Distinct, Status	diflufenzopyr
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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

Common chemical and trade names are used in this publication. The use of trade names is for clarity by the reader. Due to the large number of generic products available ISU is not able to include all products. Inclusion of a trade name does not imply endorsement of that particular brand of herbicide and exclusion does not imply non-approval.

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... and justice for all

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