2021 Herbicide Guide for Iowa Corn and Soybean Production

Volunteer Corn in Storm-damaged Fields

The 2020 derecho damaged millions of acres of corn in Iowa, which creates the potential for large populations of volunteer corn in 2021. While not persistent, it is highly competitive with both corn and soybean. Weather conditions last fall resulted in significant germination of corn seed in many fields prior to soils cooling down; however, most fields will still have sufficient corn seed remaining to produce problems this season.

An important step in developing management plans for 2021 is identifying herbicide resistant traits in the hybrids planted in 2020. Glyphosate (Roundup) and glufosinate (Liberty) are two effective options to manage volunteer corn, but many corn hybrids contain resistance traits for one or both of these herbicides.

As with other weeds, controlling emerged volunteer corn at planting to ensure a weed-free start is critical. Delaying planting can reduce populations by allowing some of the corn seed to germinate prior to planting. No preemergence herbicide will provide effective control of volunteer corn in either corn or soybean.

Management in soybean

Rotating fields to soybean or some other broadleaf crop provides the best options for managing volunteer corn. Several Group 1 herbicides (ACCase inhibitors) are available that provide effective control in soybean. Due to the competitiveness of volunteer corn with soybean, applications should be targeted for when the corn is less than 12 inches in height, especially when high densities are present. Herbicide rates should be based on size and density of the volunteer corn. Use the higher range of rates when treating large plants or high densities. Tank-mixing a Group 1 herbicide with broadleaf herbicides can result in reduced grass control due to antagonism between products. Most Group 1 labels provide instructions on minimizing this risk, whether by increasing rates or using sequential applications. If an Enlist corn hybrid was planted in 2020, use either clethodim or sethoxydim since Enlist corn provides resistance to fluazifop and quizalifop.

Based on the trait package of the prior year's corn, glyphosate or glufosinate may provide an alternative to Group 1 herbicides. Since glufosinate is a contact herbicide, two applications generally are required for complete volunteer corn control.

Management in corn

Caution is advised when planting corn in fields with significant storm damage due to limited control options for volunteer corn. Again, the traits of last year's corn dictate available options; determine whether glyphosate or glufosinate are a viable treatment due to the absence of one, or both, of these traits. If last year's corn had both glyphosate and glufosinate resistance, there are no postemergence control options, placing the 2021 crop at risk if high populations of volunteer corn are present.

One small caveat. While availability is likely limited for 2021, another option would be to plant an Enlist corn hybrid since the Enlist trait package provides resistance to 2,4-D, glyphosate and certain Group 1 herbicides (only 'fops'). Assure II (quizalofop) is registered for use on Enlist hybrids, and provides effective control of volunteer corn. Other 'fop' herbicides are not registered for use on these hybrids.

Contents

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Dicamba Update

Dicamba had a tumultuous 2020 with a court ruling in June that immediately vacated the labels of three products used in dicamba-resistant soybean (XtendiMax w/VGT; FeXapan w/VGT; Engenia). This ruling was overridden by state regulatory agencies and the EPA, allowing use of the products during 2020, but not without significant confusion following the ruling.

Late in 2020 EPA granted new five-year labels for Xtendimax with VGT, Tavium plus VGT, and Engenia. This article will provide a short overview of major changes in the labels, but users must always reference product labels and websites for specific language and requirements.

What has changed

- The requirement for use of a volatility reducing agent (VRA) or pH buffering agent is probably the most significant change on the labels. The VRAs are pH buffers that reduce conversion of dicamba to the volatile form. Only VRAs described on the product's website can be used.
- Dicamba cannot be applied in soybean after June 30. The XtendiMax label also prohibits application after the R1 soybean stage of soybean, whereas Tavium restricts applications aft.er the V4 soybean stage. The date restriction will limit applications later in the season when temperatures favoring volatility are more likely.
- The 110-foot downwind buffer within fields for spraying fields adjacent to sensitive areas has been increased to 240 ft. The labels still prohibit application when adjacent downwind areas contain sensitive crops (including non-dicamba-resistant soybean), fruits and vegetables, and other susceptible plants. The labels differ in how residential areas (i.e. farmsteads) are classified; carefully read labels or consult with manufacturers to clarify restrictions.
- The downwind buffer for spraying in counties with endangered species has increased from 110 ft. to 310 ft.; the omnidirectional buffer remains at 57 ft. The counties within Iowa with restrictions have also changed for 2021. Visit the EPA website Bulletins Live! (https://www.epa.gov/endangered-species/bulletins-live-two-view-bulletins) for current listings.

What remains the same

- Apply only one hour aft.er sunrise through two hours before sunset.
- Apply when wind speeds are between 3 and 10 MPH; do not apply during temperature inversions.
- Do not apply if sensitive crops are in an adjacent downwind field.
- Maximum boom height of 24 inches and ground speed of 15 mph.
- Only use nozzle/pressure combinations approved on product website.
- Only mix with products that are approved on the product website.
- Dicamba-specific training is still required for applicators, although there are slight changes in this requirement.

Both dicamba and 2,4-D pose a greater risk of off-target injury than other herbicides due to their ability to induce plant responses at lower percentages of application rates. It is the applicator's responsibility to properly set up sprayer and avoid applications when conditions increase the likelihood of off-target movement and damage (e.g. susceptible plants in adjacent areas, high winds, temperature inversions, high temperatures).

Designing Resilient Weed Management Programs

Herbicide-resistant weeds continue to spread rapidly across Iowa, threatening the current cropping system that is based on herbicidal weed control. Weeds with multiple resistances pose the biggest threat. More than 90% of waterhemp populations collected in Iowa fields in 2019 are resistant to three herbicide groups. Giant ragweed and horseweed/marestail are the other major resistant weeds in the state, but other weeds will continue to evolve resistance to herbicides as long as we are heavily dependent on chemical weed control.

For most growers, adjusting herbicide programs will be the simplest and 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. 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 to achieving success. The herbicide use rate is critical in determining its effectiveness. Ensure that the individual components of a program are used at rates that will control target weeds. Other factors that determine the effectiveness of a herbicide program include: 1) the nature of the weed infestation in the field, including species present, density of weeds, 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.

It is important to recognize that relying solely on herbicides will fail at winning the struggle against herbicide resistance. This article provides a brief overview of the types of herbicide strategies used in corn and soybean production, including the description of their strengths and weaknesses. The article concludes with a description of alternative strategies that provide opportunities to enhance weed control and protect the value of herbicides.

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, morninglories) 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 crop emergence, reducing likelihood of success. Greater likelihood of success in corn than in soybean due to characteristics of available herbicides and more rapid canopy development.
- *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 own sprayer so that they have more control of when fields get sprayed.
- *Approaches:* Two approaches typically are used for total post programs. The introduction of Roundup Ready crops led to the popularity of sequential applications made 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 5-7 days of application can result in weed escapes early in the season.

Preemergence followed by Postemergence Program

- **Advantages**
  - Provides most consistent control across a broad range of environmental conditions.
  - Preemergence component protects yield from early-season competition.
  - Easily incorporates multiple herbicide groups, therefore reducing selection pressure.
- **Disadvantages**
  - Requires multiple applications and the associated costs.
- Appropriate for any weed infestation, takes advantage of the benefits of both preemergence and postemergence herbicides.
- *Approaches:* There is considerable flexibility in these programs based on the nature of the weed infestation. In fields with low to moderate grass infestations, the preemergence component can target the grasses while the focus of the postemergence component would be the broadleaf weeds. Programs providing redundant control of target weeds with the PRE and POST components will provide the most consistent weed control and best management of herbicide resistance.
- Addition of 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 to 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 weeds being present when the crop emerges. The particular herbicide program 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 preplant applications due to insufficient weed growth to result in translocation to underground structures. Activity of glyphosate on dandelion and some winter annuals can be very slow during cool temperatures in the spring, and fall applications may provide better control of these weeds in fields with heavy infestations. The addition of 2,4-D ester to glyphosate will improve control of marestail (horseweed), giant ragweed, and many mustard species.

2,4-D ester is most often used in combination with other herbicides to improve activity on emerged broadleaf weeds, specifically marestail, giant ragweed and mustards. While 2,4-D has limited soil activity due to rapid microbial degradation, applications made prior to planting corn or soybean can cause significant injury. Ester formulations have less stringent restrictions on preplant applications than amines due to the shorter half-life and lower soil availability of ester products. In soybean, applications of up to 0.5 lb. ae/A must be applied at least 7 days prior to planting. Restrictions for preplant applications for corn vary among labels, but an example would be 7 days prior to planting for up to 0.5 lb. ae/A and 14 days for 0.5-1.0 lb. ae/A. There is no planting restriction when using 2,4-D formulations registered for use on Enlist crops (Enlist One, Enlist Duo).

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) enhances activity of paraquat.

Dicamba may be used in combination with glyphosate or other herbicides to improve activity on certain broadleaf weeds. On non-dicamba resistant soybean, a minimum of 14 days between an application of 0.25 lb./A and planting is required, in addition to at least one inch of rainfall. No delay is required with preplant applications to Xtend soybean when using products registered for use on dicamba-resistant soybean.

Residual herbicides with foliar activity. Many products used for preemergence control have foliar activity (e.g. herbicide groups 2, 5, 14, and 27). In fields with low to moderate infestations of small annual weeds at planting, these herbicides may have sufficient activity at planting to control the emerged weeds. The potential for omitting specific burndown herbicides (i.e. glyphosate) is dependent upon making 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. Herbicide resistant weeds continue to spread rapidly across Iowa. Sustaining the current production system is dependent on incorporating alternative management strategies that reduce the reliance on herbicides. 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. 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 inches or less reduce the time needed to achieve canopy coverage of the interrow area, therefore suppressing emergence and growth of weeds later in the season. Increasing soybean seeding rates to achieve more than 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 provide numerous benefits in Iowa production systems, but our relatively short growing season limits the amount of biomass that a cover crop accumulates by normal planting dates for both corn and soybean. The level of weed suppression provided by a cover crop is directly related to the quantity of aboveground biomass present at the timing of termination. 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.

For effective weed suppression, a uniform stand of the cover crop is required. Planting with a drill will provide a uniform stand more consistently than broadcast applications. In most years delaying termination of the cover crop until mid-May or later will be required for effective control of weeds like waterhemp that emerge throughout June. Cover crops can provide very effective control of winter annual weeds such as marestail and field pennycress when established shortly after harvest.

Harvest weed seed control. The majority of weed seed found in the seed bank are produced by weeds that escape control within the field. Restricting the spread or destroying weed seeds present at crop harvest is an effective way of reducing herbicide

selection pressure and the resultant evolution of herbicide-resistant weeds. Australians have developed several 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. HWSC can fit well into our cropping system without changing other aspects of corn and soybean production.

For HWSC to be effective, weed seed must be retained on plants at the time of harvest. Seed retention varies widely among species, and some species shatter a high percentage of seed by typical harvest dates. However, research has shown that 80 to 95 percent of seeds of waterhemp and other species are retained on the plant at normal soybean harvest dates. During harvest, weed seeds are concentrated in the chaff as it moves through the combine, stems and other larger material are contained in a separate stream within the combine. Rather than spreading the weed seed back into the field with the chaff, HWSC isolates the chaff fraction from the larger material and prevents the seed from being broadcast back into the field. HWSC has greater utility in soybean than corn since corn heads do not collect weed seeds as efficiently as soybean headers. This is advantageous since more weed seed are typically produced in soybean due to the greater competitiveness of corn.

Chaff lining and tramlining deposit the chaff and weed seed in an 18 to 24-inch wide band behind the combine. More than 90% of the weed seed entering the combine is placed within the chaff line. Chaff lining is the least expensive version of HWSC, requiring a simple insert in the combine that keeps chaff separate from other material, and then places the chaff behind the combine. It is best suited for no-till since tillage redistributes the weed seed within the chaff line over a larger area. Current research is determining the fate of weed seeds within the chaff and how best to manage the weeds within this band.

Mechanical destruction of weed seed collected by the combine using high-impact mills also holds promise in managing herbicide-resistant weeds. Chaff and weed seed are run through a cage mill that is mounted at the rear of combine below the straw spreader/chopper. Research has shown that seed destructors are effective at killing more than 90% of the weed seed collected by the combine. This technology is developing rapidly and several manufacturers have developed models for the Australian market. In the near future it is likely that combine manufacturers will offer the option of having an 'after-market' internal seed destructor installed when purchasing a combine.

Summary

Weeds are the universal pest. Every field has an economic level of weed infestation every year. Our 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. Taking the time to critically examine herbicide programs, to insure multiple sites of action are controlling target weeds, is the first step in developing resilient weed management systems. 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]

			Grasses					Broadleaves									Perennials		
Weed response to selected herbicides E = excellent G = good F = fair P = poor	**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 NXT, etc. (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 etc.	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, etc. (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 Vapor Grip Technology 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
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 (glufosinate)[3]	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
Roundup (glyphosate)[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
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 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 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]

			Grasses					Broadleaves									Perennials		
Weed response to selected herbicides E = excellent G = good F = fair P = poor	**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	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
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 (glufosinate)[3]	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
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

[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 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	**A. I.**	**HG**	**Rate/A**	**Grazing**	**Hay harvest**	**Removal before slaughter**	**Grazing**	**Hay harvest**
2, 4-D	2, 4-D	4	1.5 to 2.0 lb ae	0	7 days	0	0	7 days
Clarity and many others	dicamba	4	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	4, 2	1 - 3.3 oz	0	0	0	0	0
Cimarron Max (co-pack)	metsulfuron methyl + dicamba + 2,4-D	2, 4, 4	0.25-1 oz A + 1-4 pt B	0	0	30 days	7 days	37 days
Cimarron X-Tra	metsulfuron methyl + chlorsulfuron	2, 2	0.1 - 1.0 oz	0	0	0	0	0
Crossbow	triclopyr + 2,4-D	4, 4	1 - 6 qt	0	14 days	3 days	Growing season	Growing season
Curtail	clopyralid + 2,4-D	4, 4	2 - 4 qt	0	7 days	7 days*	14 days	7 days
Escort XP	metsulfuron methyl	2, 2	Up to 1.7 oz	0	0	0	0	0
ForeFront HL	aminopyralid + 2,4-D	4, 4	1.2 - 2.1 pt	0	7 days	0	0	7 days
Grazon P&D	picloram + 2,4-D	4, 4	3 - 4 pt	0	30 days	3 days	7 days	30 days
Milestone	aminopyralid	4	3 - 7 oz	0	0	0	0	0
Overdrive	dicamba + diflufenzopyr	4, 19	4 - 8 oz	0	0	0	0	0
PastureGard HL	triclopyr + fluroxypyr	4, 4	1 - 1.5 pt	0	14 days	3 days	1 year	1 year
Rave	dicamba + triasulfuron	4, 2	2 - 5 oz	0	37 days	30 days	7 days	37 days
Redeem R&P	triclopyr + clopyralid	4, 4	1.5 - 4 pt	0	14 days	3 days	Growing season	Growing season
Remedy Ultra	triclopyr	4, 19	1 - 2 qt	0	14 days	3 days	Growing season	Growing season
Surmount	picloram + fluroxypyr	4, 4	1.5 - 6 pt	0	7	3	14	7
Tordon 22K	picloram	4	< 2 pt	0	0	3	14	14
			> 2 pt	0	14	3	14	14
Weedmaster	dicamba + 2,4-D	4, 4	1 - 4 pt	0	7 days	30 days	7 days	7 days

*7 days slaughter interval if Curtail was freshly applied, withdrawal not needed if 2 weeks or more have elapsed since application.

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 lb atrazine		0.75 lb atrazine	1.5 pt atrazine 4L
	27	0.24 lb mesotrione		0.18 lb mesotrione	5.8 oz Callisto
	27	0.06 lb bicyclopyrone		0.045 lb bicyclopyrone	N/A
Acuron Flexi	27	0.08 lb bycylopyrone	2.25 qt	0.72 oz bicyclopyrone	N/A
	27	0.32 lb mesotrione		0.18 lb mesotrione	5.8 oz Callisto
	15	2.86 lb S-metolachlor		1.61 lb S-metolachlor	27 oz Dual II Magnum
Alluvex WSG	2	16.7% rimsulfuron	1.5 oz	0.25 oz rimsulfuron	1 oz Resolve SG
	2	16.7% thifensulfuron		0.25 oz thifensulfuron	0.5 oz Harmony SG
Anthem	15	2.087 lb pyroxaslufone	10 oz	0.16 lb pyroxasulfone	3 oz Zidua
	14	0.063 lb fluthiacet-methyl		0.08 oz fluthiacet-methyl	0.7 oz Cadet
Anthem Maxx	15	4.174 lb pyroxasulfone	5 oz	0.16 oz pyroxasulfone	3 oz Zidua
	14	0.126 lb fluthiacet-methyl		0.08 oz 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 pounds fluthiacet		0.06 oz 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		0.26 oz topramezone	0.73 oz Armezon
Basis Blend	2	20% rimsulfuron	0.825 oz	0.167 oz rimsulfuron	0.67 oz Resolve
	2	10% thifensulfuron		0.083 oz thifensulfuron	0.16 oz Harmony
Bicep II MAGNUM, Cinch ATZ, Medal II AT, Charger Max ATZ	15	2.4 lb S-metolachlor	2.1 qt	1.26 lb S-metolachlor	1.31 pt Dual II MAGNUM
	5	3.1 lb atrazine		1.63 lb atrazine	3.25 pt Aatrex 4L
Bicep Lite II MAGNUM, Cinch ATZ Lite, Charger Max ATZ Lite	15	3.33 lb S-metolachlor	1.5 qt	1.25 lb S-metolachlor	1.31 pt Dual II MAGNUM
	5	2.67 lb atrazine		1 pound atrazine	32 oz atrazine 4L
Breakfree NXT ATZ	15	4.3 lb acetochlor	2 qt	2.1 lb acetochlor	2.4 pt Breakfree NXT
	5	1.7 lb atrazine		1.7 lb atrazine	3.4 pt atrazine 4L
Breakfree NXT Lite	15	4.3 lb acetochlor	2 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		1.52 oz 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	1.44 oz mesotrione	3 oz Callisto
	5	3.2 lb atrazine		0.6 lb atrazine	1.2 pt Aatrex 4L
Capreno	2	0.57 lb thiencarbazone	3 oz	0.16 oz thiencarbazone	NA
	27	2.88 lb tembotrione		1.09 oz 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 thiencarbazone		0.5 oz thiencarbazone	
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 qts	2 lb acetochlor	2.29 pt Harness 7E
	5	1.34 lb atrazine		1 lb atrazine	1 qt atrazine 4L
DiFlexx Duo	27	0.27 lb tembotrione	32 oz	0.067 lb tembotrione	2.5 oz Laudis
	4	1.86 lb dicamba		0.31 lb dicamba	10 oz DiFlexx
Distinct 70WDG	19	21.4% diflufenzopyr	6 oz	1.3 oz diflufenzopyr	1.3 oz diflufenzopyr
	4	55% dicamba		3.3 oz dicamba	6 oz Banvel
Enlist Duo	4	1.6 lb 2,4-D choline salt	4.75 pt	0.95 lb ae 2,4-D	1.9 pt 2,4-D 4A
	9	1.7 lb glyphosate DMA		1 lb ae glyphosate	2.0 pt Durango DMA
Expert 4.9SC	15	1.74 lb S-metolachlor	3 qts	1.3 lb S-metolachlor	1.4 pt Dual II Mag.
	5	2.14 lb atrazine		1.61 lb atrazine	1.6 qts Aatrex 4L
	9	0.74 lb ae glyphosate		0.55 lb ae glyphosate	1.5 pt Glyphosate 3L
Fierce	14	33.5% flumioxazin	3.0 oz	1 oz flumioxazin	2 oz Valor
	15	42.5% pyroxasulfone		1.28 oz pyroxasulfone	1.5 oz Zidua
FulTime NXT	15	2.7 lb acetochlor	3 qts	2 lb acetochlor	2.5 pt Surpass 6.4EC
	5	1.34 lb atrazine		1 lb atrazine	2 pt atrazine 4L
Halex GT	15	2.09 lb S-metolachlor	3.6 pt	0.94 lb S-metolachlor	1 pt Dual II Magnum
	27	0.209 lb mesotrione		1.44 oz mesotrione	3 oz Callisto
	9	2.09 lb glyphosate		0.94 lb glyphosate ae	1.5 pt Touchdown HiTech
Harness MAX	15	3.52 lb acetochlor	75 fl oz	2.05 lb acetochlor	2.3 pt Harness
	27	0.33 lb mesotrione		0.188 lb mesotrione	6 oz Callisto
Harness Xtra, Confidence Xtra	15	4.3 lb acetochlor	2.3 qts	2.5 lb acetochlor	2.9 pt Harness 7E
Keystone LA NXT	5	1.7 lb atrazine		0.98 lb atrazine	1 qt atrazine 4L
Harness Xtra 5.6L, Confidence Xtra 5.6	15	3.1 lb acetochlor	3 qts	2.325 lb acetochlor	2.66 pt Harness 7E
Keystone NXT	5	2.5 lb atrazine		1.875 lb atrazine	1.9 qts atrazine 4L

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)
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
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 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 qt	0.2 lb mesotrione	6 oz Callisto
	15	2.68 lb S-metolachlor		2 lb S-metolachlor	2 pt Dual II MAGNUM
	5	1 lb atrazine		0.75 lb atrazine	0.75 qt Aatrex 4L
NorthStar	2	7.5% primisulfuron	5 oz	0.375 oz primisulfuron	0.5 oz Beacon 75SG
	4	43.9% dicamba		2.20 oz dicamba	4.4 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 45.0% 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 oz	0.13 oz carfentrazone	0.5 oz Aim
	2	50% halosulfuron		0.51 oz 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
Resicore	15	2.8 lb acetochlor	2.5 qt	1.75 lb acetochlor	2 pt Surpass NXT
	27	0.3 lb mesotrione		0.188 lb mesotrione	6 oz Callisto
	4	0.19 lb clopyralid		0.119 lb clopyralid	5 oz Stinger
Resolve Q	2	18.4% rimsulfuron	1.25 oz	0.23 oz rimsulfuron	0.9 oz Resolve DF
	2	4% thifensulfuron		0.05 oz thifensulfuron	0.1 oz Harmony SG
Revulin 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
Scorch	4	1 lb gal dicamba	1.5 pt	0.187 lb dicamba	0.37 pt Clarity
	4	3.02 lb 2,4-D		0.57 lb 2,4-D	1.1 pt 2,4-D LVE 4
	4	0.75 lb fluroxypyr		0.14 lb fluroxypyr	0.4 pt Starane Ultra

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)
Sequence	9	2.25 lb glyphosate	4 pt	1.12 lb glyphosate	1.75 pt Touchdown
	15	3 lb S-metolachlor		1.5 lb S-metolachlor	1.63 pt Dual II MAGNUM
Solstice	27	3.78 lb mesotrione	3.15 oz	1.49 oz mesotrione	3 oz Callisto
	14	0.22 lb fluthiacet-methyl		0.08 oz fluthiacet-m	0.75 oz Cadet
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	1.63 pt 2,4-D 4E
Status 56WDG	19	17.1% diflufenzopyr	5 oz	0.8 oz diflufenzopyr	0.8 oz diflufenzopyr
	4	44% dicamba		0.125 lb 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, Trisidual	15	3.75 lb acetochlor	2 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	0.57 lb saflufenacil	14 oz	0.06 oz saflufenacil	0.17 oz Sharpen
	15	5 lb dimethenamid-P		0.55 oz dimethenamid-P	0.73 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	0.5 oz halosulfuron	0.66 oz Permit
	4	55% dicamba		0.125 lb dicamba	4 oz Banvel

Soybean Herbicide 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% thifensulfuron		0.15 oz thifensulfuron	0.3 oz Harmony
	2	5% 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		0.08 oz fluthiacet	0.7 oz Cadet
Authority Assist	14	33.3% sulfentrazone		0.21 lb sulfentrazone	5.6 oz Authority 75DF
	2	6.67% imazethapyr		0.67 oz imazethapyr	3.4 oz Pursuit AS
Authority Edge	14	2.73 lb sulfentrazone	10 oz	0.21 lb sulfentrazone	5.6 oz Authority 75DF
	15	1.52 lb pyroxasulfone		0.12 lb pyroxasulfone	2.3 oz Zidua
Authority Elite, BroadAxe XC	14	0.7 lb sulfentrazone	25 oz	0.14 lb sulfentrazone	0.19 lb Authority 75DF
	15	6.3 lb S-metolachlor		1.23 lb S-metolachlor	0.16 gal Dual II MAGNUM
Authority First/Sonic	14	62.1% sulfentrazone	8 oz	0.31 lb sufentrazone	6.6 oz Authority 75DF
	2	7.96% cloransulam-methyl		0.64 oz cloransulam-methyl	0.76 oz FirstRate
Authority MAXX	14	62.12% sulfentrazone	7 oz	4.3 oz sulfentrazone	5.7 oz Authority 75DF
	2	3.88% chlorimuron		0.28 oz chlorimuron	1.1 oz Classic 25DF
Authority MTZ	14	18% sulfentrazone	16 oz	0.18 lb sulfentrazone	3.8 oz Authority 75DF
	5	27% metribuzin		0.27 lb metribuzin	0.36 lb Metribuzin 75DF
Authority Supreme	14	20.66% sulfentrazone	10 oz	0.13 lb sulfentrazone	0.17 lb Authority 75DF
	15	20.66% pyroxasulfone		0.13 lb pyroxasulfone	2.4 oz Zidual
Authority XL	14	62.2% sulfentrazone	8 oz	5 oz sulfentrazone	6.6 oz Authority 75DF
	2	7.8% chlorimuron		0.6 oz chlorimuron	2.4 oz Classic
Boundary 7.8EC, Presidual	15	5.2 lb S-metolachlor	2.1 pt	1.4 lb S-metolachlor	1.5 pt Dual II MAG.
	5	1.25 lb metribuzin		0.3 lb metribuzin	0.4 lb Metribuzin 75DF
Canopy 75DF	2	10.7% chlorimuron-ethyl	6 oz	0.5 oz chlorimuron	2 oz Classic 25DF
	5	64.3% metribuzin		3 oz metribuzin	0.25 lb Metribuzin 75DF
Canopy EX	2	22.7% chlorimuron	1.5 oz	0.34 oz chlorimuron	1.36 oz Classic
	2	6.8% tribenuron		0.10 oz tribenuron	0.10 oz tribenuron
Cheetah Max	10	2 lb glufosinate	34 oz	0.53 lb glufosinate	1.81 pt Liberty
	14	1 lb fomesafen		0.27 lb fomesafen	1.13 pt Flexstar
Crusher	2	25% rimsulfuron	1 oz	0.25 oz rimsulfuron	1 oz Resolve DF
	2	25% rimsulfuron		0.25 oz rimsulfuron	0.5 Harmony SG
Enlist Duo	4	1.6 lb ae 2,4-D choline salt	4 pt	0.8 lb ae 2,4-D	1.63 pt 2,4-D 4A
	9	1.7 lb ae glyphosate		0.85 lb ae glyphosate	1.5 pt Roundup WMax

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)
Enlite 47.9DG	14	36.2% flumioxazin	2.8 oz	1 oz flumioxazin	2 oz Valor
	2	8.8% thifensulfuron		0.25 oz thifensulfuron	0.5 oz Harmony SG
	2	2.8% chlorimuron ethyl		0.08 oz chlorimuron ethyl	0.32 oz Classic 25 DF
Envive 41.3DG	14	29.2% flumioxazin	3.5 oz	1 oz flumioxazin	2 oz Valor
	2	2.9% thifensulfuron		0.10 oz thifensulfuron	0.2 oz Harmony SG
	2	9.2% chlorimuron ethyl		0.32 oz chlorimuron ethyl	1.3 oz Classic 25DF
Extreme	2	1.8% imazethapyr	3 pt	1.02 oz imazethapyr	4 oz Pursuit DG
	9	22.0% glyphosate		0.75 lb glyphosate	1.5 pt Roundup
Fierce 76.0% WDG	14	33.5 % flumioxazin	3 oz	1 ounce flumioxazin	2 oz Valor
	15	42.5% pyroxasulfone		1.28 oz pyroxasulfone	1.5 oz Zidua
Fierce XLT	14	24.57% flumioxazin	4 oz	1 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	1 pt Flexstar
	9	2.26 lb glyphosate		1 lb glyphosate	1.63 pt 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		0.67 oz 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	2.0 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 oz imazethapyr	4 oz Pursuit AS
Panoflex 50.0% 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
Panther Pro	14	0.67 lb flumioxazin/gal	12 oz	0.06 lb flumioxazin	2 fl oz Panther SC
	2	0.56 lb imazethapyr		0.053 lb imazethapyr	3.2 fl oz Pursuit
	5	3 lb metribuzin		0.28 lb metribuzin	6 oz of a metribuzin 75% WDG

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)
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 lb metolachlor	2 pt	1.25 lbmetolachlor	1.2 pt Stalwart
	2	0.25 lb imazethapyr		1 oz imazethapyr	4 oz Pursuit
Pursuit Plus 2.9E	2	0.2 lb imazethapyr	2.5 pt	0.063 lb imazethapyr	4 oz Pursuit 2S
	3	2.7 lb pendimethalin		0.84 lb pendimethalin	2 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 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	1.63 pt Touchdown
Sonic	14	6.21% sulfentrazone	8 oz	0.361 lb sulfentrazone	6.6 oz Authority 75DF
	2	7.96% cloransulam-methyl		0.64 oz 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	0.5 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 oz Valor
	2	84% chloransulam		0.5 oz cloransulam	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
Tavium plus VGT	4	1.12 lb dicamba a.e.	56.5 fl oz	0.5 lb dicamba	22 oz Xtendimax with VGT
	15	2.26 lb s-metolachlor		1 lb s-metolachlor	1 pt Dual Magnum
Torment	14	2 lb fomesafen	1 pt	0.25 lb fomesafen	2.1 pt Flexstar
	2	0.5 lb imazethapyr		1 ounce imazethapyr	4 oz Pursuit
Trivence WDG	2	3.9% chlorimuruon-ethyl	6 oz	0.23 oz chlorimuron	1 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

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)
Valor XLT	14	30.3% flumioxazin	3 oz	0.9 oz flumioxazin	1.76 oz Valor
	2	10.3% chlorimuron ethyl		0.3 oz chlorimuron	1.24 oz Classic
Varisto	6	4 lb bentazon	27 oz	0.84 lbs bentazon	0.84 quarts Basagran
	2	0.187 lb imazamox		0.64 oz imazamox	5.1 oz Raptor
Warrant Ultra	15	2.82 lb acetochlor	50oz	1.1 lb acetochlor	3 pts Warrant
	14	0.63 lb fomesafen		0.25 lb fomesafen	1 pt Reflex
Zidua Pro	14	0.48 lb saflufenacil	4.5 oz	0.26 oz saflufenacil	0.73 oz Sharpen
	2	1.33 lbs imazethapyr		0.75 oz imazethapyr	3 oz Pursuit
	15	2.28 lbs pyroxasulfone		1.28 oz pyroxasulfone	1.5 oz Zidua

Herbicide Sites of Action

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

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

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

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

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

Tradename	Herbicide Group No.	Active Ingredient
2,4-D, Enlist One/Duo, and others	4	2,4-D
Accent Q	2	nicosulfuron
Aim	14	carfentrazone
Assure II	1	quizalofop
atrazine	5	atrazine
Autumn	2	iodosulfuron
Balance Flexx	27	isoxaflutole
Banvel/Clarity/DiFlexx/ 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
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
Llnex, 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

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