2007 Herbicide Guide for Iowa Corn and Soybean Production

Product and management update

Micheal D. K. Owen, Extension Weed Specialist, Iowa State University

Introduction

Despite the importance of glyphosate-based crop systems, there is a need for continued investigation and development of new tactics to manage weeds effectively and economically. It is interesting that larger farm size and higher percentage of income attributable to grain is associated with growers willingness to accept alternative weed management strategies and the adoption of integrated weed management programs, based on information collected by University of Wisconsin weed scientists. The concern for timely weed management in order to protect crop yields becomes premiere in POST-based corn and soybean systems, whether based on glyphosate or any other herbicide. Iowa State University recommends the use of herbicides that provide residual weed control in corn and soybeans. The early preplant application of residual herbicides is an excellent option to reduce weed management risks.

Consider that it is critical to reduce application timing risk; while many growers now have sprayers and combined with the custom herbicide application industry, the approximate 22 million acres of row crops in Iowa can receive a herbicide treatment in a relatively short period of time, there is still a major risk of making a timely POST application. **The risk of making a timely POST herbicide application has less to do with controlling weeds and more to do with protecting potential crop yield.** Recognize that herbicide applications are at the mercy of the environmental conditions, while weeds continue to grow irrespective of the weather. Furthermore, the ability to make a timely herbicide application is dictated on the ability to assess that which is impossible to predict – when weeds begin to compete with the crop yield potential. Thus, there is still an important role for new or existing herbicides in weed management beyond the concerns caused by the evolution of herbicide resistant weed biotypes and weed population shifts. Some of the new herbicides and weed management issues facing crop production in 2007 are discussed below.

Disclaimer

An interesting and important change that has occurred in the crop protection industry is the "reintroduction" of existing "generic" herbicides. Currently, there are many brands of many herbicides (e.g. acetochlor) offered by many companies. It is impossible to keep track of all new materials; in some cases the companies have not responded to requests for information and there is a space limitation on what can be included in publications. Thus, be it known that not all herbicide brands are included in this and other ISU publications. Lack of inclusion does not mean that that product is not a good choice, nor does inclusion mean that the product mentioned should be considered the product of choice.

Issues to consider

There are a few issues resulting from the 2006 growing season that should be factored into 2007 production plans. Most of these problems are not surprisingly caused by localized environmental conditions.

Volunteer corn

Given some of the unfavorable wind conditions and stalk diseases last summer, the potential for volunteer corn in 2007 is likely to be significant in localized areas. Where harvest was difficult due to lodged or wind-damaged corn, growers should make plans to manage the anticipated volunteer corn problem.

Volunteer corn management has become more difficult than in the past. In soybeans, glyphosate has been an excellent herbicide to control volunteer corn. However, with the increasing adoption of glyphosate-resistant corn hybrids, growers have experienced problems effectively and consistently controlling volunteer corn in soybeans, even if a non-glyphosate-resistant hybrid was planted. Recognize that the glyphosate-resistant trait is transmitted via pollen. Thus, non-glyphosate-resistant hybrids may be pollinated by

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neighboring corn that is glyphosate-resistant resulting in an unexpected infestation of glyphosate-resistant volunteer corn.

In soybeans, the management of volunteer corn generally has more options than in corn production. The use of a DNA herbicide (i.e. pendimethalin) will help suppress volunteer corn. Furthermore, there are a number of POST products available (i.e. Select) that will effectively control volunteer corn and can be tank-mixed with glyphosate. In corn, the problem of controlling volunteer corn is difficult whether the corn or volunteer weed is glyphosate-resistant or not. Perhaps the best option may be to consider planting a glufosinate-resistant hybrid if the plan is to follow corn with corn and the previous corn hybrid was not a glufosinate-resistant hybrid. If this is not an option, and if the previous hybrid was not glyphosate-resistant and rotation to soybeans is not possible, glyphosate will likely control most of the volunteer corn. However, pollen trespass resulting in volunteer glyphosate-resistant volunteers is still an issue. If a non-herbicide-resistant hybrid is planned, or if a glyphosate-resistant hybrid follows a glyphosate-resistant hybrid, tillage may be the best and likely sole option. Consider aggressive tillage to bury the volunteer corn seeds and plan to use cultivation to remove the inter-row volunteer plants. Recognize that tillage also has economic and environmental costs.

Herbicide carryover

The potential for herbicide carryover is predicted to be high in specific areas of Iowa, depending on the rainfall that occurred in May and June. Late season rains likely had little effect on herbicide degradation. The timing of herbicide application and the rate of herbicides applied also significantly impact herbicide carryover. The later the application and the higher the rate of herbicide applied, the greater the potential for carryover. The soil characteristics will also influence the amount of carryover that the rotational crop experiences. Finally, and perhaps the most important consideration, is the rotational crop health which is a factor of the environmental conditions next spring. If conditions are favorable for crop growth, carryover will be less of a factor than if the rotational crop is experiencing environmental stress.

Obviously, if you are rotating corn with corn or soybean with soybeans, there is little concern for herbicide carryover to the rotational crop. Also recognize that there is a difference between the ability to detect herbicide residues and actual herbicide carryover. The latter infers that the rotational crop is negatively affected by the previous herbicide application. Also consider that in most instances, crop yield potential is not significantly impacted by slight symptoms of herbicide carryover.

The herbicides that have the potential to carryover are typically those used in corn production and cause injury to soybeans. However, some ALS-inhibitor herbicides (i.e. Scepter) and PPO-inhibitor (i.e. Flexstar) herbicides used in soybeans have the potential to injure corn grown in rotation. Herbicides used for weed control in corn that have the potential for carryover and injure soybeans include, but are not limited to atrazine, Balance Pro, Callisto (and mesotrione used in various prepackage mixtures), Impact and others.

Future products

Generally, products that do not have current registration are not included in Iowa State University recommendations. However, it is important to have an awareness of future opportunities, so these products, while not currently available for commercial use are described. In many instances, the companies have already issued press notification of the products. Recognize that the inclusion of these products does not constitute a recommendation for use.

Status 56WG

Status 56WG is a product developed by BASF that should be commercially available for corn weed control in 2007, although at the time of printing, has yet to be registered. Status 56WG is a prepackage mixture of dicamba, diflufenzopyr (Distinct) and isoxadifen (a potent safener). The mode of action for Status 56WG is on plant growth regulator hormones (PGR) where the herbicides cause an imbalance of the hormones resulting in the death of susceptible broadleaf weeds. Research conducted by ISU demonstrated the relative crop safety of Status 56WG when compared to other PGR herbicides that do not contain the safener isoxadifen.

GF-1885

Dow AgroSciences plan on a first quarter 2007 registration of GF-1885 and anticipate a limited launch in 2007 and a full scale product introduction in 2008. No commercial name has been announced for the prepackage mixture of acetochlor, flumetsulam and clopyralid which represents three herbicide modes of action. The crop safener dichlormid is also included in the 4.25 a.i. suspo-emulsion formulation. GF-1885 will be positioned for early season weed control in herbicide-resistant corn (glyphosate- and glufosinate-resistant hybrids).

New products

There are number of "new" products which represent previously registered herbicides that are now off patent or have been picked up by various distributors and companies for use in corn and soybeans. It is not possible to list all of these products accurately. Thus only a limited number of products are included in this section.

Authority First/Sonic

FMC and Dow AgroSciences have announced a long-term supply agreement where FMC will supply sulfentrazone (Authority) and Dow AgroSciences will provide cloransulam-methyl (FirstRate). The products will be marketed as Authority First and Sonic by FMC and Dow AgroSciences, respectively for weed control in soybeans. Weeds such as common waterhemp, common lambsquarters giant ragweed, and marestail will be targeted, particularly in glyphosate-resistant soybeans. The prepackage

mixtures can be applied early preplant, preplant incorporated, preplant surface, preemergence and as a preplant burndown. Two herbicide mechanisms of action are included in the products; PPO inhibition (sulfentrazone) and ALS inhibition (cloransulam-methyl) and some residual control is provided.

ET

Nichino America, Inc. will market ET 2.5% EC herbicide/defoliant. ET (pyraflufen ethyl) is a PPO inhibitor herbicide with postemergence activity but without residual activity. ET is registered as a preplant burndown and post harvest herbicide in corn and soybeans and demonstrates activity on pigweed species, velvetleaf, morningglories, wild buckwheat, and field bindweed.

Impact

Impact herbicide (topramezone) is marketed by AMVAC for use POST use in corn. Impact is a HPPD-inhibitor herbicide and inhibits pigment synthesis. Impact is active on many annual grass and broadleaf weeds. Impact has residual activity and may represent some risk of carryover. Note that there is an application restriction of 0.5 oz/A for Iowa north of I-80 but excluding the area that is both north of Highway 20 and west of Highway 71. South of I-80, 0.75 oz/A can be applied.

Tenkoz Priority Herbicide

Tenkoz Priority Herbicide is a prepackage mixture of carfentrazone-ethyl (PPO inhibitor) and halosulfuron-methyl (ALS inhibitor) registered for POST application to corn through the 8-leaf collar stage of corn development. Priority Herbicide provides control of many broadleaf weeds.

Conclusions

While there are few new herbicides available for 2007, those that are registered will potentially provide a valuable herbicide alternative for weed management in Iowa crop production systems. Recognize that while glyphosate-based crop production systems are increasingly important to Iowa, it is important to consider alternatives to supplement glyphosate for weed management. Importantly, the use of soil-applied herbicide in corn and soybean production is an excellent way to reduce the risk of untimely POST herbicide application, manage herbicide selection pressure for the evolution of herbicide-resistant weeds or weed population shifts, and importantly to consistently and effectively protect crop yields.

Role of preemergence herbicides in glyphosate resistant crops

Robert Hartzler, Extension Weed Specialist, Iowa State University

The broad-spectrum activity and wide application window of glyphosate allows weed management systems which rely solely on this product. This represents a major change from the mid-90's when it wasn't unusual to use four of five herbicides to stay ahead of waterhemp and other weeds. The simplicity of the glyphosate-based system obviously provides several benefits to farmers, yet this very trait also creates risks. Understanding these risks may aid in the development of management systems that are more profitable and protect the integrity of glyphosate.

The primary risks in relying solely on glyphosate for weed control in corn and soybean are: 1) protecting crop yields with a total postemergence program, and 2) selecting weeds able to survive typical glyphosate use rates. Whereas the success of many weed management decisions is determined simply by the presence or absence of weeds, judging the success in managing these risks is not quite as easy as looking for a clean field at harvest.

Reducing early-season competition

Total postemergence programs are based on the fact that crops can tolerate competition with weeds for a period of time without yield loss. The critical period is defined at the time after planting that weeds first begin to impact yields. The difficulty comes in predicting when this 'free ride' ends. If the initial postemergence application is delayed beyond the critical period, yield losses can accumulate rapidly. The critical period varies with crop, cultural practices, weed infestation, and environmental conditions. Interactions among these variables make it impossible to accurately predict when yields are first impacted by weeds, yet we know that under some conditions competition occurs very early in the season. The risk of losing yield potential due to the early-season weed competition is an inherent risk of management systems based on glyphosate and glyphosate-resistant crops.

There are two primary approaches to managing early-season competition in glyphosate-resistant crops. The first involves sequential postemergence applications, therefore allowing the first to be applied early while crops and weeds are small which minimizes the

risk of losing yield potential. A second application is typically required to control late-emerging weeds since the first application is made before the crop canopy has had a chance to develop.

The second tactic involves substituting a preemergence herbicide for one of the postemergence applications. The goal of the preemergence herbicide is to reduce the number of weeds that emerge with the crop, rather than provide full-season weed control. The head start provided the crop by the preemergence herbicide delays the onset of early-season competition, allowing the post application to be put off until the crop canopy has developed sufficiently to minimize problems with late-emerging weeds.

Research conducted in 2005 demonstrated the value of preemergence herbicides in glyphosate resistant crops. Both Harness Xtra® (1.2 qt/A) and INT*RR*O® (2 qt/A) reduced the weed growth present at the time of glyphosate applications (Table 1). Harness Xtra® resulted in greater reductions than INT*RR*O® due to the corn herbicide's broader spectrum activity (acetochlor + atrazine vs alachlor).

Early-season competition reduced yield at two locations when glyphosate was applied at the V6 stage of crop development, which corresponded to weed heights of 4 to 8 inches. Corn yield was reduced 5% at Ames, whereas soybean yield was reduced by 16% at Kanawha. The preemergence treatment reduced weed competition sufficiently to eliminate yield loss at these. At the other locations, weed densities were insufficient to affect yields at the V6 stage regardless of the preemergence treatment.

This research highlights the difficulty in relying on total postemergence programs – it is impossible to accurately predict when weeds begin to impact yields. Misjudging when to apply the postemergence treatment can lead to large economic losses. The main factors determining the critical period are the density of weeds and time of weed emergence in relation to the crop. The likelihood of yield loss is directly

Table 1. Effect of preemergence herbicides on the quantity of weed biomass present at the time of postemergence applications.

	Harness Xtra® (Corn)		INT*RR*O® (Soybean)		
Treatment	**Ames**	**Nashua**	**Ames**	**Nashua**	**Kanawha**
	----- Weed Biomass g/m² (% reduction) -----				
Control	27	6	53	21	68
Pre	3 (89)	0.2 (95)	21 (60)	10 (52)	33 (51)

Table 2. Effect of preemergence herbicide on selection pressure on several weed species.

	Change in Selection Pressure (%)	
Species	**2 qt INT*RR*O®**	**1.2 qt Harness Xtra®**
Foxtail	-90	-75
Waterhemp	-90	-97
Velvetleaf	+38	-24

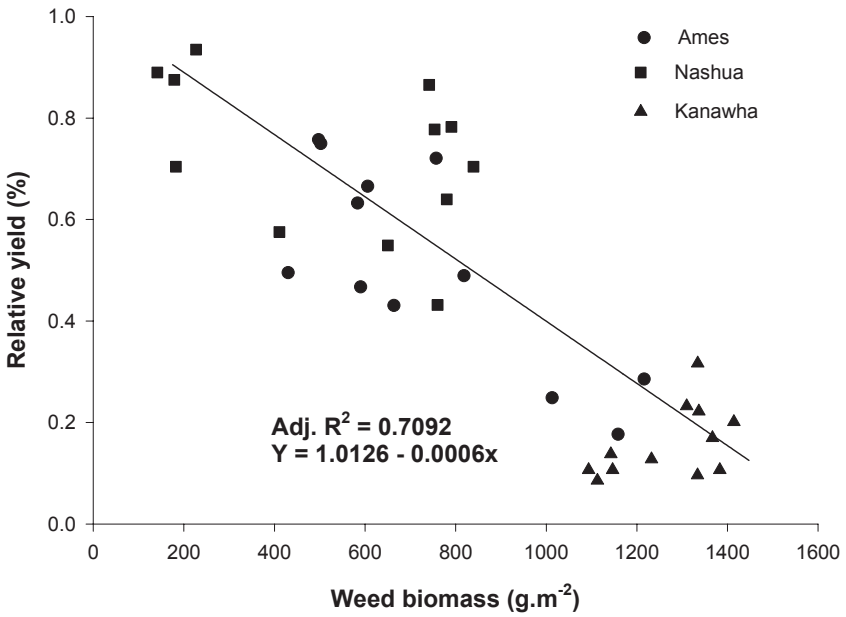

Figure 1. Relationship between full-season weed biomass and soybean yields.

related to weed biomass (Figure 1). Preemergence herbicides provide a wider window of application by reducing weed growth early in the season.

Reducing selection pressure

A primary concern with today's weed management systems is our heavy reliance on glyphosate. The more glyphosate is used, the greater the likelihood of selecting weeds with traits allowing them to survive this herbicide. Sequential applications or tank mixes of alternative herbicides can reduce the potential for selecting glyphosate resistant weeds in glyphosate resistant crops by placing alternative selection pressures on weed communities.

The effectiveness of a preemergence herbicide in protecting the value of glyphosate is determined by how effective the soil-applied product is against the weeds present in the field. If the herbicide has little activity on a major weed in a field, or if the rate is too low to provide broad-spectrum control, the preemergence herbicide will provide little value in reducing the likelihood of weed shifts.

The importance of selecting an appropriate foundation herbicide is illustrated in the following table. Both herbicides were effective against foxtail and waterhemp, and reduced the number of weeds of theses species controlled by glyphosate by at least 75% (Table 2). Neither Harness Xtra® nor INT*RR*O® was effective against velvetleaf, and thus they had little effect on selection pressure on this weed. INT*RR*O® actually increased selection pressure by reducing competition from other weeds, therefore increasing survival of velvetleaf compared to plots not receiving a preemergence herbicide.

To fully eliminate the risk of weed shifts induced by glyphosate, a preemergence herbicide would need to provide redundant weed control – that is, the residual herbicide would need to control weeds as effectively as glyphosate. Obviously, common sense and economics prevent this approach. However, selecting herbicides that have good activity on the primary weeds found in the field should reduce the selection pressure sufficiently to reduce the risk of shifts to weeds capable of surviving glyphosate.

Conclusion

The unique characteristics of glyphosate have greatly simplified weed management in corn and soybeans. While it is hard to argue against simplicity, I think the words of a British mathematician should be considered. Alfred North Whitehead (1861-1947) made the following quote: seek simplicity and mistrust it. Mistrust might be too harsh of a word, but glyphosate and glyphosate resistant crops must be used wisely to maximize profits and protect the value of this tool. As more acres are converted to glyphosate resistant corn resulting in continuous planting of glyphosate resistant crops, preemergence herbicides provide an opportunity to reduce risks associated with early-season competition and weed shifts.

Corn Herbicide Effectiveness Ratings[1]

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

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

[1]Ratings in this table are based on full label rates. Premix products containing ingredients marketed as single a.i. products may not be listed in this table.
[2]ALS-resistant biotypes of these weeds have been identified in Iowa. These biotypes may not be controlled by all ALS herbicides.
[3]Use only on designated resistant hybrids.
*Degree of perennial weed control is often a result of repeated application.
This chart should be used only as a guide. Ratings of herbicides may be higher or lower than indicated depending on soil characteristics, managerial factors, environmental variables, and rates applied. The evaluations for herbicides applied to the soil reflect appropriate mechanical weed control practices.

Soybean Herbicide Effectiveness Ratings[1]

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

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

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[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.
*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.

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	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Accent Gold	6.5% nicosulfuron 6.5% rimsulfuron 19.1% flumetsulam 51.7% clopyralid	2.9 oz	0.1885 oz nicosulfuron 0.1885 oz rimsulfuron 0.5539 oz flumetsulam 1.5 oz clopyralid	0.25 oz Accent 0.1885 oz rimsulfuron 0.69 oz Python* 3.66 oz Stinger* *= 3.0 oz of Hornet
Accent Gold WDG	5.4% nicosulfuron 5.4% rimsulfuron 15.9% flumetsulam 51.4% clopyralid	3.5 oz	0.1885 oz nicosulfuron 0.1885 oz rimsulfuron 0.5539 oz flumetsulam 1.5 oz clopyralid	0.25 oz Accent 0.1885 oz rimsulfuron 0.69 oz Python* 3.66 oz Stinger* *= 3.0 oz of Hornet
Axiom 68DF	54.4% flufenacet 13.6% metribuzin	16.0 oz	8.64 oz flufenacet 2.17 oz metribuzin	14.4 oz Define 2.9 oz Sencor DF
Axiom AT	19.6% flufenacet 4.9% metribuzin 50.5% atrazine	3.0 lb	9.41 oz flufenacet 2.35 oz metribuzin 1.52 lb atrazine	15.7 oz Define 3.1 oz metribuzin 1.5 lb atrazine
Basis 75DF	50% rimsulfuron 25% thifensulfuron	0.33 oz	0.167 oz rimsulfuron 0.083 oz thifensulfuron	0.167 oz rimsulfuron 0.33 oz Pinnacle 25DF
Basis Gold 89.5DF	1.34% rimsulfuron 1.34% nicosulfuron 86.8% atrazine	14 oz	0.188 oz rimsulfuron 0.188 oz nicosulfuron 12.15 oz atrazine	0.188 oz rimsulfuron 0.25 oz Accent 75DF 13.5 oz atrazine 90DF
Bicep II MAG. 5.5L, Cinch ATZ	2.4 lb S-metolachlor 3.1 lb atrazine	2.1 qt	1.26 lb S-metolachlor 1.63 lb atrazine	21 oz Dual II MAGNUM 52 oz atrazine 4L
Bicep Lite II MAG, Cinch ATZ Lite	3.33 lb S-metolachlor 2.67 lb atrazine	1.5 qt	1.24 lb S-metolachlor 1.00 lb atrazine	21 oz Dual II MAGNUM 32 oz atrazine 4L
Buctril + Atr.	1.0 lb bromoxynil 2.0 lb atrazine	2.0 pt	0.25 lb bromoxynil 0.50 lb atrazine	1 pt bromoxynil 2E 1 pt atrazine 4L
Bullet 4ME	2.5 lb alachlor 1.5 lb atrazine	4.0 qt	2.5 lb alachlor 1.5 lb atrazine	2.5 qt Micro-Tech 4ME 1.5 qt atrazine 4L
Celebrity Plus	46.6 % dicamba 10.6% nicosulfuron 18.1% diflufenzopyyr	4.7 oz	2 oz dicamba 0.031 lb nicosulfuron 0.8 oz diflufenzopyr	4 oz Banvel 0.67 oz Accent

Corn Herbicide Package Mixes (continued)

Herbicide	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Degree Xtra	2.7 lb acetochlor 1.34 lb atrazine	3 qt	2 lb acetochlor 1 lb atrazine	36.6 oz Harness 7E 1 qt atrazine 4L
Distinct 70WDG	21.4 % diflufenzopyr 55.0% dicamba	6 oz	1.3 oz diflufenzopyr 3.3 oz dicamba	1.3 oz diflufenzopyr 6 oz Banvel
Epic 58DF	48% flufenacet 10% isoxaflutole	12 oz	0.36 lb flufenacet 0.075 lb isoxaflutole	9.6 oz Define 1.6 oz Balance
Equip	30% foramsulfuron 2% iodosulfuron	1.5 oz	0.45 oz foramsulfuron 0.03 oz iodosulfuron	1.29 oz Option -
Exceed 57WG	28.5% prosulfuron 28.5% primisulfuron	1 oz	0.018 lb prosulfuron 0.018 lb primisulfuron	0.5 oz Peak 57WG 0.38 oz Beacon 75SG
Expert 4.9SC	1.74 lb S-metolachlor 2.14 lb atrazine 0.74 lb ae glyphosate	3 qt	1.3 lb S-metolachlor 1.61 lb atrazine 0.55 lb ae glyphosate	1.4 lb Dual II Mag. 1.6 qt Aatrex 4L 1.5 pt Glyphosate 3L
FieldMaster	2.0 lb acetochlor 0.75 lb glyphosate 1.5 lb atrazine	4.0 qt	2.0 lb acetochlor 0.75 lb glyphosate 1.5 lb atrazine	2.3 pt Harness 24 oz Roundup Ultra 1.5 qt atrazine 4L
FulTime 4CS	2.4 lb acetochlor 1.6 lb atrazine	4 qt	2.4 lb acetochlor 1.6 lb atrazine	3 pt Surpass 6.4EC 3.2 pt atrazine 4L
Guardsman 5L	2.33 lb dimethenamid 2.67 lb atrazine	4 pt	1.17 lb dimethenamid 1.34 lb atrazine	1.6 pt Frontier 6E 2.7 pt atrazine 4L
G-Max Lite 5L	2.25 lb dimethenamid 2.75 lb atrazine	3.0 pt	0.84 lb dimethenamid-P 1.0 lb atrazine	18 oz Outlook 2 pt Aatrex 4L
Guardsman Max 5L	1.7 lb dimethenamid-P 3.3 lb atrazine	3.4 pt	0.7 lb dimethamid-P 1.4 lb atrazine	15 oz Outlook 1.4 lb atrazine 4L
Harness Xtra	4.3 lb acetochlor 1.7 lb atrazine	2.3 qt	2.5 lb acetochlor 0.98 lb atrazine	46 oz Harness 7E 1 qt atrazine 4L
Harness Xtra 5.6L	3.1 lb acetochlor 2.5 lb atrazine	3 qt	2.325 lb acetochlor 1.875 lb atrazine	42.5 oz Harness 7E 1.9 qt atrazine 4L
Hornet WDG	18.5% flumetsulam 60% clopyralid	5 oz	0.924 oz flumetsulam 0.195 lb clopyralid	1.15 oz Python WDG 6.68 oz Stinger 3S
Keystone 5.25L	3.0 lb acetochlor 2.25 lb atrazine	2.7 qt	2.0 lb acetochlor 1.5 lb atrazine	2.5 pt Surpass 6.4E 3.0 pt Aatrex 4L

Corn Herbicide Package Mixes (continued)

Herbicide	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Keystone LA 5.5L	4.0 lb acetochlor 1.5 lb atrazine	2.0 qt	2.0 lb acetochlor 0.75 lb atrazine	2.5 pt Surpass 6.4E 1.5 pt Aatrex 4L
Laddok S-12 5L	2.5 lb bentazon 2.5 lb atrazine	1.67 pt	0.52 lb bentazon 0.52 lb atrazine	1.0 pt Basagran 4S 1.0 pt atrazine 4L
Lariat 4L	2.5 lb alachlor 1.5 lb atrazine	4 qt	2.5 lb alachlor 1.5 lb atrazine	2.5 qt Lasso 4E 1.5 qt atrazine 4L
Lexar 3.7L	1.74 lb S-metolachlor 1.74 lb atrazine 0.224 lb mesotrione	3.5 qt	1.52 lb S-metolachlor 1.52 lb atrazine 0.196 lb mesotrione	1.6 pt Dual II Mag. 3 pt Aatrex 4L 6.27 oz Callisto
Liberty ATZ	1.0 lb glufosinate 3.3 lb atrazine	32 oz	0.25 lb glufosinate 0.825 lb atrazine	20 oz Liberty 0.825 qt atrazine 4L
Lightning 70DF	52.5% imazethapyr 17.5% imazapyr	1.28 oz	0.672 oz imazethapyr 0.224 oz imazapyr	0.96 oz Pursuit 70DG 0.78 oz Arsenal 28.7DF
Lumax	0.268 lb mesotrione 2.68 lb S-metolachlor 1.0 lb atrazine	3 qts	0.2 lb mesotrione 2.0 lb S-metolachlor 0.75 lb atrazine	6.4 oz Callisto 2 pt Dual II MAGNUM 0.75 qt Aatrex 4L
Marksman 3.2L	1.1 lb dicamba 2.1 lb atrazine	3.5 pt	0.48 lb dicamba 0.92 lb atrazine	0.96 pt Banvel 4S 1.84 pt atrazine 4L
NorthStar	7.5% primisulfuron 43.9% dicamba	5.0 oz	0.375 oz primisulfuron 2.20 oz dicamba	0.5 oz Beacon 75SG 4.0 oz Banvel 4L
Priority	12.3% carfentrazone 50% halosulfuron	1.0 oz	0.008 lb carfentrazone 0.032 lb halosulfuron	0.5 oz Aim 0.68 oz Permit
Radius	3.57 lbs flufenacet 0.43 lbs isoxaflutole	16 oz	0.47 lb flufenacet 0.05 lb isoxaflutole	15 oz Defince 4SC 1.7 oz Balance Pro
ReadyMaster ATZ	2 lb glyphosate 2 lb atrazine	2 qt	1 lb glyphosate 1 lb atrazine	1 qt Roundup Ultra 1 qt atrazine 4L
Shotgun 3.25L	2.25 lb atrazine 1 lb 2,4-D	2 pt	0.56 lb atrazine 0.25 lb a.e. 2,4-D	1.12 pt atrazine 4L 0.53 pt Esteron 99 3.8E
Spirit 57WG	14.25% prosulfuron 42.75% primisulfuron	1 oz	0.1425 oz prosulfuron 0.4275 oz primisulfuron	0.25 oz Peak 57WG 0.57 oz Beacon 75SG

Corn Herbicide Package Mixes (continued)

Herbicide	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
Steadfast 75DF	50% nicosulfuron 25% rimsulfuron	0.75 oz	0.37 oz nicosulfuron 0.19 oz rimsulfuron	0.5 oz Accent -
Steadfast ATZ	2.7% nicosulfuron 1.3% rimsulfuron 85.3% atrazine	14 oz	0.38 oz nicosulfuron 0.18 oz rimsulfuron 0.75 lb atrazine	0.5 oz Accent - 1.5 pt Atrazine 4L
Surpass 100 5L	3 lb acetochlor 2 lb atrazine	2.5 qt	1.88 lb acetochlor 1.25 lb atrazine	1.18 qt Surpass 6.4E 1.25 qt atrazine 4L
WideMatch 1.5EC	0.75 lb fluroxypyr 0.75 lb clopyralid	1.3 pt	0.125 lb fluroxypyr 0.125 lb clopyralid	10.6 oz Starane 1.5E 5.3 oz Stinger 3S
Yukon	12.5% halosulfuron 55% dicamba	4 oz	0.031 lb halosulfuron 0.125 lb dicamba	0.66 oz Permit 4.0 oz Banvel

Soybean Herbicide Package Mixes

Herbicide	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	6.21% sulfentrazone 7.96% cloransulam-methyl	8.0 oz	0.31 lb sufentrazone 0.04 lb cloransulam-methyl	6.6 oz Authority 75DF 0.76 oz FirstRate
Axiom 68DF	54.4% flufenacet 13.6% metribuzin	13 oz	0.44 lb flufenacet 1.77 oz metribuzin	11.7 oz Define 2.36 oz Sencor 75DF
Boundary 7.8EC	5.2 lbs s-metolachlor 1.25 lbs metribuzin	2.1 pt	1.4 lb s-metolachlor[1] 0.3 lb metribuzin	1.5 pt Dual II MAG. 6.4 oz Sencor 75DF
Canopy 75DF	10.7% chlorimuron ethyl 64.3% metribuzin	6 oz 0.24 lb	0.64 lb chlorimuron metribuzin	2.57 oz Classic 25DF 5.14 oz metribuzin 75DF
Commence 5.25E	2.25 lb clomazone 3.00 lb trifluralin	2.5 pt	0.70 lb clomazone 0.94 lb trifluralin	1.4 pt Command 4E 1.9 pt Treflan 4E
Detail 4.1E	0.5 lb imazaquin 3.6 lb dimethenamid	1 qt	0.125 lb imazaquin 0.90 lb dimethenamid	0.67 pt Scepter 1.5S 1.20 pt Frontier 6.0E
Domain 60DF	24.0% flufenacet 36.0% metribuzin	16 oz	0.24 lb flufenacet 0.36 lb metribuzin	6.4 oz Define 0.48 lb Sencor 75DF
Extreme	1.8% imazethapyr 22% glyphosate	3 pt	0.064 lb imazethapyr 0.75 lb glyphosate	1.44 oz Pursuit DG 24 oz Roundup
FrontRow	flumetsulam chloransulam	5 acres/pkg	0.15 oz flumetsulam 0.25 oz chloransulam	0.12 oz Python 80WDG 0.3 oz FirstRate 84WDG
Fusion 2.67E	2 lb fluazifop 0.67 lb fenoxaprop	8 fl oz	0.125 lb fluazifop 0.042 lb fenoxaprop	8 fl oz Fusilade DX 2E 8 fl oz Option II 0.67E
Galaxy 3.67S	3 lb bentazon 0.67 lb acifluorfen	2 pt	0.75 lb bentazon 0.17 lb actfluorfen	1.5 pt Basagran 4S 0.67 pt Blazer 2S
Pursuit Plus 2.9E	0.2 lb imazethapyr 2.7 lb pendimethalin	2.5 pt	0.063 lb imazethapyr 0.84 lb pendimethalin	4.0 oz Pursuit 2S 2.00 pt Prowl 3.3E
Sequence 5.25L	3.0 lb S-metolachlor 2.25 lb glyphosate	3 pt	1.13 lb S-metolachlor 0.84 lb ae glyphosate	1.2 pt Dual Magnum 26 oz Touchdown Total
Stellar 3.1E	2.4 lb lactofen 0.7 lb flumiclorac	5 fl oz	0.094 lb lactofen 0.027 lb flumiclorac	6 fl oz Cobra 2E 4 fl oz Resource 0.86E
Storm 4S	2.67 lb bentazon 1.33 lb acifluorfen	1.5 pt	0.50 lb bentazon 0.25 lb acifluorfen	1 pt Basagran 4S 1 pt Blazer 2S
Synchrony STS DF	31.8% chlorimuron 10.2% thifensulfuron	0.5 oz	0.159 oz chlorimuron 0.051 oz thifensulfuron	0.64 oz Classic 25DF 0.068 oz Harmony GT

Herbicide Site of Action and Injury Symptoms

Herbicides kill plants by disrupting an essential physiological process. 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 family generally have the same site of action. The mechanism by which a herbicide kills a plant is known as its "mode of action." For example, triazine herbicides interfere with photosynthesis by binding to the D1 protein 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 injury problems and for designing weed management programs with a low risk of selecting for herbicide-resistant weed populations.

ACCase Inhibitors

The ACCase enzyme is involved in the synthesis of fatty acids. Two herbicide families attack this enzyme. 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 is responsible for the resistance.

ALS Inhibitors

Several chemical families interfere with acetolactate synthase (ALS), an enzyme involved in the synthesis of branched-chain amino acids, specifically valine, leucine, and isoleucine. These amino acids are necessary for protein synthesis and plant growth. Generally, these herbicides are absorbed in plant 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 noted there. Symptoms include plant stunting, chlorosis (yellowing), and tissue necrosis (death), and are evident 1 to 4 weeks after herbicide application, depending upon the plant species and environmental conditions. Soybeans and other affected broad-leaves often develop reddish veins on undersides of leaves. Symptoms in corn include reduced secondary root formation, stunted roots, shortened internodes, leaf malformations (chlorosis, window-paning) and nutrient deficiency. However, symptoms typically are not distinct or consistent. Factors such as soil moisture, temperature, and soil compaction can enhance the occurrence of injury or may 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.

Microtubule Inhibitors

Dinitroaniline (DNA) herbicides inhibit cell division by interfering with the formation of microtubules. Dinitroaniline herbicides are soil-applied and absorbed mainly by roots. Very little herbicide translocation into 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 thick and short. Hypocotyl swelling also occurs. The inhibited root growth causes tops of plants to be stunted and often to demonstrate a dark green color. 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

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

Photosystem II Inhibitors

Several families of herbicide bind to a protein involved in electron transfer in Photosystem II (PSII). These herbicides inhibit photosynthesis, which may result in chlorosis of plant leaves followed by necrosis of leaf tissue. A secondary substance formed as a result of photosynthesis inhibition may be responsible for 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 occurs 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 (interveinal chlorosis). Lower leaves are most affected, and new leaves may be unaffected. Triazine and urea herbicides generally are absorbed both by roots and foliage, whereas benzothiadiazole and nitrile 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.

Photosystem I Inhibitors

Herbicides in the bipyridilium family rapidly disrupt cell membranes, resulting in wilting and tissue death. They capture electrons moving through Photostystem I (PSI) and produce highly destructive compounds. Very little translocation of bipyridilium herbicides occurs due to loss of plant 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

The specific site of action is an enzyme involved in synthesis of a precursor of chlorophyll; the enzyme is referred to as PPO. Postemergence applied diphenyl ether herbicides (e.g., aciflurofen) kill weed seedlings through contact action, membrane destruction, and photosynthesis inhibition. 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 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 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.

Enolpyruvyl Shikimate Phosphate Synthase (EPSPS) Inhibitors

Glyphosate is a substituted amino acid that interferes with amino acid synthesis by inhibiting the EPSPS enzyme. This enzyme is involved in the synthesis of several essential amino acids. Glyphosate is nonselective and is very tightly bound in soil, so no root uptake occurs. 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) or proliferation of vegetative buds.

Glutamine Synthetase Inhibitors

Glufosinate (Liberty) inhibits the enzyme glutamine synthetase, causing a buildup of ammonia in the plant which becomes phytotoxic. 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. The herbicide has no soil activity. Liberty is nonselective except to crops that carry the Liberty Link gene.

Hydroxyphenyl Pyruvate Dioxygenase (HPPD) Inhibitors

Isoxaflutole (Balance Pro), mesotrione (Callisto), and topramezone (Impact) bind to HPPD, an enzyme involved in the synthesis of carotene pigments. Injury symptoms include bleaching or chlorosis. Although the chemicals have the same site of action, they are not chemically related. The herbicides are absorbed both by roots and foliage.

Diterpene Inhibitors

Clomozone interferes with the synthesis of the same pigments as the HPPD inhibitors, but acts at a different enzyme within the metabolic pathway. Sensitive plants exposed to the herbicide turn white. Clomazone is xylem mobile and taken up in roots and shoots. Differential metabolism of clomazone confers tolerance to plants. Clomozone has a relatively high vapor pressure and may volatilize off the soil surface resulting in off-target injury.

Auxin Transport Inhibitors

Diflufenzopyr (Distinct) has a unique mode of action in that it inhibits the transport of auxin, a naturally occurring growth regulator. Diflufenzopyr 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 through the soil for some residual activity. Injury symptoms are similar to growth regulator herbicides.

Lipid Synthesis Inhibitors

Although the specific target site for the thiocarbamate herbicides has not been identified, it is believed the primary site of action is lipid synthesis. In grasses, thiocarbamate herbicides inhibit meristem activity and cause abnormal emergence of leaves from the coleoptile. The growth of susceptible broadleaf weeds is inhibited, and plants exhibit cupped or crinkled leaves. Uptake may occur through seeds, shoots, and roots; shoots are more affected than roots. These herbicides are soil-applied and most must be physically incorporated into the soil due to volatility characteristics. Corn injury from thiocarbamate herbicides is demonstrated by leaves not properly unrolling from the coleoptile. Leaves are stunted and twisted, often appearing knotted. In recent years, antidotes or safeners have been developed that help to prevent thiocarbamate injury to corn. These are formulated directly with the herbicide. The protective mechanism of these antidotes is not known, but they may enable corn to more rapidly degrade the herbicides. The antidotes are formulated directly with the herbicides; Sutan+ contains R-25788, and Eradicane contains R-29148. Soybean injury from thiocarbamate herbicides occurs as slowed emergence and crinkling of leaves on seedling plants. The antidotes or safeners do not protect soybeans from thiocarbamate herbicides.

Unknown Site of Action

Herbicides in the amide family (also referred to as acetanilides or acetamides) inhibit root and shoot growth causing stunted, malformed seedlings. The specific site of action and mode of action of this herbicide family is unknown. Normal cell division, cell elongation, and protein synthesis are potentially inhibited. The herbicides must be present in early stages of germination and growth of weeds for effective control. These herbicides are most effective on annual grass weeds, although some small-seeded annual broadleaf weeds are also sensitive. Injury symptoms to corn from these herbicides include leafing out underground and failure of leaves to properly unfurl. Soybean injury from these herbicides occurs in the form of a shortened mid-vein in the leaflets resulting in crinkling and a heart-shaped appearance. Dimethenamid (Frontier) and flufenacet (Axiom) have slightly different chemical structures than the amide herbicides, but it is believed they kill plants in the same manner as the amides.

ACCase inhibitor	
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, Arrow, others	clethodim

ALS inhibitors	
imidazolinones	
Lightning	imazethapyr + imazapyr
Pursuit	imazethapyr
Pursuit Plus	imazethapyr + pendimethalin
Raptor	imazamox
Scepter	imazaquin
Squadron	imazaquin + pendimethalin
sulfonanilides	
FirstRate, Amplify	chloransulam
Hornet WDG	flumetsulam + clopyralid
Python	flumetsulam
sulfonylureas	
Accent	nicosulfuron
Accent Gold	nicosulfuron + rimsulfuron + clypyralid + flumetsulam
Ally, Cimarron	metsulfuron
Basis	rimsulfuron + thifensulfuron
Basis Gold	rimsulfuron + nicosulfuron + atrazine
Beacon	primisulfuron
Canopy	chlorimuron + metribuzin
Celebrity Plus	nicosulfuron + dicamba + diflufenzopyr
Classic	chlorimuron
Equip	foramsulfuron + iodosulfuron + safener
Exceed, Spirit	prosulfuron + primisulfuron
Express	tribenuron
Harmony GT	thifensulfuron
NorthStar	primisulfuron + dicamba
Option	foramsulfuron + safener
Permit	halosulfuron
Resolve	rimsulfuron
Steadfast	nicosulfuron + rimsulfuron
Steadfast ATZ	nicosulfuron + rimsulfuron + atrazine
Synchrony STS	chlorimuron + thifensulfuron
Yukon	halosulfuron + dicamba

Microtubule inhibitor

dinitroanilines	
Balan	benefin
Commence	trifluralin + clomazone
Prowl H_2O, Pentagon, Pendimax, others	pendimethalin
Sonalan	ethalfluralin
Surflan	oryzalin
Treflan, others	trifluralin

Synthetic auxin

benzoic	
Banvel, Clarity, others	dicamba
Celebrity Plus	dicamba + nicosulfuron + diflufenzopyr
Distinct	dicamba + diflufenzopyr
Marksman, others	dicamba + atrazine
NorthStar	dicamba + primisulfuron
Yukon	dicamba + halosulfuron
phenoxy	
many	MPCA
many	2,4-D
Butyrac, Butoxone	2,4-DB
pyridines	
Crossbow	triclopyr + 2,4-D
Grazon P&D	picloram + 2,4-D
Hornet WDG	clopyralid + flumetsulam
Redeem	triclopyr + clopyralid
Milestone	aminopyralid
Stinger, Transline	clopyralid
Tordon	picloram

Photosystem II inhibitors

benzothiadiazole	
Basagran	bentazon
Galaxy, Storm	bentazon + acifluorfen
Laddok	bentazon + atrazine
nitriles	
Buctril, others	bromoxynil
Buctril + atrazine	bromoxynil + atrazine
triazines	
AAtrex, others	atrazine
Evik	ametryne
Princep	simazine
Sencor	metribuzin
ureas	
Karmex	diuron
Lorox	linuron

Photosystem I inhibitors

Diquat, Reward	diquat
Gramoxone Max	paraquat

Protoporphyrinogen Oxidase (PPO) inhibitors

aryl triazolinones	
Aim	carfentrazone
Authority, Spartan	sulfentrazone
Authority First, Sonic	sulfentrazone + cloransulam
Canopy XL	sulfentrazone + chlorimuron
Command Xtra	sulfentrazone + clomazone
diphenyl ethers	
Blazer, UltraBlazer	acifluorfen
Cobra, Phoenix	lactofen
ET	pyraflufen
Flexstar, Reflex	fomesafen
Goal	oxyfluorfen
phenylphthalimides	
Gangster	flumioxazin + cloransulam
Resource	flumiclorac
Valor	flumioxazin

Enolpyruvyl shikimate phosphate synthase (EPSPS) inhibitors

Roundup, Touchdown, others	glyphosate
ReadyMaster ATZ	glyphosate + atrazine
Extreme	glyphosate + imazethapyr
Sequence	glyphosate + s-metolachlor

Glutamine synthetase inhibitors

Liberty	glufosinate
Liberty ATZ	glufosinate + atrazine

Hydroxyphenyl pyruvate dioxygenase (HPPD) inhibitors

Balance Pro	isoxaflutole
Epic, Radius	isoxaflutole + flufenacet
Callisto	mesotrione
Impact	topramezone
Lexar, Lumax	mesotrione + atrazine + s-metolachlor

Diterpene inhibitors

Command	clomazone
Command Xtra	clomazone + sulfentrazone

Auxin transport inhibitors

Distinct	diflufenzopyr + dicamba

Lipid synthesis inhibitors

Eradicane, others	EPTC + R-29148
Sutan +	butylate + R-29148
Sutazine	butylate + R-29148 + atrazine

Unknown

amides or acetanilides	
Axiom, Domain	flufenacet + metribuzin
Axiom AT	flufenacet + metribuzin + atrazine
Bicep II MAGNUM, Bicep Lite II MAGNUM, Cinch ATZ, others	s-metolachlor + atrazine + safener
Boundary	metolachlor + metribuzin
Bullet	alachlor + atrazine
Define	flufenacet
Degree, Harness, Surpass, TopNotch, others	acetochlor + safener
Dual II MAGNUM, Cinch, others	s-metolachlor + safener
Domain	flufenacet + metribuzin
Epic, Radius	flufenacet + isoxaflutole
FieldMaster	acetochlor + atrazine + glyphosate + safener
Frontier, Outlook, others	dimethenamid
FulTime, Surpass 100	acetochlor + atrazine + safener
Guardsman Max, others	dimethenamid + atrazine
Lariat	alachlor + atrazine
Lasso, Intrro, MicroTech	alachlor

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.

Prepared by Micheal D. K. Owen, Professor, Department of Agronomy and Robert G. Hartzler, Professor, Department of Agronomy. Design by Brent A. Pringnitz, Extension Program Specialist, Department of Agronomy.