2008 Herbicide Guide for Iowa Corn and Soybean Production

Weed management in 2008 – weed shifts, volunteer corn, and stewardship

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Introduction

There are a number of new developments and considerations for weed management for 2008. Glyphosate continues to dominate as a weed control tactic in soybean and corn, and it is a certainty that more herbicide resistant corn will be planted. While the benefits of the glyphosate technology are many, there are several unintended consequences. These unintended consequences include new weed problems, evolved glyphosate resistance and volunteer crop management issues. Thus, the need to include stewardship to supplement crop production tactics becomes increasingly important.

Weed population shifts

Agriculture imparts selection pressure on weed communities that inevitably result in weed population shifts. The most influential selective forces that act on a weed community are tillage (disturbance) and herbicide regimes. Production systems used in glyphosate resistant crops (GRCs) increases selection pressure on the weed community due to the limited number herbicides (glyphosate) used to control weeds and increased selection pressure increases weed population shifts. The definition of a weed population shifts includes evolved herbicide resistance and naturally tolerant weed populations which developed as a result of the selection pressure(s) imposed by the crop production system. Specifically for GRCs, both "types" of weed population shifts have occurred in response to grower use of glyphosate in GRC-based systems. In Iowa, we have documented weed shifts involving naturally tolerant weed populations, but glyphosate-resistant weed populations have not been validated. However, anecdotal evidence strongly supports the supposition that glyphosate-resistant weed populations exist in Iowa.

Speed of weed population shifts

It has been interesting to follow the predictions of how quickly weed shifts would develop. Early predictions suggested that shifts in weed populations would not evolve. Other predictions suggested that weed population shifts were inevitable and would occur sooner rather than later. Shifts to tolerant weed species were predicted to occur between 5 to 8 years after the adoption of GRCs and that species with resistance to glyphosate would evolve slower while others reported that the speed at which weed shifts were expected to occur was uncertain. This time frame is more or less accurate in Iowa production systems. However, exceptions to these general do occur and the likelihood that weed population shifts will occur quicker than suggest must not be ignored.

For example, resistance to glyphosate in isolated common waterhemp plants was observed two years after the commercialization of GR soybean and in horseweed, glyphosate resistance was widely distributed three years after GR soybean commercialization. In the case of common waterhemp, the progression from an occasional glyphosate-resistant individual to a major problem in fields has taken longer than observed for horseweed. This is due, in part, to the genetics that is thought to control resistance in common waterhemp (polygenic) and the reproductive strategy found in common waterhemp (dioecious plant). Horseweed is an excellent example of a weed species with a specialized dispersal mechanism that has facilitated a wide-spread, economically important weed population shifts in a relatively short period of time. Most annual weeds in Iowa do not have specialized dispersal mechanisms. However, production practices (tillage and harvesting equipment) and socio-economic factors (fewer growers farming more acres over a larger distance) has minimized the requirement for specialization of seed dispersal in order for herbicide resistance to spread relatively quickly.

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Glyphosate resistance in weeds

The evolution of resistance to glyphosate is an accepted fate of repeated use of glyphosate in GRCs. It is now apparent that there were fewer constraints on the evolution of glyphosate resistance than originally proposed and resistance to glyphosate has evolved in many species and is widely distributed. While glyphosate resistant weeds have not been "officially" documented in Iowa, it is highly likely that populations exist and are awaiting "discovery". Thus there is a need for alternative tactics to manage weeds in GRCs and the lack of alternatives continues to be a concern. Growers need to initiate stewardship immediately in order to maintain glyphosate-based weed management in GRCs.

Marestail

Marestail populations continue to escalate as a significant weed problem in GRCs. Marestail is adapted to conservation tillage and has demonstrated the ability to evolve resistance to glyphosate. Anecdotal reports suggest that glyphosate-resistant horseweed populations are now frequent in the mid-Atlantic, mid-south, and Mississippi River Delta and Midwest regions of the United States. The difficulty of managing marestail with alternative herbicides reinforces the fact that horseweed is a significant agronomic problem. Marestail is becoming a more frequent problem in Iowa and it is highly probable that glyphosate-resistant populations exist.

Common waterhemp

Common waterhemp is well-adapted to the prevailing crop systems in the Midwest, secondarily evolved resistance to most ALS inhibitor herbicides and ultimately evolved resistance to glyphosate. The first reports of common waterhemp control problems with glyphosate were in 1998 in fields near Badger and Everly, Iowa. Recent anecdotal reports from Iowa growers indicate that the difficulties of effectively managing common waterhemp with glyphosate are increasing rapidly. Given the ability of common waterhemp to adapt to ecologically diverse agro ecosystems and numerous herbicide mechanisms of action, management options are often few.

Species naturally "tolerant" to glyphosate

While a number of weeds have been described as having natural "tolerance" to various herbicides, ecological adaptation to the crop system, specifically the tillage regime and environmental conditions that prevail is of greater importance. However, several weeds which have historically demonstrated adaptation to the crop system have increased with the grower adoption of GRCs.

Common lambsquarters

Common lambsquarters is adapted to conservation tillage systems and has been a difficult weed to manage in many crops. Anecdotal observations across the Midwest have suggested that common lambsquarters populations were not responding to glyphosate. However, common lambsquarters populations were confirmed as glyphosate resistant in Ohio and current assessments in Indiana and Wisconsin also suggest the presence of glyphosate-resistant populations. There are populations in Iowa that are suspected to be glyphosate resistant.

Giant ragweed

Giant ragweed has been a significant weed problem in Ohio and Indiana for a number of years and is described as the major weed problem in those states. In GRCs, giant ragweed populations increased over time in long-term study conducted in Wisconsin and selection pressure from ALS-inhibiting herbicides caused rapid population shifts to the resistant biotypes. Recent reports indicate that glyphosate-resistant giant ragweed populations evolved rather quickly and are now widely distributed across Ohio and Indiana. Anecdotal reports from growers in Iowa and Wisconsin suggest that there is a high probability that glyphosate-resistant giant ragweed populations have or will soon evolve in these states.

Velvetleaf

Velvetleaf is difficult to control with glyphosate. However, the tolerance of this economically important weed to glyphosate was not an issue until the wide spread adoption of GRCs. Recent reports suggested that the survival of velvetleaf after exposure to glyphosate can be high. However, overall velvetleaf populations do not appear to be increasing dramatically as a result of GRCs and may likely be declining because the species is not well-adapted to the prevailing conservation tillage systems that are a significant component of GRCs.

Asiatic dayflower

Asiatic dayflower has been a serious, albeit scattered weed problem in soybean fields in the Midwest. Recent information suggests that Asiatic dayflower is spreading although not quickly. Apparent natural tolerance to glyphosate and other biological characteristics (i.e. extended germination period) contribute to the inability of growers to effectively manage this weed. Research has not demonstrated any consistent herbicide control tactics and it is anticipated that Asiatic dayflower populations will continue to increase given the predominance of GRCs.

Other species

There are a number of anecdotal reports from Iowa of weeds that are increasing in GRCs. Evening primrose has been reported to be an isolated but significant problem in specific Iowa fields where GRCs are cultivated. Wild parsnip is another biennial plant that has been reported to be invading GRCs (and other non-GR cultivars) in Iowa. Wild parsnip is commonly found in roadsides, ditches and right-of-ways, but until recently was not observed to be a significant problem in row crops. Pokeweed is a perennial weed that has increased in fields. It is unlikely that the ecological adaptation is attributable to GRCs other than the fact that GRC-based systems are predominately no tillage. Finally, field horsetail has

effectively invaded row crop fields from field margins. Field horsetail is extremely tolerant of most herbicides including glyphosate.

Managing "traited" corn as a volunteer or when replanting is necessary

The 2007 spring planting conditions were not ideal and resulted in a significant number of corn acres that required replanting. ISU has discussed problems with destroying a corn stand or controlling volunteer corn in soybeans when the hybrid has herbicide resistance trait(s) in the past, but the message was reinforced this in 2007. With regard to destroying a corn stand, if the hybrid is Liberty Link, the task is relatively simple. Glyphosate will effectively destroy an unwanted corn stand if the only herbicide resistant trait is for glufosinate or the corn is not herbicide resistant. However, even in non-herbicide resistant corn hybrids, traits for glyphosate resistance show up and result in ineffective destruction of the stand. When the herbicide resistance trait is for glyphosate, the use of glufosinate is less consistent. And when traits are stacked, the tactics for managing corn in corn can be difficult at best. Some states in the Eastern Corn Belt received special labels for post grass herbicides labeled but the delay between application and replanting was problematic. Tillage may be the best solution. For controlling volunteer corn in soybean, glyphosate can be very effective unless the previous corn crop was Roundup Ready®. Another consideration is whether or not the glyphosate resistance trait moved into a non-herbicide resistant corn crop resulting in de facto Roundup Ready® volunteers. Thus, management of volunteer corn in soybeans is better handled by using a post grass herbicide registered for soybeans.

Conclusions

Stewardship of weed management tools is of premier importance to Iowa growers. Use as many weed management tactics as possible in order to maintain effective, consistent and economically rewarding weed management. With regard to weed shifts, the pervasive question that must be answered is if a weed population shift is economically important. Regardless, there is an urgent need to establish stewardship to protect glyphosate resistant crops and extend the utility of glyphosate as an effective herbicide.

New herbicide products for 2008

Robert Hartzler, extension weed specialist, Iowa State University

Several new products are, or are expected to be, available for use in the 2008 growing season. It is wise to evaluate how any new technology fits within an operation by initially using on a limited basis. However, since most of the new products are based on previously registered active ingredients, many farmers may already have experience with these materials. In addition, since most active ingredients are off patent, they may be sold under new trade names by a variety of manufacturers. Failure to include these products in this bulletin is not intended to imply non-approval.

DuPont has released two new products based on the active ingredients in Valor, Harmony GT and Classic will receive registration in time for the 2008 season. Both products will provide burndown of winter and summer annual weeds and some residual activity of broadleaf weeds. They can be applied up to 30 days ahead of planting until prior to soybean emergence. **Enlite 47.9DG** consists of 36.2% flumioxazin + 8.8% thifensulfuron + 2.8% chlorimuron ethyl. The use rate is 2.8 oz, which will provide the equivalent of 2 oz Valor, 1/3 oz Harmony GT and 1/3 oz Classic. It is targeted for northern Iowe due to the lower chlorimuron rate which provides greater rotation flexibility than Envive. **Envive 41.3DG** consists of 29.2% flumioxazin + 2.9% thifensulfuron + 9.2% chlorimuron ethyl. The maximum label rate of 5.3 oz/A will provide the equivalent of 3 oz Valor, 0.2 oz Harmony GT and 1.9 oz Classic. The higher rates of flumioxazin and chlorimuron rate in Envive compared to Enlite will enhance residual control, but brings risks of carryover in fields with variable pH.

Valent has introduced **Valor XLT**, a premix of flumioxazin and chlorimuron. It is labeled for fall, EPP and PRE applications in soybean at rates from 3 to 5 oz/A. A 5 oz rate provides the equivalent of 3 oz Valor + 2 oz Classic. Valor XLT should not be used on fields treated with an amide type herbicide (Dual, IntRRo, etc.). The maximum rate on soils with a pH >6.8 is 2.5 oz.

Dow AgroSciences has introduced **Surestart SE**, a product containing the active ingredients found in Surpass and Hornet (3.75 lb acetochlor + 0.29 lb clopyralid + 0.12 lb flumetsulam). A 2 pt rate of Surestart provides the equivalent of 1.2 pt Surpass 6.4E and

approximately 2.5 oz of Hornet WDG (ratio of clopyralid and flumetsulam are different in Hornet and Surestart). The label states that Surestart is only to be used on herbicide resistant corn (RR or LL) and is intended to provide early season control of weeds in order to allow optimum timing of the postemergence herbicide. Can be applied preplant, preemergence or early postemergence (up to 11" corn or 1 to 2" weeds).

FMC will introduce **Authority MTZ** (18% sulfentrazone + 27% metribuzin) for preplant and preemergence applications in soybean. The registered rates are 12 to 20 oz/A, a 16 oz rate will provide the equivalent of 3.8 oz Authority and 1 pt Sencor 4L. Authority MTZ should not be applied on soils with a pH greater than 7.5. **Rage D-Tech** is a premix containing carfentrazone (Aim) and 2,4-D. It can be used as a burndown in corn and soybean, where the carfentrazone will improve activity of 2,4-D on winter annuals, and postemergence in corn.

Syngenta has released **Halex GT** for use in glyphosate resistant corn. It is a premix of glyphosate, S-metolachlor (Dual) and mesotrione (Callsto). The product is designed for early post applications to control emerged weeds and provide residual control. A 3.6 pt rate will provide the equivalent of 1 pt Dual Magnum, 3 oz Callisto and 24 oz Touchdown HiTech. The product does not contain the safener present in Dual II Magnum, so it is not recommended for preemergence applications. It can be applied up to 30" or 8 leaf corn.

Bayer anticipates a label for tembotrione (**Laudis**) in time for the 2008 growing season. This herbicide inhibits the activity of HPPD, an enzyme involved in the synthesis of carotene pigments. It will be labeled for postemergence applications in corn for broadleaf and grass control. While Laudis has significantly more grass activity than other products with the same mode of action (Callisto and Impact), it should not be viewed as a stand-alone grass product for most weed infestations. The use rate will be 3 oz/A, and will need to be used with a COC or MSO plus UAN. A half pound of atrazine is recommended as a tank-mix partner to improve the consistency of broadleaf control. Laudis includes the safener isoxadifen, allowing use on seed, sweet and popcorn, as well as field corn.

New herbicide resistant traits in development

As it has become more difficult and expensive to discover and register new herbicides, companies have focused efforts on introducing genes that will provide resistance to existing products. In the past year several announcements have been made of new genes in the process of being registered and incorporated into commercial lines of corn and soybean.

Bayer will be introducing Liberty Link soybeans to the market in 2008. A limited number of acres will be planted in 2008 (approximately 15,000 in Iowa), with full release anticipated for 2009. The resistance mechanism is the same as that used in LL corn, an enzyme that rapidly metabolizes glufosinate.

Monsanto acquired development rights from the University of Nebraska for a gene that provides resistance to dicamba in soybean via rapid metabolism of the herbicide. Commercial release is anticipated in 2012 or 2013.

DuPont will introduce Optimum GAT, a trait that provides resistance to both glyphosate and ALS herbicides. Glyphosate resistance is achieved through an enzyme that metabolizes glyphosate, compared to an insensitive site of action that is used in Roundup Ready and Agrisure GT crops. A variety of ALS herbicides could be used in conjunction with glyphosate, but none will have activity on ALS resistant waterhemp or other resistant species. A target date of 2009 is targeted for soybean, whereas Optimum GAT corn is hoped to be released in 2010.

Dow AgroSciences is developing DHT (Dow Herbicide Trait) that provides resistance to phenoxy (2,4-D) and AOPP (Assure, Poast, etc.) herbicides. Launch is expected in 2012 for corn and 2013-14 for soybean.

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, Breakfree, 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
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	F	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
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-E	F-G	F	G	F	F	G-E	G-E	G-E	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
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	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
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
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.
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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
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
Breakfree ATZ 5.25L	3.0 lb acetochlor 2.25 lb atrazine	2.7 qt	2.0 lb acetochlor 1.5 lb atrazine	2.5 pt Breakfree 6.4E 3.0 pt atrazine 4L
Breakfree ATZ Lite 5.5L	4.0 lb acetochlor 1.5 lb atrazine	2.0 qt	2.0 lb acetochlor 0.75 lb atrazine	2.5 pt Breakfree 6.4E 1.5 pt 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
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
Halex GT	2.09 lb *S*-metolachlor 0.209 lb mesotrione 2.09 lb glyphosate	3.6 pt	0.94 lb *S*-metolachlor 0.09 lb mesotrione 0.94 lb glyphosate ae	1.0 pt Dual II Magnum 3.0 oz Callisto 24 oz Touchdown HiTech
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

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 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
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
SureStart SE	3.75 lb acetochlor 0.29 lb clopyralid 0.12 lb flumetsulam	2.0 pt	0.94 lb acetochlor 1.2 oz clopyralid 0.48 oz flumetsulam	1.2 pt Surpass 6.4E 3.2 oz Stinger 3S 0.6 oz Python WDG
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 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)
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
Authority MTZ	18% sulfentrazone 27% metribuzin	16 oz	0.18 lb sulfentrazone 0.27 metribuzin	3.8 oz Authority 75DF 1.0 pt Sencor 4L
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
Enlite 47.9DG	36.2% flumioxazin 8.8% thifensulfuron 2.8% chlorimuron ethyl	2.8 oz	1.0 oz flumioxazin 0.25 oz thifensulfuron 0.08 chlorimuron ethyl	2.0 oz Valor 0.33 oz Harmony GT 0.32 oz Classic

Soybean 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)
Envive 41.3DG	29.2% flumioxazin 2.9% thifensulfuron 9.2% chlorimuron ethyl	5.3 oz	1.5 oz flumioxazin 0.15 oz thifensulfuron 0.49 oz chlorimuron ethyl	3.0 oz Valor 0.20 oz Harmony GT 1.9 oz Classic
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
Gangster (co-pack)	51% flumioxazin 84% chloransulam	3.6 oz	1.5 oz flumioxazin 0.5 oz chloransulam	3.0 oz Valor 0.6 oz FirstRate
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 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 thick and short. Hypocotyl swelling also occurs. 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

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. 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 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) and proliferation of vegetative buds, or in some cases cause bleaching of foliage.

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. It is sold only in combination with dicamba. 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. Status (dicamba + diflufenzopyr) includes a safener to improve crop safety.

Lipid Synthesis Inhibitors

Two families of chemistry, the thiocarbamates and amide, are believed to inhibit the synthesis of lipids. The specific site of action was unknown until relatively recently, but now it is believed these chemicals inhibit a family of elongase enzymes that are responsible for the formation of very long chain fatty acids. These compounds are important components of membranes and the cuticle. 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. Safeners have been developed that help to prevent thiocarbamate injury to corn. These safeners 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 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. Safeners are formulated with metolachlor (Dual II Magnum) and acetochlor (Harness, Surpass, others) to reduce the risk of corn injury.

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, Status	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, Status	diflufenzopyr + dicamba

Lipid synthesis inhibitors

thiocarbamates	
Eradicane, others	EPTC + R-29148
Sutan +	butylate + R-29148
Sutazine	butylate + R-29148 + atrazine
amides or acetanilides	
Bicep II MAGNUM, Bicep Lite II MAGNUM, Cinch ATZ, others	s-metolachlor + atrazine + safener
Boundary	metolachlor + metribuzin
Bullet	alachlor + atrazine
Degree, Harness, Surpass, TopNotch, others	acetochlor + safener
Dual II MAGNUM, Cinch, others	s-metolachlor + safener
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.

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