

2010 Herbicide Guide for Iowa Corn and Soybean Production

New options for weed management in 2010

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Weed management in 2009 was, as usual, a mixed vision of apparent successes and obvious failures. In general, less than complete planning left many producers in dire straits for weed management options after planting. Wet conditions precluded many planned programs and thus once again, untold yield potential was lost due to weed interference. While the postemergence (POST) herbicide applications were generally successful (in killing weeds), it is clear that Iowa fields are becoming more populated by weeds that do not respond to the “programs of choice”. Furthermore, the widespread lack of using an herbicide strategy that includes a residual herbicide resulted in high weed population densities later in the growing season. This does not portend well for the 2010 growing season.

Notable observations from the 2009 growing season include the fact that common waterhemp is indeed the weed of significance for Iowa and increasing in importance and control is becoming more difficult; giant ragweed has become a major problem in many areas; new herbicide resistant weed populations have been documented and the number of resistant populations continue to increase at an increasing rate; weeds are generally not thought to be a serious problem despite consistent evidence to the contrary; and growers (mistakenly) believe that new traits and yet-to-be-discovered herbicides will resolve all weed management problems.

Crop injury and surfactants

A number of reports of significant corn injury from late POST herbicide

applications have been reported in the past few years. While ISU research has not been able to demonstrate this problem, collaborator research reported consistent “arrested” ear development from surfactant applications made to V14 corn. While the research did not eliminate the possibility of an interaction between the surfactant and herbicide, the consistency of the results suggest that there is a significant contribution of the surfactant to the observed injury. Importantly, late POST applications should not be considered a viable weed control tactic and in most cases, the late applications are not described on the herbicide labels.

Crop yield protection

Iowa growers continue to lose significant crop yield potential because of delayed POST herbicide applications. This loss of yield potential attributable to early season weed interference (in corn and soybean) was well demonstrated in 2009 where wet and windy conditions did not allow timely POST herbicide applications. The issue revolves around effective time management and the high likelihood that the weather is likely to interfere with herbicide application plans. The best way to better manage time in the spring with regard to weed management issues is to apply a residual herbicide early preplant (EPP) late in March or early April. This is an effective strategy in corn as well as soybean and is a recommendation of long standing by Iowa State University Weed Science. Recognize that expectations as to what the EPP treatment will provide must be realistic. Full-season weed control from one herbicide treatment is a myth devised by ad agencies. While growers

will use the excuse that the EPP residual treatments cost more, be assured that the crop yield potential that they protect will likely be considerably more than the cost of the herbicide treatment.

Stewardship

The concept of stewardship in weed management includes the previous topics and ultimately follows the principles of **Integrated Weed Management** (IWM). In the current context, production practices that focus on genetically engineered crops (e.g. Roundup Ready® or Liberty Link®) tend to emphasize simplicity and convenience resulting in the recurrent use of single herbicides. Stewardship should be a major consideration regardless of the crop types grown.

An important misconception about the current crop production systems which focus on Roundup Ready® crops is that there are fewer management options. Generally speaking, most of the historically important and effective herbicides are still available, either as proprietary products or as generic products. Furthermore, other alternative weed management tactics (i.e. mechanical weed control) are also

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available. The problem is that growers generally do not see the value of including alternative tactics, or do not choose to adopt them because they do not represent strategies that are simple or convenient. The truth is that growers cannot afford not to adopt alternative tactics and must implement stewardship in their crop production systems or face the eminent loss of utility of the important pest traits that comprise most of the corn and soybean acres. Importantly, these same stewardship practices and the plethora of weed management tactics are also available for “conventional” crops as well. Without using a diverse weed management program that accommodates the principles of IWM, weeds ultimately will adapt to the simple and convenient tactics that predominate crop production in Iowa. Without implementing stewardship, yield will be lost, weed shifts will occur and herbicide resistant weed populations will escalate.

Product update

There have been a number of new herbicides and herbicide combinations made available recently. The following discussion will attempt to summarize the new (and some previously existing) products but the list is not likely inclusive of all available products, particularly given the plethora of generic products currently available. Inclusion of a product does not constitute a de facto recommendation and exclusion does not mean that the product should not be considered for use.

Herbicides

Accent® Q is a prepackage herbicide mixture from DuPont that contains nicosulfuron and isoxadifen (safener) that can be applied POST to corn for the control of emerged grass weeds and some broadleaf weeds. Apply 0.9 ounces of product per acre to small grasses. Accent® Q can be applied to corn up to 20” tall or V6, whichever is more restrictive. ALS resistant weeds will not be controlled.

Callisto® Xtra is a prepackage herbicide mixture from Syngenta that contains mesotrione and atrazine and will be positioned in glyphosate-tolerant corn as an additive to glyphosate.

Callisto® Xtra is formulated as a 3.7lb/gal EC and contains 0.5 lb of mesotrione and 3.2 lbs atrazine per gallon. Callisto® Xtra will provide POST control of some annual grasses and broadleaf weeds and also provide residual control of some broadleaf weeds. Apply 20.0 to 24.0 ounces of product per acres POST to corn and small weeds. Do not apply Callisto® Xtra to corn that is taller than 12”.

Freestyle™ is a prepackage herbicide mixture from DuPont specifically designated for POST application to Optimum GAT® corn and soybean cultivars. The prepackage mixture includes three herbicides, all of which are ALS inhibitor herbicides. These include chlorimuron ethyl, thifensulfuron methyl and tribenuron methyl. Apply 0.66 to 1.3 ounces of product per acre. Freestyle™ should improve control of weeds that are difficult to manage with glyphosate (i.e. winter annual weeds) but will not control weeds that have evolved resistance to ALS inhibitor herbicides (i.e. common waterhemp).

Instigate™ is a prepackage mixture from DuPont specifically designated for PRE application to Optimum GAT® corn hybrids. The prepackage mixture includes three herbicides two of which are ALS inhibitor herbicides (rimsulfuron and chlorimuron ethyl) and an HPPD inhibitor herbicide (mesotrione). Apply 6.9 to 10.3 ounces of product per acre. This prepackage mixture provides residual control of some broadleaf and annual grass weeds as well as contact activity on emerged weeds. The best geographic fit is typically south of I-80 due to recropping considerations and soil pH issues.

Integrity™ is a prepackage herbicide mixture from BASF that includes Kixor® (saflufenacil 6) and dimethenamid-P for EPP, PPI, and PRE applications in corn. Integrity™ contains a PPO inhibitor herbicide (saflufenacil) and a choracetamide herbicide (dimethenamid-P) that inhibits weed root and shoot development. Integrity™ will provide burndown control of annual broadleaf weeds and residual control of annual grass and broadleaf weeds.

Apply 10 to 16 ounces of product per acre. Refer to the label for specific details about application procedures and restrictions.

Kixor® is an herbicide concept that will be marketed by BASF. Kixor® (saflufenacil) will be sold as a component of other products such as Sharpen™, Integrity™ and Optill™. Kixor® is a PPO inhibitor herbicide in a new herbicide class (pyrimidinedione). Kixor® provides contact activity as well as residual control of some broadleaf weeds.

Optill™ is a prepackage herbicide mixture from BASF that includes Kixor® (saflufenacil) and imazethapyr for burndown, PPI or PRE applications in Clearfield corn hybrids and soybeans for control of annual grass and broadleaf weeds. Optill™ contains a PPO inhibitor herbicide (saflufenacil) and an ALS inhibitor herbicide (imazethapyr). Apply 2.0 ounces of product per acre. Refer to the label for specific details about application procedures and restrictions.

Prequel™ is a prepackage mixture from DuPont for burndown weed control that also provides residual control of winter annuals, grass and broadleaf weeds. Prequel contains an HPPD inhibitor herbicide (isoxaflutole) and an ALS inhibitor herbicide (rimsulfuron). Prequel can be used in GM corn and conventional hybrids and can be applied prior to planting or PRE. Apply prior to crop emergence as injury to emerged corn is likely.

Sharpen™ is Kixor® (saflufenacil) for burndown and residual broadleaf weed control in corn and soybean (and other crops). Applications may be made EPP surface applied or incorporated (up to 14 days prior to planting) or PRE. Do not apply after crop emergence as severe injury will occur. Refer to the label to determine the appropriate rate of application.

Steadfast® Q is a prepackage herbicide mixture from DuPont that contains nicosulfuron and rimsulfuron (ALS inhibitor herbicides) and isoxadifen (safener) that can be applied POST to corn for the control of emerged grass weeds and some broadleaf weeds. The

rimsulfuron in Steadfast® Q provides some residual weed control. Apply 1.5 ounces of product per acre to small grasses. Steadfast® Q can be applied to corn up to 20" tall or V6, whichever is more restrictive. ALS resistant weeds will not be controlled.

Traverse™ is a prepackage herbicide mixture from DuPont specifically designated for EPP (fall and spring) and PRE applications to Optimum GAT® corn and soybean cultivars and POST applications to Optimum GAT™ corn through V6 stage of development. The prepackage mixture includes two ALS inhibitor herbicides; chlorimuron ethyl and rimsulfuron methyl. Apply 2.6 to 3.9 ounces of product to the soil and 2.0 ounces of product POST. Some residual control may be available from the higher rates of application. Annual grasses and many broadleaf weeds are controlled by Traverse™ but ALS resistant weeds will not be affected.

Trigate™ is a prepackage herbicide mixture from DuPont specifically designated for POST application to Optimum GAT® corn. The prepackage mixture includes three herbicides two of which are ALS inhibitor herbicides (rimsulfuron and tribenuron methyl) and an HPPD inhibitor herbicide (mesotrione). Apply 3.75 ounces of product per acre POST to small weeds on Optimum GA™ corn up to the V6 stage of development. Trigate™ controls many annual grass and broadleaf weeds and some winter annuals.

Vida™ herbicide is marketed by Gowan and will be positioned as a tank mix companion for glyphosate for PRE burndown applications for broadleaf weed control in corn and soybeans. Vida™ is pyraflufen ethyl and formerly marketed as ET herbicide. While Vida™ does have an EPOST label, crop injury can be severe. Vida™ is a PPO inhibitor herbicide.

Crop technologies

Dow AgroScience herbicide tolerant trait technology (DHT) continues to be developed and field trials have been underway for several years. It is anticipated that submissions for registrations will begin or have begun

recently. Registrations must be handled on the trait side as well as the chemical side of the technology. EPA submission for the herbicide tolerances/registrations are anticipated to occur in 2010 while Dow AgroScience will likely request that the USDA deregulate the corn trait in the third quarter 2009. There are several DHT traits currently under development under development. The traits will allow crop plants to metabolize phenoxy and ACCase inhibitor herbicides whether applied preemergence or postemergence. Importantly, Dow AgroScience is developing a robust stewardship program to accompany the marketing programs. The positioning of the DHT traits will be directed for "hard to control" weeds and the approach will be to partner the DHT traits with other technologies, systems and deliver the technology in the top germplasms. Dow AgroScience reportedly will market the DHT technologies in combination with their currently available soil-applied residual herbicides.

Dicamba soybean development continues with an anticipated commercial availability of 2013. The new dicamba tolerance trait will be stacked with glyphosate resistance and provide an alternative herbicide strategy for controlling problem broadleaf weeds including those broadleaf weeds that have evolved resistance to glyphosate.

Liberty Link® corn and soybeans cultivars are commercially available and represent an alternative to Roundup Ready® cultivars. Bayer Crop Science have made an excellent "Trait and Technology Use Manual" available to growers and have emphasized the need to include stewardship with this genetically modified crop technology. The Liberty Link® trait provides tolerance to Ignite® (glufosinate) herbicide which is a non-selective POST contact herbicide. It is critically important to recognize the glufosinate is a different herbicide than glyphosate; differences include the specific mechanism of action, the means by which weeds are controlled (contact action for glufosinate versus translocation for glyphosate) and the relative size of weed that glufosinate

will consistently control compared to glyphosate. However, from a crop yield protection perspective, glufosinate and glyphosate should be applied at the same early application time.

Optimum GAT® continues to be developed with an anticipated commercial introduction in corn scheduled for 2010 pending regulatory approval. U.S. approvals of the Optimum GAT trait in corn are anticipated by the end of the year. Pioneer is planning for controlled releases of Optimum GAT corn in 2010 and 2011. This means limited volume and grain channeled to appropriate markets. Optimum GAT soybeans are planned to be introduced in the U.S. in 2011.

Conclusions

The number of weed management options continue to increase for Iowa corn and soybean production. Current systems will continue to be based on GM crop technologies, primarily glyphosate tolerant crops. However, the availability of glufosinate tolerant crops will provide an important alternative for growers who have or anticipate weed management challenges with glyphosate. Conventional crops also have more choices for weed control than in the past. The key to effective weed management, however, is to include as many strategies as possible and make sure that the strategies are applied in a timely fashion thus protecting crop yield potential. Without stewardship and the adoption of IWM, any and all systems for weed control will ultimately fail in the long term, and significant profit will be lost in the short term.

The cost of convenience: Impact of weeds on crop yields

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Introduction

Populations of weeds capable of affecting crop yields are present in every field during every year. Perhaps it is the ubiquitous nature of weeds that leads to the complacency in their management across Iowa and the Midwest. A survey of Wisconsin corn and soybean fields found that weeds were managed in a way that resulted in yield losses in more than 10% of surveyed fields, with an average yield loss of slightly less than 10%.

Due to the variability in environmental conditions and herbicide performance, completely risk-free weed management programs are not economically feasible. However, understanding the interactions between crops and weeds can aid the design and implementation of management programs with minimal risk of yield loss.

Crop-Weed Interference

A complicating factor in managing weeds is our inability to accurately predict their yield impact early in the growing season. Various types of thresholds have been implemented for managing insects and diseases, and these tools simplify decision making. Although there are many reasons why thresholds have been less successful in weed management, the primary reason is the trophic level of the different pest classes. Both insects and plant pathogens are consumers, i.e. they derive their energy from the crop, whereas weeds are producers, i.e. they derive their energy from solar energy. Thus, the interaction between weeds and crops is completely different than that between the other pest classes and crops. This difference results in the interactions between weeds and crops being much less predictable than those with insects and pathogens.

The primary mechanism resulting in yield losses when weeds and crops coexist is competition for limited resources. Light, water and nutrients

are the resources most commonly competed for by crops and weeds. The specific resource responsible for yield losses varies with the individual situation. For example, velvetleaf would compete for light much more effectively with soybean than it would with corn. Annual grasses may compete with corn for nitrogen early in the growing season. Effective weed management programs limit competition by minimizing weed numbers and placing the crop in a situation in which has an advantage in capturing resources over weeds.

While competition is the primary interaction between crops and weeds, other types of interactions also influence crop responses to weeds. Plants are able to sense the presence of neighboring plants and may alter their growth pattern in response to these neighbors, even in the absence of limiting resources. This is known as a shade avoidance response, and typically involves increased stem elongation to allow one plant to gain a height advantage over others. This response may be responsible for yield losses that occur when weeds compete for short periods of time early in the growing season when there may be sufficient resources available to satisfy the needs of both the crop and weed.

Recent research efforts have focused on the role of light quality in interactions between crops and weeds. All plants have a photoreceptor (phytochrome) that can detect slight changes in the ratio of red and far red light. Since chlorophyll strongly absorbs red light, light reflected off leaves has a low red:far red ratio (R:FR). Changes in R:FR are what allow plants to know there are potential competing plants nearby. Experiments that eliminate competition for resources but allow changes in R:FR due to the presence of adjacent weeds have shown significant responses in corn shortly after emergence. Corn growing in the presence of weeds changed its

growth habit compared to weed-free plants within three days of emergence. Although there were no differences in biomass at this time, corn growing in the presence of weeds had a greater shoot:root ratio than plants growing in weed-free conditions. This indicates the weedy corn sacrificed its root system by reallocating resources to shoot growth. At 15 days after emergence, the weedy corn accumulated 36% less biomass than weed-free seedlings. The sensitivity of corn to neighboring vegetation declined relatively quickly with age, thus weeds present at or shortly after corn emergence had the greatest effect on the light response by corn. The alteration in allocation of resources to the roots and shoots of the plant will influence the corn responses to the presence of weeds and other environmental stresses for the remainder of the season.

The critical period of competition

Weeds that compete with the crop for the entire growing season have the greatest effect on crop yield. Fortunately this scenario rarely happens in modern corn and soybean production. More typically, weeds are present either early in the growing season and then eliminated, or they emerge later in the season after management practices have been implemented.

The critical period is an important concept in understanding interactions between crops and weeds. The premise of the critical period is that weeds can coexist with crops for certain periods of time without impacting yield potential. The critical period is the point of time when yield potential is impacted. Once the critical period is breached, crop yield is lost and removal of the weeds will not recover this lost yield. There are two critical periods. The first involves weeds that emerge with the crop and are allowed to compete until postemergence control tactics are implemented. The second involves weeds that emerge

after the crop is established, typically after control practices are completed. This paper focuses on early-season competition involving weeds that emerge with the crop.

The importance of early-season competition was dramatically increased with the introduction of glyphosate resistant (GR) crops. Although the competitive relationship between weeds and GR crops is the same as that with conventional crops, the effectiveness of glyphosate allows weeds to be controlled effectively long after the critical period is breached. The longer weed control is delayed, the more bushels lost to competition. The typical yield loss curve to varying periods of early-season competition in corn is shown in Figure 1. In this research (Gower et al. 2003), the critical period was 2” weeds – removing weeds before they reached a 2” height prevented any yield loss associated with weed competition, delaying control until weeds exceeded 2” resulted in significant yield losses.

The difficulty in managing postemergence herbicide applications is that the critical period is extremely variable depending upon the unique situation of individual fields. Factors that influence the critical period include weed density, weed species,

Table 1. Response of corn to early-season competition. Initial glyphosate application made at indicated time, and then followed by a second application to control late-emerging weeds.

Weed height at glyphosate application	Percentile				
	10 th	25 th	50 th	75 th	90 th
	----- % yield loss -----				
2”	0	0	2	5	13
4”	0	0	4	10	14
6”	0	2	9	14	23

weed emergence time in relation to the crop, competitiveness of the crop, cultural practices used, soil conditions, environment, and anything else that influences the growth of the crop or weed.

The data used to generate the curve in Figure 1 represents the average yield response from 35 experiments conducted under a wide range of conditions. With narrow profit margins, farming for the average is a sure way to lose money. One way of evaluating risk is to look at the number of locations that had a specific response (Table 1). In this research the average critical period was 2” weed height. However, at this growth stage 50% of the experiments had a yield loss less than 2%, whereas 50% of the experiments would have

experienced a yield loss greater than 2%. Each person has a different level of risk acceptance. Some might see that in 10% of the fields (10th percentile) no yield was lost when weed control was delayed until 6” weed height and be willing to accept those odds. Others might see that ten percent of the fields (90th percentile) experienced greater than 13% yield loss when the weeds were controlled at the 2” height and decide that a total post program presents too great of a risk.

While the authors of this article did not explain factors responsible for the variation in the yield response at the different locations (Table 1), it is likely that differences in weed infestations played a major role. Weed densities ranged from 2 - 325 plants/ft² among the locations. It is likely that locations in the 10th percentile had low weed populations, whereas those in the 90th percentile had some of the highest weed populations.

The potential for weeds to reduce yields early in the season is understood by most persons involved in crop production. However, the speed at which yield losses can accumulate is often underestimated. The number of bushels lost per day due to competition from a heavy grass infestation increased rapidly as the season progressed (Table 2). From emergence until the V2 stage, an average of 0.5 bushels was lost each day application was delayed. Two weeks later when the corn was at the V5 stage, more than 15 bu/A was lost during each day of competition.

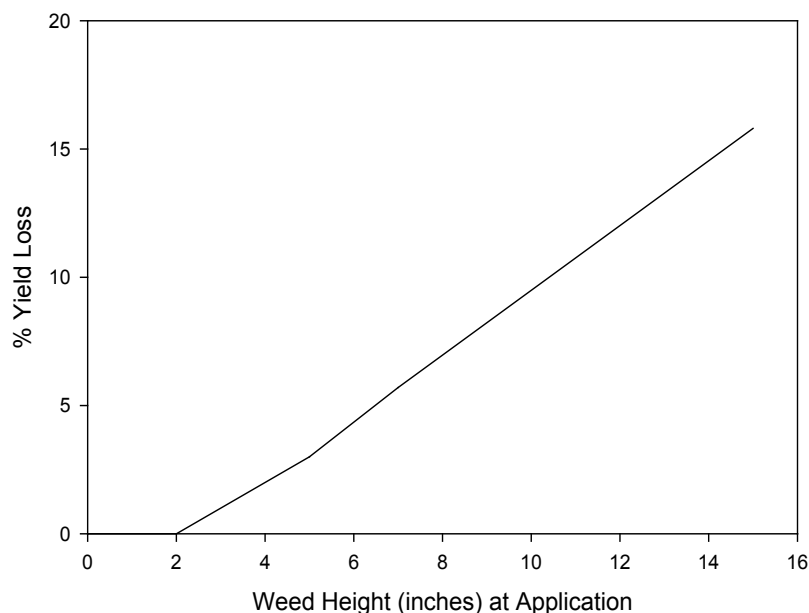


Figure 1. Average response of corn yield to postemergence application timing at 35 locations across the Midwest. Gower et al. 2003.

Managing early-season competition

The critical period simplifies weed management by indicating when weeds need to be controlled to achieve full yield potential. Unfortunately, our inability to accurately predict the critical period results in a certain level of risk whenever weeds are allowed to establish at the same time as the crop. The risk can be minimized either by implementing control tactics very early in the growing season, or by minimizing weed populations that establish with the crop with the use of preemergence herbicides.

Risks of early-season yield losses in a total postemergence program can be reduced by making the initial postemergence application very early in the season. The primary gamble with this approach is that weather conditions, or other factors, often prevent the initial application from being made when intended. Also, changes in light quality due to the presence of weeds can impact corn growth soon after emergence,

Table 2. Average daily yield loss due to weed competition at different times early in the growing season. Kanawha, IA.

Corn Stage	Bushels/A
VE to V2	0.5
V2 to V4	1.1
V4 to V5	17.2

long before the onset of competition for resources. How often the shade avoidance response impacts yield potential is unclear.

The second approach to protecting against early-season yield loss is the use of preemergence herbicides. Preemergence herbicide applications reduce the risk compared to relying on early herbicide applications by minimizing weed numbers during crop establishment. Concerns over the cost of the preemergence product have limited this practice, especially in soybean, and the reductions in glyphosate price for 2010 will encourage many growers to forgo this practice.

Summary

A significant percentage of fields in Iowa suffer reduced yields due to weed competition. Unfortunately, much of the yield loss is due to the implementation of flawed management strategies, rather than failed herbicide performance or uncontrollable 'acts of nature'. Our complacent attitude towards weeds may result in this behavior.

This article has focused on early-season competition in corn, and has described how large yield losses can occur relatively early in the growing season. The same principles hold for soybean. Although soybean are somewhat more tolerant of early-season competition than corn, situations occur where their yield potential is dramatically reduced during the first few weeks after establishment. As with corn, the critical period is highly variable depending upon the unique situations of a field, and unable to be predicted accurately. Although planning on an early postemergence application can reduce the risk of yield loss, the application of a preemergence herbicide will provide more stable yields regardless of crop.

Herbicide resistant weeds in Iowa: glyphosate and other herbicides

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Introduction

There has been concern about the evolution of glyphosate resistance in some Iowa weeds for many years although the field-wide existence of any problems has not been previously reported. It is important to recognize that in reality, common waterhemp (*Amaranthus rudis*) with resistance to glyphosate was reported in fields near Everly and Badger, Iowa as early as 1998. However, the likelihood of weeds evolving resistance to herbicides pre-dates glyphosate-resistant weed biotypes by five decades. The first identification of herbicide resistant weed biotypes pre-dates glyphosate-resistance by four decades and currently there are 19 herbicide mechanisms of action to which weeds have evolved resistance which compromise 334 weed biotypes from 190 weed species and infest an area that is impossible to estimate (Heap, 2004). To date, 16 weed species have evolved resistance to glyphosate. All of these incidents of evolved herbicide resistance have one thing in common; the mismanagement of herbicide use.

Herbicide resistant weeds in Iowa

A number of recent publications describe the herbicide resistant weed situation in Iowa. These include previous ICM papers, refereed journal publications, ICM Newsletter articles and blogs. Iowa has a long history of weeds resistant to triazine herbicides, particularly common lambsquarters (*Chenopodium album*) and redroot pigweed (*Amaranthus retroflexus*). More recently, resistance to ALS inhibitor herbicides has been identified in Iowa shattercane (*Sorghum bicolor*), common waterhemp, giant ragweed (*Ambrosia trifida*), common cocklebur (*Xanthium strumarium*), and common sunflower (*Helianthus annuus*) populations. It should be noted that while only a few ALS resistant species have been reported

in Iowa, globally 103 weed species have been identified as having ALS resistant biotypes. Many of these weed species exist in Iowa and it is possible that ALS resistant biotypes exist but have yet to be identified. Giant foxtail (*Setaria faberi*) populations that have evolved resistance to ACCase inhibitor herbicides have also been identified in Iowa.

Recently, weeds that have evolved resistance to PPO inhibitor herbicides have been identified in Iowa. A recent series of experiments in grower fields across Iowa has identified common waterhemp populations that are resistant to PPO inhibitor herbicides. Globally, three weed species with PPO resistant biotypes have been identified and importantly all of these biotypes are reported to have multiple resistances to other herbicides (i.e. PPO resistance and ALS resistance). The results from the Iowa experiments demonstrate multiple resistances in common waterhemp to PPO and ALS herbicides. Finally, populations of glyphosate resistant giant ragweed have been identified in Iowa in 2009. Experiments are currently underway to better characterize these populations as well as to evaluate suspected putative glyphosate resistant populations of common waterhemp and horseweed (marestail) (*Conyza canadensis*).

Management of herbicide resistant weeds

The first point that must be understood is that weeds are able to adapt to whatever crop production system that is used and to any and all weed management tactics implemented. Changes in weed communities in response to agriculture and specifically to herbicides are inevitable and represent an excellent ecological example of “Darwinian Evolution” in fast forward. Weed shifts (which includes the evolution of herbicide resistant weed populations) have always been

a feature of agriculture and the only thing that is different now compared to the beginning of “modern” production agriculture is the scale of the enterprises and the limited number of weed management tactics that are used.

Just as was experienced during the “ALS inhibitor herbicide era”, glyphosate quickly became the primary if not sole tactic for weed control and predictably, the tactic quickly began to fail. It is suggested that agriculture is at the precipice of glyphosate resistance in the Midwest weed populations. In the Midsouth, Southeast and Delta, agriculture has stepped off the precipice as is seen in the prevalence of glyphosate resistant horseweed (marestail) and Palmer pigweed (*Amaranthus palmeri*) populations. However, in the Midwest, most of the weed populations are still sensitive to glyphosate but this situation will likely be short-lived unless the plethora of available alternatives for weed management is quickly included by growers. Is the inclusion of these alternative tactics by growers something that growers willingly accept?

The evidence suggests that growers will not proactively include alternative strategies as they tend not to believe that a problem exists until it is found in their fields. Given the biology of weeds, once the problem is discovered, it is likely too late and remediation is the only strategy available. Unfortunately, control of glyphosate resistant weeds maybe more challenging and management options more difficult than prior to the occurrence of the evolved resistance.

What is the solution of managing herbicide resistant weeds? Simply put, do not facilitate the evolution of herbicide resistance. While this is likely too late in the case of ALS inhibitor herbicide resistance in Iowa, deterring the evolution of resistance to glyphosate, glufosinate and PPO inhibitor herbicides is well within the reach of many Iowa

growers. A well-thought and timely integrated weed management (IWM) program is the key component. Most growers will balk at this and the reasons provided for why they will not implement an IWM program will include (not in the order of importance) expense, time requirement, lack of convenience, lack of simplicity, and failure to recognize the inevitability of herbicide resistant weed populations. Those growers who have glyphosate resistant weed populations are likely to adopt glufosinate resistant crops, but this herbicide will also ultimately have resistant weed populations evolve unless growers shift to IWM programs. See table 1 for components of IWM programs.

Conclusions

Iowa has now joined most of the other Midwest states and has weed populations resistant to most of the commonly used herbicide families including glyphosate and PPO inhibitor herbicides. Importantly, some of the herbicide resistant common waterhemp populations demonstrate

resistance to several herbicide families and typically are cross resistant to all ALS inhibitor herbicides. While glyphosate resistance is not as widely found in Iowa as in other Midwest states, anecdotal evidence suggests that without immediate proactive adoption of IWM tactics, Iowa agriculture faces the same dire consequences of widely dispersed glyphosate resistant weed populations as currently found in some neighboring states. Fortunately, the choices available for weed management have increased despite concerns that the adoption of genetically modified crops has diminished available tactics. These tactics can include the use genetically modified crops and should include alternative herbicides and other cultural and mechanical strategies. While many growers still believe in the myth that a new “silver bullet” will soon become commercially available, it is unlikely that anything new of the magnitude demonstrated with the introduction of genetically engineered crops is forthcoming in near future. Thus, growers need to develop

diverse IWM programs to optimize weed management, protect crop yield potential and deter the impending evolution of new herbicide resistant weed populations with the many tactics and herbicides currently available.

Table 1. Components of successful Integrated Weed Management (IWM) programs

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- Use of alternative herbicides to control “weeds of concern” (i.e. common waterhemp)
 - Use of alternative herbicide application timing (i.e. a herbicide with soil activity should be applied early preplant on all acres regardless of the genetically engineered trait in the crop)
 - Scouting
 - Recognize the selectivity differences of different herbicides – use products that will control the weeds that occur in the fields
 - Use the correct herbicide rates – reduced herbicide rates can contribute to the evolution of herbicide resistant biotypes
 - Protect crop yield – successfully killing weeds is not synonymous with weed management. Killing weeds after they have caused significant losses of crop yield potential and thus profit.
 - Understand that all fields are different and thus should be managed differently
 - Consider the inclusion of mechanical tactics in specific fields or areas within fields
 - Convenience and simplicity are harbingers for the evolution of herbicide resistance
 - Optimize crop management – a competitive crop is an excellent weed management tactic
 - Weed seeds are important – management the weed seed rain by minimizing weed seed production and optimize conditions to maximize weed seed predation
 - Recognize that the most important manner by which new weeds (new species or new herbicide resistance populations) enter a field is through normal crop production practices (i.e. harvesting) – optimize sanitation as an IWM tactic by isolating problem fields and cleaning equipment after working in these fields
 - Keep detailed records for each field
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Grazing and haying restrictions for herbicides used in grass pastures

Herbicide	A.I.	Rate/A	Beef and Non-Lactating Animals			Lactating Dairy Animals		
			Grazing	Hay harvest	Removal before slaughter	Grazing	Hay harvest	
Ally		0.1 - 0.3 oz	0	0	0	0	0	0
Clarity and many others	dicamba	Up to 1 pt	0	0	30 days	7 days	37 days	37 days
		1-2 pt	0	0	30 days	21 days	51 days	51 days
		2- 4 pt	0	0	30 days	40 days	70 days	70 days
		4 - 16 pt	0	0	30 days	60 days	90 days	90 days
Cimarron	metsulfuron methyl	0.1 - 1.0 oz	0	0	0	0	0	0
Cimarron Max (co-pack)	metsulfuron methyl + dicamba + 2,4-D	0.25-1 oz A + 1-4 pt B	0	0	30 days	7 days	37 days	37 days
Cimarron X-Tra	metsulfuron methyl + chlorsulfuron	0.1 - 1.0 oz	0	0	0	0	0	0
Crossbow	triclopyr + 2,4-D	1 - 6 qt	0	14 days	3 days	Growing season	Growing season	Growing season
Escort XP	metsulfuron methyl	Up to 1.7 oz	0	0	0	0	0	0
		1.7- 3.3 oz	NA	3 days	NA	NA	3 days	3 days
ForeFront R&P	aminopyralid + 2,4-D	1.5 - 2.6 pt	0	7 days	0	0	7 days	7 days
Grazon P&D	picloram + 2,4-D	3 - 4 pt	0	0	0	7 days	30 days	30 days
Milestone	aminopyralid	3 - 7 pt	0	0	0	0	0	0
Overdrive	dicamba + diflufenzopyr	4 - 8 oz	0	0	0	0	0	0
Pasturegard	triclopyr + fluroxypyr	1.5 - 2 pt	0	14 days	3 days	1 year	1 year	1 year
Rave	dicamba + triasulfuron	2 - 5 oz	0	37 days	30 days	7 days	37 days	37 days
Redeem R&P	triclopyr + clopyralid	1.5 - 4 pt	0	14 days	3 days	Growing season	Growing season	Growing season
Remedy Ultra	triclopyr	1 - 2 qt	0	14 days	3 days	Growing season	Growing season	Growing season
Surmount	picloram + fluroxypyr	1.5-6 pts	0	7	3	14	7	7
Tordon 22K	picloram	< 2 pts	0	0	3	14	14	14
		> 2 pts	0	14	3	14	14	14
Weedmaster	dicamba + 2,4-D	1-4 pts	0	37 days	30 days	7 days	37 days	37 days
2,4-D (many tradenames) Uses may vary among products	2,4-D	2-4 pt 4 lb/G	0	30 days	3 days	7 days	30 days	30 days

Corn Herbicide Effectiveness Ratings¹

Weed response to selected herbicides

E = excellent
F = fair

G = good

P = poor

Grasses

Crop tolerance
Crabgrass
Fall panicum
Foxtail
Woolly cupgrass
Shattercane²

Broadleaves

Amaranthus spp.^{2,4,5}
Black nightshade
Cocklebur²
Common ragweed
Giant ragweed^{2,4}
Lambquarter
Smartweed
Sunflower
Velvetleaf

Perennials

Canada thistle
Quackgrass
Yellow nutsedge

Preplant/Preemergence

Atrazine	E	F	P	F	P	P	E	G	G	E	E	G	G	E	G	G	F	F
Axiom, Breakfree, Dual II Magnum, Frontier, Outlook, etc	E	E	E	E	F	F	F-G	G	G	P	P	F-G	G	P	P	P	P	P
Balance Flexx	E	G	F-G	G	G-E	F-G	G-E	F	F	P-F	F-G	F	G	G-E	F	G-E	F	G
Callisto	E	P	P	P	P	P	G-E	G-E	F-G	F-G	F-G	F	E	F-G	G-E	E	P	P
Degree, Harness, Surpass, Topnotch, etc	E	E	E	E	F-G	F-G	G	G	P	P	P	P	P-F	P-F	P	P	P	P
Hornet WDG	G	P	P	P	P	P	G-E	F-G	G	G	G	G	G	G-E	G-E	G	P	P
Pendimax, Prowl, etc	F-G	G-E	G-E	G	G	G	G	P	P	P	P	P	G-E	F	P	P-F	P	P
Pursuit ³	E	F-G	F	F-G	P-F	G	F-E	G-E	F	G	F	P	P	G-E	F-G	G	P	P
Pythion	G	P	P	P	P	P	E	F-G	F	F	F	F-G	F-G	G-E	F-G	G-E	P	P

Postemergence

Accent, Steadfast	G-E	P	G	G-E	G-E	E	G	P	F	P	P	P	P	G	G	P	F	F
Aim	G	P	P	P	P	P	F-G	G	P	P	F	G	G	P	P	E	P	P
Atrazine	G	F	P	F	P	P	E	E	E	E	E	E	E	E	E	E	E	G
Basagran	E	P	P	P	P	P	P	P	E	E	E	F	P	E	G	G-E	G*	P
Basis	F	F	F-G	G	F	G	G	P	F	F	P	G-E	G-E	G-E	G	G	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	E	E	E	G	G	F-G	F-G*	G	F
Buctril	G	P	P	P	P	P	G	G-E	E	E	E	G-E	G-E	E	G	P	P	P
Callisto	G-E	P	P	P	P	P	E	E	E	G-E	F	G	G	E	G-E	E	P	P
Distinct	F-G	P	F	F	P	F	G-E	G	E	G-E	G	G	G	E	G	G*	P	P
Equip	F-G	P	G	G-E	F-G	E	G	E	E	E	E	G	G	E	E	G-E	G*	P
Glyphosate (Roundup, Touchdown) ³	E	E	E	G-E	E	E	G-E	F-G	E	E	E	G-E	G	E	E	G	G	G-E
Hornet WDG	G	P	P	P	P	P	G-E	F	E	E	E	G-E	F	G-E	E	G-E	G	P
Ignite ³	E	E	G	G-E	E	E	G	E	E	E	E	E	G	E	E	E	F-G	G
Impact	G-E	F-G	F	G	F	F	G-E	G-E	G-E	G	G	G	G	E	E	E	P	P
Lightning ³	G-E	G	G	E	G	E	F-G	E	E	G	F-G	G-E	E	E	E	E	G	F
NorthStar	G	P	F-G	F	P	E	F-G	G	E	E	E	E	G	E	E	G	F-G	G
Option	G	P	G	G-E	F-G	E	G	E	F	F	P	P	P	P	P	G	G	P
Permit, Halomax, etc	G	P	P	P	P	P	E	P	G-E	G-E	G	P	G-E	E	E	E	P	P
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

¹Ratings 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.

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

³Use only on designated resistant hybrids.

⁴Glyphosate-resistant biotypes of these weeds have been identified in Iowa. These biotypes may not be controlled by glyphosate.

⁵PP0-resistant biotypes of common waterhemp have been identified in Iowa. These biotypes may not be controlled by PPO inhibitor herbicides.

*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 Ratings¹

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 ²	Amaranthus spp. ^{2,4,5}	Black nightshade	Cocklebur ²	Common ragweed	Giant ragweed ^{2,4}	Lambsquarter	Smartweed	Sunflower ²	Velvetleaf	Canada thistle	Quackgrass	Yellow nutsedge
Preplant/Preemergence																		
Authority/Spartan	G	P	P	P	P	P	E	E	F	F	G-E	F	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, INTRRO, 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	G-E	G	G	F-G	P	P	F-G
Sencor, TriCor, etc	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	G	F	P	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
Pythron	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-F	P-F	P-F	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	E	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	G	P	P	P
Ignite	E	E	G	G-E	E	E	G	E	E	E	G	E	E	E	E	F-G	G	F
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	E	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	E	E	P	P	P

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

²ALS-resistant biotypes have been identified in Iowa. These biotypes may not be controlled by all ALS products.

³Use only on appropriate resistant varieties.

⁴Glyphosate-resistant biotypes of these weeds have been identified in Iowa. These biotypes may not be controlled by glyphosate.

⁵PPO-resistant biotypes of common waterhemp have been identified in Iowa. These biotypes may not be controlled by PPO inhibitor herbicides.

*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
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 + Atrazine	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
Callisto Xtra	0.5 lb mesotrione 3.2 lb atrazine	24 fl oz	0.09 lb mesotrione 0.6 lb atrazine	3.0 oz Callisto 1.2 pt atrazine 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)
Capreno	0.57 thiencazone methyl 2.88 lb tembotrione	3.0 oz	0.01 lb thiencazone methyl 0.068 lb tembotrione	- -
Cinch ATZ	2.4 lb S-metolachlor 2.67 lb atrazine 1.88 isoxaflutole	2.1 qt	1.26 lb S-metolachlor 1.63 lb atrazine 0.083 lb isoxaflutole	21 oz Dual II Magnum 3.25 pt atrazine 4L 2.6 oz Balance
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
Freestyle	12.5% chlorimuron 18.75% thifensulfuron 18.75% tribenuron	0.66 oz	0.083 oz chlorimuron 0.125 oz thifensulfuron 0.125 oz tribenuron	- - -
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

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)
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
Integrity	6.24% saflufenacil 55.04% dimethenamid	13 oz	0.058 lb saflufenacil 0.5 lb dimethenamid	2.6 oz Sharpen 10.9 oz Outlook
Instigate	4.7% chlorimuron ethyl 4.7% rimsulfuron 31.2% mesotrione	6.9 oz	0.325 oz chlorimuron 0.325 oz rimsulfuron 2.15 oz mesotrione	
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
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

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)
Optill	17.8% saflufenacil 50.2% imazethapyr	2.0 oz	0.063 lb saflufenacil 0.0222 lb imazethapyr	- -
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
Require Q	0.062 lb rimsulfuron 0.481 lb dicamba	4 oz	0.016 lb rimsulfuron 0.12 lb dicamba	1.0 Resolve 3.9 Clarity/Banvel
Resolve Q	0.184 lb rimsulfuron 0.04 lb thifensulfuron	1.25 oz	0.0143 lb rimsulfuron 0.0031 lb thifensulfuron	0.9 oz Resolve 0.067 oz Harmony GT
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
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
Traverse	12.5% chlorimuron ethyl 12.5% rimsulfuron	2.6 oz	0.325 oz chlorimuron 0.325 oz rimsulfuron	- -
Trigate	6.7% rimsulfuron 5.0% tribenuron 33.3% mesotrione	3.75 oz	0.25 oz rimsulfuron 0.187 oz tribenuron 1.25 oz mesotrione	- - -

Herbicide	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)	An equivalent tank mix of (product)
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 sulfentrazone 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 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
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

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)
Flexstar GT	0.66 lb fomesafen 2.63 lb glyphosate	3.75 pt	0.309 fomesafen 1.23 lb glyphosate	- -
Freestyle	12.5% chlorimuron 18.75% thifensulfuron 18.75% tribenuron	0.66 oz	0.083 oz chlorimuron 0.125 oz thifensulfuron 0.125 oz tribenuron	- - -
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 acifluorfen	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
Sonic	6.21% sulfentrazone 7.96% cloransulam-methyl	8.0 oz	0.361 lb sulfentrazone 0.04 lb cloransulam-methyl	6.6 oz Authority 75DF 0.76 oz FirstRate
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
Traverse	12.5% chlorimuron ethyl 12.5% rimsulfuron	2.6 oz	0.325 oz chlorimuron 0.325 oz rimsulfuron	- -
Valor XLT	30.3% flumioxazin 10.3% chlorimuron ethyl	3 oz	0.056 lb flumioxazin 0.019 lb chlorimuron	1.76 oz Valor 1.24 oz Classic

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, although the specific amino acid base pair on the protein where the herbicide “attaches” may be different for different herbicides in the same family. 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 which is involved in photosynthetic electron transfer. Thus, the site of action for triazines is the D1 protein, whereas the mode of action is the disruption of photosynthesis. An understanding of herbicide mode of action is essential for diagnosing crop injury or off-target herbicide injury problems and for designing weed management programs with a low risk of selecting for herbicide-resistant weed populations.

ACCCase 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 the essential branched chain amino acids (valine, leucine, and isoleucine). This enzyme is also called acetohydroxy acid synthase (AHAS). 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 observed 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 sensitive broad-leaf plants often develop reddish veins on the undersides of leaves. Symptoms in corn include reduced secondary root formation, stunted roots, shortened internodes, leaf malformations (chlorosis, window-paning) and nutrient deficiencies. 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 (i.e. auxin) balance. These herbicides are primarily effective on broadleaf species, however some monocots are also sensitive. Uptake can occur through seeds or roots with soil-applied treatments or leaves when applied postemergence. Synthetic auxins translocate throughout plants and accumulate in 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 auxin herbicides in the absence of this herbicide. This response is poorly understood, but usually develops during periods of rapid growth, low temperatures 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 interveinal chlorosis of plant leaves followed by necrosis of leaf tissue. Other secondary substances resulting from 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 Photosystem I (PSI) and produce highly destructive secondary plant compounds. Very little translocation of bipyridilium herbicides occurs due to loss of membrane structure. Injury occurs only where the herbicide spray contacts the plant. Complete spray coverage is essential for weed control. The herbicide molecules carry strong positive charges that cause them to be very tightly adsorbed by soil colloids. Consequently, bipyridilium herbicides have no significant soil activity. Injury to crop plants from paraquat drift occurs in the form of spots of dead leaf tissue

wherever spray droplets contact the leaves. Typically, slight drift injury to corn, soybeans, or ornamentals from a bipyridilium herbicide does not result in significant growth inhibition.

Protoporphyrinogen Oxidase (PPO) Inhibitors

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., acifluofen) kill weed seedlings through contact action, membrane destruction, and ultimately 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, Ignite) 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. Ignite is nonselective except to crops that carry the Liberty Link gene.

Hydroxyphenyl Pyruvate Dioxygenase (HPPD) Inhibitors

Isoxaflutole (Balance Flexx), mesotrione (Callisto), tembotrione (Laudis), 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

Clomazone 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. Clomazone 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 plant-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 (inhibition of synthesis of very long chain fatty acids). 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 Q	nicosulfuron + safener
Ally, Cimarron	metsulfuron
Basis	rimsulfuron + thifensulfuron
Beacon	primisulfuron
Canopy	chlorimuron + metribuzin
Classic	chlorimuron
Envive	flumioxazin + thifensulfuron + chlorimuron
Enlite	flumioxazin + thifensulfuron + chlorimuron
Equip	foramsulfuron + iodoflufenuron + safener
Exceed, Spirit	propriflufenuron + primisulfuron
Express	tribenuron
Freestyle	chlorimuron + thifensulfuron + tribenuron
Harmony GT	thifensulfuron
Instigate	chlorimuron + rimsulfuron + mesotrione
NorthStar	primisulfuron + dicamba
Option	foramsulfuron + safener
Permit, Halofax	halosulfuron
Prequel	rimsulfuron + isoxaflutole
Require Q	rimsulfuron + dicamba
Resolve Q	rimsulfuron + thifensulfuron + safener
Steadfast Q	nicosulfuron + rimsulfuron + safener
Steadfast ATZ	nicosulfuron + rimsulfuron + atrazine
Synchrony STS	chlorimuron + thifensulfuron
Traverse	chlorimuron + rimsulfuron
Trigate	rimsulfuron + tribenuron methyl + mesotrione
Valor XLT	flumioxazin + chlorimuron
Yukon	halosulfuron + dicamba

Other

Corvus	thiencarbazone-methyl + isoxaflutole safener
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Microtubule inhibitor

dinitroanilines

Balan	benfen
Commence	trifluralin + clomazone
Prowl H ₂ O, Pentagon, Pendimax, others	pendimethalin
Sonalan	ethalfluralin
Surflan	oryzalin
Treflan, others	trifluralin

Synthetic auxin

benzoic	
Banvel, Clarity, others	dicamba
Distinct, Status	dicamba + diflufenzopyr
NorthStar	dicamba + primisulfuron
Require Q	rimsulfuron + dicamba
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
GrazonNext, ForeFront R&P	aminopyralid + 2,4-D
Hornet WDG	clopyralid + flumetsulam
PastureGard	triclopyr + fluroxypyr
Redeem	triclopyr + clopyralid
Remedy Ultra, Pathfinder II	triclopyr
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
AuthorityAssist	sulfentrazone + imazethapyr
Command Xtra	sulfentrazone + clomazone

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

phenylphthalimides	
Envive	flumioxazin + thifensulfuron + chlorimuron
Enlite	flumioxazin + thifensulfuron + chlorimuron
Gangster	flumioxazin + cloransulam
Resource	flumiclorac
Valor	flumioxazin
Valor XLT	flumioxazin + chlorimuron

pyrimidinedione	
Sharpen (Kixor)	saflufenacil
Integrity	saflufenacil + dimethenamid P
Optill	saflufenacil + imazethapyr
other	
Cadet	fluthiacet

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, Ignite	glufosinate
Liberty ATZ	glufosinate + atrazine

Hydroxyphenyl pyruvate dioxygenase (HPPD) inhibitors

Balance Flexx	isoxaflutole + safener
Epic, Radius	isoxaflutole + flufenacet

Callisto	mesotrione
Callisto Xtra	mesotrione + atrazine
Impact	topramezone
Lexar, Lumax	mesotrione + atrazine + s-metolachlor
Corvus	isoxaflutole + theincarbazonemethyl + safener

Diterpene inhibitors

Command	clomazone
Command Xtra	clomazone + sulfentrazone

Auxin transport inhibitors

Distinct, Status	diflufenzopyr + dicamba
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Lipid synthesis inhibitors

thiocarbamates	
Eradicane, Eptam, others	EPTC
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, Intro, 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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... and justice for all

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