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2013 Herbicide Guide for Iowa Corn and Soybean Production

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Weed management update for 2013

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The success of weed management programs, more specifically herbicide programs, varied considerably during 2012 reflecting the importance of environmental conditions on herbicide performance. Variability of success was seen not only in the postemergence herbicide applications that continue to dominate herbicide use but also in the soil-applied residual herbicides; all herbicide applications were strongly influenced by tillage system, crop planting date, timing and amount of rainfall, and resulting weed emergence timing. While more soil-applied herbicides were used in Iowa during 2012, there are still too many acres of corn and soybean that are treated only with glyphosate. Importantly, the trend of no new herbicide sites of action continues and while new herbicides will be available in 2013, they have old sites of action, many of which have existing resistant weed populations. The new products and changes in herbicides will be described in this paper. The implications of the 2012 drought on herbicide degradation and the potential for herbicide carryover will be addressed. Furthermore, an update on the development of new herbicide resistant crops and the anticipated implications of these technologies when deregulated and available commercially will be discussed.

New products and company updates

While a number of new products and premixtures are available or anticipated to be available in 2013, none of these products represent new herbicide sites of action. Given the existing resistances to available herbicide sites of action, this lack of discovery and development of new products will be increasingly problematic for weed management in Iowa agriculture and reinforces the need for a better understanding about how to best use the available herbicides to steward their continued performance. The following update includes companies that provided information about their proprietary products; inclusion in this paper does not signify endorsement nor does exclusion constitute a lack of support of the products.

BASF

BASF received registration for Zidua herbicide in corn including popcorn and sweetcorn. This product has the active ingredient pyroxasulfone which is the herbicide KIH-485 on which Iowa State University Weed Science conducted research for a number of years however the rate of pyroxasulfone used was higher than what is currently registered. Pyroxasulfone is a group 15 herbicide and inhibits very long chain fatty acid (VLCFA) synthesis; this is the same mode of action for other commercially available products such as metolachlor (e.g. Dual) and acetochlor (e.g. Warrant) and control many annual grasses and some small-seeded annual broadleaf weeds. Zidua is formulated as an 85% water dispersible granule (WG) and the 0.212 lbs A.I. can be applied early preplant (up to 45 days before planting), preplant incorporated, preemergence, early postemergence and in the fall. Fall application is not the best application timing for residual weed control in the spring and early post emergence applications must be timed prior to weed emergence. Do not apply Zidua through irrigation systems nor aerially. Only one application is allowed to corn each spring.

BASF is also developing a new formulation of dicamba for application on dicamba-resistant soybean cultivars. The new formulation will be called Engenia by BASF and is suggested to have a lower potential for volatilization than current dicamba formulations. The weed spectrum and relative efficacy is similar to available dicamba formulations. This formulation has been evaluated in more than 300 soybean field trials in 2011 and 2012 according to a recent BASF announcement and will be targeted to help control herbicide resistant weeds such as common waterhemp. Iowa State University has evaluated this product and has observed off target movement to susceptible soybean cultivars. While the risk of volatilization drift may be reduced compared to current dicamba formulations, it is not zero. Furthermore, physical drift will require the same considerations that impact all herbicides. The potential for tank contamination resulting in injury to susceptible crops is also an important management consideration.

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Bayer Crop Science

Bayer Crop Science continues moving their stewardship efforts forward by holding "Respect the Rotation" field days and promoting the use of Liberty Link corn and soybeans and Liberty herbicide. The inclusion of the trait and the herbicide as part of a more diverse weed management program makes good sense. Bayer Crop Science has also developed a very good brochure describing herbicide resistance, current herbicide resistant weeds, management tactics for herbicide resistant weeds, and herbicide modes of action. This brochure is available at http://www.bayercropscience.us/news/2012_RTR/2013WeedResistanceManagementBrochure.pdf.

Dow AgroSciences

Dow AgroSciences continues to develop 2,4-D resistance traits in soybeans and corn under the name Enlist Weed Control System. There is a chance that the corn may be deregulated for a limited commercial launch in 2013 while the earliest deregulation of the soybean cultivars is in 2015. Enlist Duo will be the Dow AgroSciences proprietary premixture of glyphosate (Group 9) and 2, 4-D choline (Group 4). This new formulation of 2,4-D is suggested to have lower volatility, less physical drift potential and other favorable characteristics compared to current 2,4-D formulations. Drift reducing agents are included in the formulation. Weed control is similar to other 2, 4-D products. Dow AgroSciences is also developing a strong stewardship program and to minimize off-target issues with Enlist Duo; this program must be followed closely.

DuPont

DuPont has registered a new premixture of rimsulfuron (Group 2) (4.17%) and mesotrione (Group 28) (41.67%) and have named this product Instigate which is formulated as a water dispersible blend. DuPont is suggesting that this mixture provides burndown activity as well as residual activity in corn. Instigate can be applied 14 days prior to planting up to V2 corn. This product is restricted for application only on corn and seed corn, popcorn, ornamental corn and sweet corn should not be treated with Instigate. Do not make an application of another HPPD inhibitor herbicide (e.g. Callisto) following an application of Instigate. Other restrictions on the label need to be followed.

Realm Q was registered for corn by DuPont in July 2012 and is a postemergence premixture of rimsulfuron (Group 2) and mesotrione (Group 27) herbicides and isoxadifen, a potent safener that will minimize the potential for crop injury from the rimsulfuron. This product provides burndown activity as well as some residual control of some annual grasses and broadleaf weeds. The amounts of rimsulfuron and mesotrione are 7.5% and 31.25% respectively by weight in the water dispersible granule formulation. Apply 4 oz product per acre to corn up to 20" tall or exhibiting 7 leaf collars, whichever is more restrictive. Crop oil concentrate or nonionic surfactant and AMS must be included and atrazine is also recommended. Do not include Basagran or foliar-applied organophosphate insecticides with Realm Q. Realm Q should not be applied aerially or through irrigation systems. The soybean rotational interval is 10 months. DuPont cautions that a potential interaction with Realm Q and Counter and Lorsban soil-applied insecticides that can result in severe crop injury and yield loss.

DuPont has labeled Cinch (Group 15) (82.4% s-metolachlor) for postemergence application in soybeans. Note that s-metolachlor does not demonstrate activity on weeds that have emerged prior to application.

FMC

FMC received registration for Anthem which is a premixture of pyroxasulfone (Group 15) and fluthiacet-methyl (Group 14) herbicides. Anthem is formulated as a "suspoemulsion" and contains 2.15 lb. active herbicide ingredient. This premixture can be applied fall or spring, preplant, preplant incorporated preemergence or postemergence. When applied postemergence to weeds, it is critical to note the weed type and size as pyroxasulfone does not demonstrate activity on emerged weeds and fluthiacet-methyl has limited activity on some small broadleaf weeds although velvetleaf control is good. Do not apply Anthem aerially or by irrigation equipment. Observe harvest intervals as detailed on the label. Anthem applied at 13 oz/A will contain 0.212 lb a.i. of pyroxasulfone. Registration of Anthem ATZ (Groups 5, 14, and 15) is pending.

Monsanto

Monsanto has registered Warrant herbicide (acetochlor, Group 15) is now registered for preplant, at-planting and preemergence surface application in soybeans. Incorporation of the encapsulated acetochlor is not recommended and up to 4 quarts of Warrant can be applied per season. These additions to the label supplement the previously labeled post emergence application in soybean. Acetochlor does not demonstrate activity on emerged weeds.

Monsanto has also detailed their 2013 recommendations in Roundup Ready corn and soybeans. A number of application scenarios are described in several tillage systems if glyphosate resistant weeds are present or absent. Monsanto is providing incentives to use alternate herbicides in combination with glyphosate for all application timings. This effort to incentivize stewardship is laudable however it specifically provides stewardship for glyphosate. All herbicide sites of action should be stewarded and it is important to consider tactics for weed management other than additional herbicides. Importantly, given the herbicide resistances that have evolved in Iowa (see later in this paper), it is critical to make sure that the alternate herbicides are active on the target weeds to best utilize the Monsanto recommendations and incentives.

Monsanto continues to develop the dicamba-resistant soybean cultivars and it is anticipated that Roundup Ready Xtend may be commercially available in 2014. The available soybean cultivars demonstrate excellent tolerance to dicamba and weed control of selected broadleaf weed was also good. However in large-plot trials conducted by Iowa State University in 2012, off-target movement of the new dicamba formulation was observed and it is clear that the utilization of this technology will require focused attention in order to minimize issues of off-target and tank contamination.

Syngenta

Syngenta has changed the formulations of three of their proprietary products to allow better handling, mixing, compatibility with sulfur-containing fertilizers and cleanup. These products include Lumax EZ (Groups 5, 15, and 27), Lexar EZ (Groups 5, 15, and 27) and a Camix replacement, Zemax (Groups 15 and 27). The ratio of herbicides in Lumax EZ is also different such that the product amount applied has increased.

Valent

Valent has registered Fierce herbicide on corn for fall and spring burndown applications or preemergence in no tillage and minimum tillage systems. Conventional tillage corn production systems are not described on the label. Fierce is formulated as a 76% water dispersible granule and is a prepackage mixture of flumioxazin (Group 14) and pyroxasulfone (Group 15) herbicides which provides contact and residual activity on susceptible weeds. The maximum seasonal application rate of 4.5 oz/A results in 0.12 lb a.i. pyroxasulfone. This product is not registered for sweet corn, popcorn or corn grown for seed. Fierce can be applied aerially.

Valent has provided detailed information and description on how to clean sprayers, mixing vessels and nurse tanks daily after the use of Valor (Group 14), Chateau (Group 14), Valor XLT (Groups 2 and 14), Gangster (Groups 2 and 14) and Fierce herbicides. Valent requires the use of Valent Tank Cleaner which is described to neutralize and remove these herbicides from tanks, hoses and nozzles when mixed at the correct concentration and kept in the equipment over night.

Table 1. Assessment of herbicide carryover risk for specific herbicides

Risk assessment	Herbicide
High	Atrazine
	Chlorimuron (e.g Canopy, Authority XL, Envive, Valor XLT and others)
	Imazaquin (e.g. Scepter)
	Simazine (e.g. Princep and others)
Moderate to slight	Fomesafen (e.g. Reflex, Flexstar, Prefix)
	Clopyralid (e.g. Hornet)
	Cloransulam (e.g. FirstRate, Hornet, Gauntlet and others)
	Imazethapyr (e.g. Pursuit)
	Dinitroaniline herbicides (e.g. Prowl, Treflan and others)
	HPPD inhibitor herbicides (e.g. Balance Flexx, Callisto, Lumax, Lexar, Laudis, Caprino, Impact and others)

Herbicide carryover

Given the lack of rain during the summer and fall 2012, the potential for herbicide carryover must be a consideration for 2013 plans. However, the extent of herbicide carryover and the actual risk of carryover injury to rotational crops will vary widely in Iowa and will be strongly influenced by a number of factors including but not limited to the specific herbicide, rate and timing of application and the weather, particularly the conditions that exist for the rotational crop in 2013. An article describing these factors can be found at http://www.extension.iastate.edu/CropNews/2012/0807hartzlerowen.htm. Specific herbicides and an assessment of carryover potential are listed in Table 1.

Generally, if herbicides applied in 2012 were applied in a timely fashion and if growing conditions for the 2013 crop are favorable, the likelihood of herbicide carryover that results in significant crop injury is slight. However, if multiple applications of the same herbicide or herbicide site of action (e.g. multiple applications of HPPD inhibitor herbicides) were used, if high rates of the herbicides were applied and the herbicides were applied later in the growing season, the risk of carryover increases.

There is no good way to determine the potential for herbicide carryover. While there have been discussions about conducting bioassays to assess the level of carryover, these are not going to provide an accurate assessment of the carryover. Importantly there is a good chance of either a false positive (carryover is likely) or a false negative (carryover is unlikely). If you determine, by whatever means, that carryover is a strong possibility, it may be advisable to plant a rotational crop that is not sensitive to the herbicide. Past experiences on changing tillage plans do not suggest that this is an advisable solution for a number of reasons, not the least of which that changing tillage is unlikely to resolve the potential for herbicide carryover.

Conclusions

While there have not been any new herbicide sites of action discovered and made commercially available in over 20 years, many manufacturers continue to develop older products and products based on older herbicide sites of action. However, the likelihood of having a truly new herbicide in the next ten years is not good. Thus, it is critical that we use the available products more wisely and include more diverse weed management tactics in order to preserve the herbicides and crop traits currently available. Other issues brought about by unfavorable weather conditions will add further complexity to decisions about which herbicides to use and how to use them in 2013. Finally, the weed community has not been sedentary and continues to demonstrate the principles of natural selection; resistance in weeds, particularly common waterhemp, continues to increase at an increasing rate. Multiple resistances within populations are becoming more prevalent. All of these indicate the need for diligence and management in order to maintain effectively weed control. The simplicity and convenience of using only glyphosate, as was done in the previous decade and unfortunately continues in this decade, has resulted in problems that cannot be addressed with any one tactic or herbicide. Better weed management begins with the inclusion of more diverse tactics, scouting and using multiple herbicides with alternative effective sites of action.

Herbicide resistance and Palmer pigweed in Iowa

Mike Owen, professor and Extension weed specialist, Agronomy, Iowa State University

The success of past weed management programs, more specifically herbicide programs that focused primarily on single herbicide sites of action, continues to haunt the future management of weeds in Iowa. The evolved resistances to herbicide in Iowa weed populations reinforce the fact that weeds continue to be the most important, ubiquitous, resilient and enduring pest complex in agriculture. The Iowa Soybean Association (ISA) has funded Iowa State University Weed Science to conduct a project to assess herbicide resistance in Iowa soybean fields. Preliminary data from this ISA project are presented.

Iowa herbicide resistant weed update

In 2008, approximately 220 fields with common waterhemp populations were sampled arbitrarily and screened for resistance to glyphosate. In 2011, the ISA funded a proposal to further evaluate herbicide resistance in Iowa. More than 200 common waterhemp populations and a number of giant ragweed (Ambrosia trifida) and horseweed (aka. marestail, Conyza canadensis) were collected in 2011 and similar collections were made in 2012 (Figure 1). Evaluations of the populations are currently underway and approximately 60% of the 2011 common waterhemp collections have been evaluated for putative resistance to five sites of herbicide action; the populations of giant ragweed and horseweed will be evaluated after the common waterhemp populations have been completed. The herbicide sites of action included are representatives of the ALS inhibitor herbicides (Group 2), PSII inhibitors (Group 5), EPSPS (Group 9), PPO inhibitor herbicides (Group 14) and HPPD inhibitor herbicides (Group 27). Representatives of each of these herbicide sites of action were applied postemergence to common waterhemp populations in the greenhouse at the typical field use rates and at four times this rate. A summary of the evaluations thus far can be seen at *www.weeds.iastate.edu/mgmt/2012/resistancereport.html.*

Most of the weed populations designated as resistant still contain sensitive plants but resistance will become the primary phenotype if the herbicide(s) continue to be used. These evaluations are ongoing and as new populations are evaluated, the information will be included in the website.

As anticipated, most of the common waterhemp populations in Iowa have evolved resistance to the ALS inhibitor herbicides (Figure 2). More than 95% of the populations evaluated thus far demonstrate a resistant phenotype when challenged with a field rate of imazethapyr. When the rate increased to 4X, 88% of the populations were still evaluated as resistant.

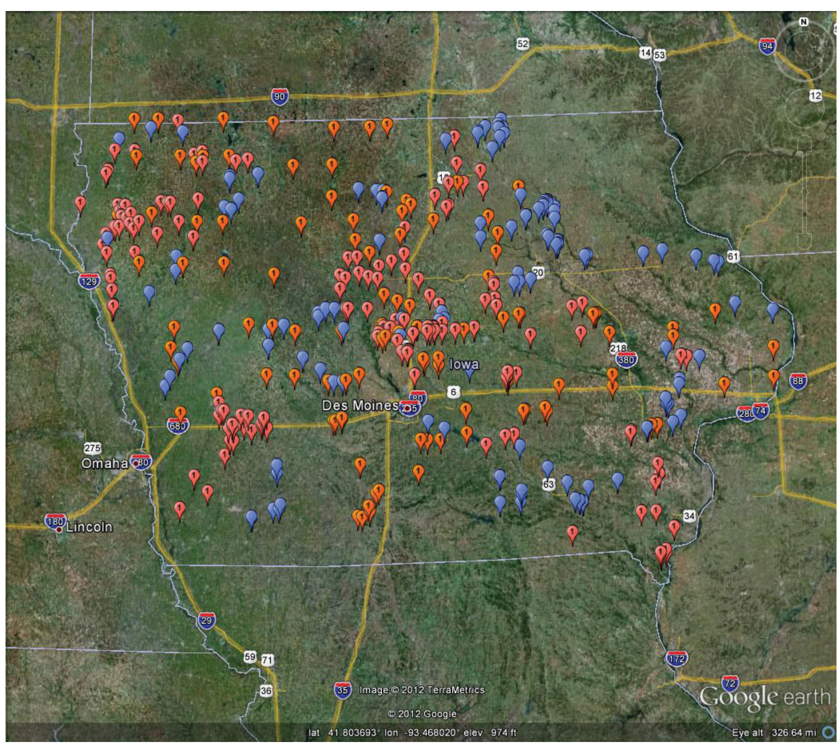

Figure 1. Iowa weed populations collected in 2008, 2011 and 2012 used to assess herbicide resistance.

The rate of the PSII herbicide did not change the relative percentages of the resistant populations as 58% and 57% of the common waterhemp populations had a resistant phenotype to 1X and 4X atrazine, respectively (Figure 2). When the common waterhemp populations evaluated thus far were treated with a field rate of glyphosate, 54% of the common waterhemp populations were assessed to be resistant while the number declined to 22% when the glyphosate rate was quadrupled (Figure 2). There was no effect of lactofen rate on the percentage of resistance in common waterhemp; 6% were resistant to the field rate while 5% were resistant to the 4X rate (Figure 2). There was a significant effect of rate for mesotrione as 28% of the common waterhemp populations evaluated thus far were assessed to be resistant to the field rate of mesotrione while the percentage declined to 4% at the 4X rate (Figure 2).

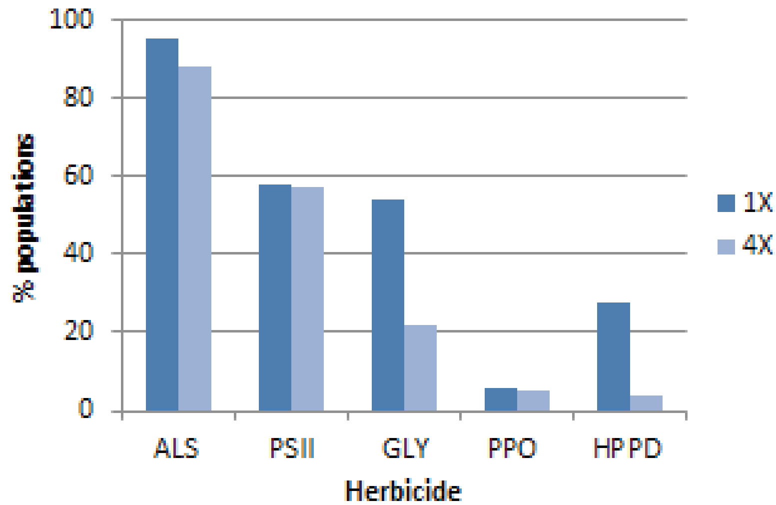

Figure 2. Preliminary data describing Iowa common waterhemp (Amaranthus tuberculatus) populations collected in 2011 resistance(s) to field application rates (1X) and four times this rate of five herbicides; imazethapyr (ALS), atrazine (PSII), glyphosate (GLY), lactofen (PPO), and mesotrione (HPPD)

One important aspect of the ISA sponsored project is the ability to assess multiple resistances in the weed populations. Given that common waterhemp has demonstrated the ability to evolve resistance to six different sites of herbicide action (the five included in this study and the auxinic herbicides (Group 4) dicamba and 2, 4-D), it is critically important to know exactly what herbicides are still effective when planning a common waterhemp management program. When populations have evolved resistance to more than one site of herbicide action, the herbicide options available quickly decline.

A majority of the common waterhemp populations from the 2011 collections evaluated thus far demonstrated multiple resistances (Figure 3). The most prevalent multiple resistant phenotype was populations of Iowa common waterhemp that were resistant to ALS inhibitor herbicides, PSII herbicides and glyphosate (29%). Common waterhemp populations that had evolved resistance to two sites of herbicide action accounted for 32% of the field evaluated thus far. Resistance to three herbicide sites of action included 37% of the populations (the dominate phenotype was resistance to ALS/PSII/GLY) while resistance to four herbicide sites of action included 14% of the populations. Three populations (2%) were resistant to all herbicide sites of action tested while 2% of the populations evaluated thus far were sensitive to all five herbicide sites of action (Figure 3).

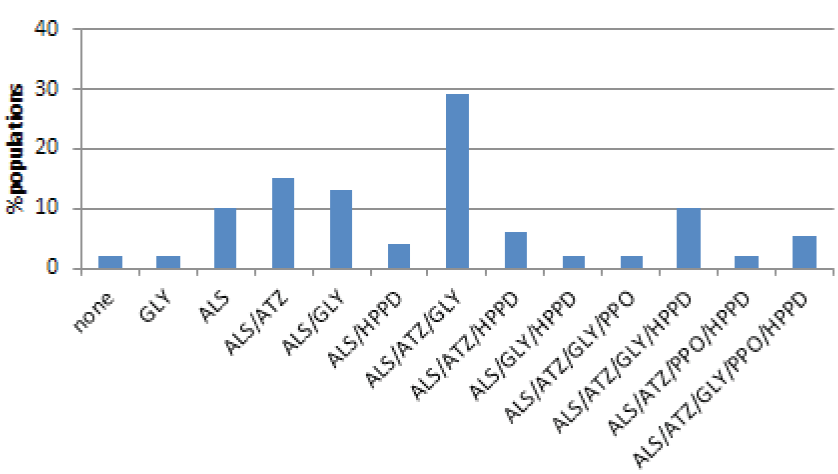

Figure 3. Preliminary data assessing Iowa common waterhemp populations demonstrating resistance to multiple herbicide sites of action

Based on the preliminary data, it is clear that managing herbicide resistant populations of common waterhemp will become increasingly challenging in the near future. Of great concern is the resistance to the HPPD inhibitor herbicides. It is important to recognize that the data is preliminary but if the trend established thus far holds when the 2012 collections are completed, the prevalence of resistant phenotypes will make weed management in corn and soybean increasingly difficult.

Recognize that this screen is with the postemergence application of these herbicides; there is a possibility the common waterhemp populations may respond differently to soil-applied herbicides. Furthermore, the heritability of resistance, particularly the HPPD inhibitor herbicides, will influence how quickly this phenotype emerges in common waterhemp. Regardless, these preliminary data indicate that better management of weeds in Iowa is of utmost importance and alternatives strategies must be quickly adopted in order to maintain effective weed management.

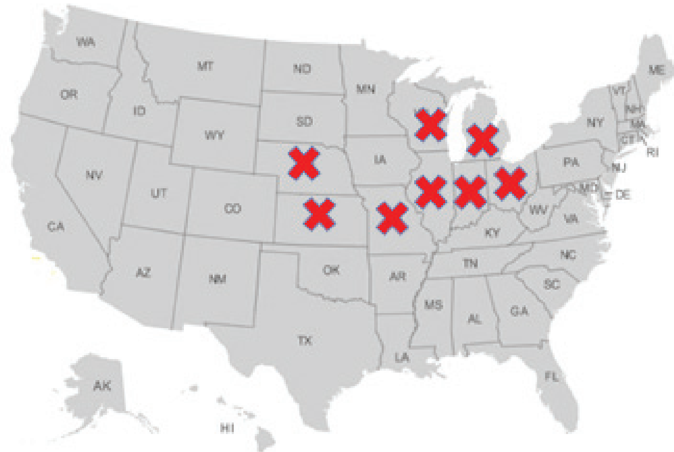

Figure 4. Midwest States with documented infestations of Palmer pigweed

Palmer pigweed

Palmer pigweed has been a significant problem in cotton and soybean production in the Mississippi Delta and the Southeastern United States. Interestingly, this weed originated in the arid Southwestern United States and was not a major concern until the unprecedented adoption of the glyphosate-resistant crop technologies. In many respects, Palmer pigweed is similar to common waterhemp) which dominates fields in the Midwest United States. These weeds are dioecious (male flowers and female flowers on separate plants), adapted to current tillage and crop production systems, produce incredible numbers of seeds and have opportunistic germination habits.

Palmer pigweed, like common waterhemp has evolved resistances to several herbicides including the ALS inhibitor herbicides and glyphosate. However, Palmer pigweed seems to be more aggressive in growth and competitive habit with crops. Research conducted at Kansas State University a number of years ago demonstrated that Palmer pigweed and common waterhemp would approach the same heights but Palmer pigweed produced approximately 30% more dry matter. The problem is that with current agricultural practices, the mobility of weeds no longer is a function of natural processes (i.e. gravity or water) to move seeds. Palmer pigweed seeds have been documented in cotton meal which is used as livestock feed and in manure. When these products move across state lines and are used, they provide a new opportunity for Palmer pigweed to establish a new "colony". As a result, Palmer pigweed infestations are appearing many states away for the original infestations. Palmer pigweed infestations have been identified in Southwest Michigan and Wisconsin (Figure 4). While there are no documented samples of Palmer pigweed in the Ada Hayden Herbarium at Iowa State University or verified Palmer pigweed infestations identified by Iowa State University weed scientists, it is highly likely that Palmer pigweed populations exist in Iowa and if established, will adapt quickly to Iowa production systems.

The best way to keep Palmer pigweed from becoming a serious problem in Iowa is to identify the initial infestations and control them prior to seed production. Use whatever extraordinary tactics as deemed necessary. However, given the likelihood that the Palmer pigweed will have evolved herbicide resistance(s), the best tactic is hand removal. An excellent pigweed identification brochure is available at http://www.weeds.iastate.edu/weed-id/waterhemp/default.htm from Iowa State University. If a suspected infestation is discovered, please save one plant and send to: Micheal D.K. Owen, 3218 Agronomy Hall, Ames, IA 50011 with the contact information. Then destroy all of the other plants before they flower.

Conclusions

The Iowa weed communities have not been sedentary and continue to demonstrate the principles of natural selection; resistance in weeds, particularly common waterhemp, continues to increase at an increasing rate. Multiple resistances within populations are becoming more prevalent. All of these indicate the need for diligence and management in order to maintain effectively weed control. While a majority of fields have not shifted to resistant biotypes as the dominant phenotype, the change is occurring rapidly. The simplicity and convenience of using only glyphosate, as was done in the previous decade and unfortunately continues in this decade, has resulted in problems that cannot be addressed with any one tactic or herbicide. Better weed management begins with the inclusion of more diverse tactics, scouting and using multiple herbicides with alternative effective sites of action. Scouting is particularly important to keep Palmer pigweed from becoming the next big agricultural problem.

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[2]	Amaranthus spp.[2,4,5,6]	Black nightshade	Cocklebur[2]	Common ragweed	Giant ragweed[2,4]	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 Flexx	E	G	F-G	G	G-E	F-G	G-E	F	P-F	F-G	P	G	G-E	F	G-E	P	P	G
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	G-E	F-G	G	G	G	G	G-E	G-E	G	P	P	P
Linex/Lorox	G	P	P	P	P	P	G-E	F	F	G	P	G-E	G-E	F	F	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	G	G-E	F-G	G	P	P	P
Python	G	P	P	P	P	P	E	F-G	F	G	F	F-G	G-E	F-G	G-E	P	P	P
Sharpen (Kixor)	G	P	P	P	P	P	G-E	G-E	G	G	G	G-E	G	G-E	G-E	P	P	G
Postemergence																		
Accent, 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, Basis Blend	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	G-E	F	E	E	G-E	F	G-E	E	G-E	G	P	P
Ignite[3]	E	E	G	G-E	E	E	G	E	E	E	G	G	E	E	E	F-G	G	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
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, Halomax, 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	G	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

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.

[1]Ratings are based on full label rates. Premix products containing ingredients marketed as single a.i. products may not be listed in this table.
[2]ALS-resistant biotypes of these weeds have been identified in Iowa. These biotypes may not be controlled by all ALS herbicides.
[3]Use only on designated resistant hybrids.
[4]Glyphosate-resistant biotypes of these weeds have been identified in Iowa. These biotypes may not be controlled by glyphosate.
[5]PPO-resistant biotypes of common waterhemp have been identified in Iowa. These biotypes may not be controlled by PPO inhibitor herbicides.
[6]HPPD-resistant biotypes of common waterhemp have been identified in Iowa. These biotypes may not be controlled by HPPD herbicides.
*Degree of perennial weed control is often a result of repeated application.

Soybean Herbicide Effectiveness Ratings[1]

Weed response to selected herbicides

E = excellent G = good
F = fair P = poor

		Grasses					Broadleaves									Perennials		
	Crop tolerance	Crabgrass	Fall panicum	Foxtail	Woolly cupgrass	Shattercane[2]	Amaranthus spp.[2, 4, 5,6]	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	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, INTO, 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
Linex/Lorox	F	P	P	P	P	P	G-E	F	F	G	P	G-E	G-E	F	F	P	P	P
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	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	G	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-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	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
Ignite	E	E	G	G-E	E	E	G	E	E	E	G	G	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	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

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

Grazing and haying restrictions for herbicides used in grass pastures

			Beef and Non-Lactating Animals			Lactating Dairy Animals	
Herbicide	**A.I.**	**Rate/A**	**Grazing**	**Hay harvest**	**Removal before slaughter**	**Grazing**	**Hay harvest**
Ally		0.1 - 0.3 oz	0	0	0	0	0
Clarity and many others	dicamba	Up to 1 pt	0	0	30 days	7 days	37 days
		1 - 2 pt	0	0	30 days	21 days	51 days
		2 - 4 pt	0	0	30 days	40 days	70 days
		4 - 16 pt	0	0	30 days	60 days	90 days
Chaparral	aminopyralid + metsulfuron methyl	1 - 3.3 oz	0	7 days	0	0	0
Cimarron Max (co-pack)	metsulfuron methyl + dicamba + 2,4-D	0.25-1 oz A + 1-4 pt B	0	0	30 days	7 days	37 days
Cimarron X-Tra	metsulfuron methyl + chlorsulfuron	0.1 - 1.0 oz	0	0	0	0	0
Crossbow	triclopyr + 2,4-D	1 - 6 qt	0	14 days	3 days	Growing season	Growing season
Escort XP	metsulfuron methyl	Up to 1.7 oz	0	0	0	0	0
		1.7 - 3.3 oz	NA	3 days	NA	NA	3 days
ForeFront HL	aminopyralid + 2,4-D	1.2 - 2.1 pt	0	7 days	0	0	7 days
Grazon P&D	picloram + 2,4-D	3 - 4 pt	0	0	0	7 days	30 days
Milestone	aminopyralid	3 - 7 oz	0	0	0	0	0
Overdrive	dicamba + diflufenzopyr	4 - 8 oz	0	0	0	0	0
PastureGard HL	triclopyr + fluroxypyr	1 - 1.5 pt	0	14 days	3 days	1 year	1 year
Rave	dicamba + triasulfuron	2 - 5 oz	0	37 days	30 days	7 days	37 days
Redeem R&P	triclopyr + clopyralid	1.5 - 4 pt	0	14 days	3 days	Growing season	Growing season
Remedy Ultra	triclopyr	1 - 2 qt	0	14 days	3 days	Growing season	Growing season
Surmount	picloram + fluroxypyr	1.5 - 6 pts	0	7	3	14	7
Tordon 22K	picloram	< 2 pts	0	0	3	14	14
		> 2 pts	0	14	3	14	14
Weedmaster	dicamba + 2,4-D	1-4 pts	0	37 days	30 days	7 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

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)
Anthem	2.087 lb pyroxasulfone 0.063 lb fluthiacet-methyl	10 oz	2.6 oz pyroxasulfone 0.08 fluthiacet	3.1 oz Zidua 0.7 oz Cadet
Basis 75DF	50% rimsulfuron 25% thifensulfuron	0.33 oz	0.167 oz rimsulfuron 0.083 oz thifensulfuron	0.67 oz Resolve 0.16 oz Harmony
Basis Blend	20% rimsulfuron 10% thifensulfuron	0.825 oz	0.167 oz rimsulfuron 0.083 oz thifensulfuron	0.67 Resolve 0.16 oz Harmony
Bicep II MAGNUM, 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 Aatrex 4L
Bicep Lite II MAGNUM	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
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 Aatrex 4L
Capreno	0.57 lb thiencarbazone 2.88 lb tembotrione	3.0 oz	0.01 lb thiencarbazone 0.068 lb tembotrione	- 2.5 oz Laudis
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
Corvus	1.88 lb isoxaflutole 0.75 lb thiencarbazone	5.6 oz	1.3 oz isoxaflutole 0.5 oz thiencarbazone	5.1 oz Balance Flexx
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

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)
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
Fierce	33.5% flumioxazin 42.5% pyroxasulfone	3 oz	1 oz flumioxazin 1.28 oz pyroxasulfone	2 oz Valor 1.5 oz Zidua
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
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	2.9 pt 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	4.17% rimsulfuron 41.67% mesotrione	6.0 oz	0.25 oz rimsulfuron 2.5 oz mesotrione	1.5 oz Resolve 5 oz Callisto
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
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

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)
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
Medal 11 AT	3.1 lb atrazine 2.4 lbs S-metolachlor	2.1 qts	1.63 lb atrazine 1.26 lb S-metolachlor	2 qt Aatrex 4L 1.3 pt Dual II MAGNUM
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
Optill	17.8% saflufenacil 50.2% imazethapyr	2.0 oz	0.35 oz saflufenacil 1 oz imazethapyr	1 oz Sharpen 4 oz Pursuit AS
Prequil 45% DF	15% rimsulfuron 30% isoxaflutole	2 oz	0.3 oz rimsulfuron 0.59 oz isoxaflutole	1.2 oz Resolve 1.2 oz Balance Pro
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 Define 4SC 1.7 oz Balance Pro
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
Sequence	2.25 lbs glyphosate 3 lbs S-metolachlor	4 qt	1.12 lbs glyphosate 1.5 lbs S-metolachlor	28 oz Touchdown or HiTech 26 oz Dual II MAGNUM
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 Q	25.2% nicosulfuron 12.5% rimsulfuron	1.5 oz	0.37 oz nicosulfuron 0.19 oz rimsulfuron	0.68 oz Accent Q 0.19 oz rimsulfuron
SureStart SE/Tripleflex	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

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)
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
Verdict	6.24% saflufenacil 55.04% dimethenamid-P	14 oz	0.992 oz saflufenacil 0.547 lb dimethenamid-P	2.8 oz Sharpen 11.7 oz Outlook
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
Zemax	3.34 lb s-metolachlor 0.33 lb mesotrione	2 qt	1.67 lb s-metolachlor 0.17 lb mesotrione	1.7 pt Dual II Magnum 5.4 oz Callisto

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 Assist	33.3% sulfentrazone 6.67% imazethapyr	10 oz	3.3 oz sulfentrazone 0.67 oz imazethapyr	4.4 oz Authority 75DF 2.7 oz Pursuit AS
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
Authority XL	62.2% sulfentrazone 7.8% chlorimuron	8 oz	5.0 oz sulfentrazone 0.6 oz chlorimuron	6.6 oz Authority 75DF 2.4 oz Classic
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
Canopy EX	22.7% chlorimuron 6.8% tribenuron	1.5 oz	0.34 oz chlorimuron 0.10 oz tribenuron	1.36 oz Classic 0.10 tribenuron

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)
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
Flexstar GT 3.5	0.56 lb fomesafen 2.26 lb glyphosate	3.5 pt	0.245 lb fomesafen 1.0 lb glyphosate	16 oz Flexstar 26 oz Touchdown HiTech
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
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
OpTill	17.8% saflufenacil 50.2% imazethapyr	2 oz	0.35 oz saflufenacil 1.0 oz imazethapyr	1 oz Sharpen 4 oz Pursuit AS
Prefix	46.4% S-metolachlor 10.2% fomesafen	2 pt	1.09 lb S-metolachlor 0.238 lb fomesafen	1.14 pt Dual Magnum 0.95 pt Reflex
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
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
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 chemical family (e.g. triazine, phenoxy, etc.) 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 which is involved in photosynthetic electron transfer. Thus, the site of action for triazines is the D1 protein, whereas the mode of action is the disruption of photosynthesis. An understanding of herbicide mode of action is essential for diagnosing crop injury or off-target herbicide injury problems, whereas knowledge of the site of action is needed for designing weed management programs with a low risk of selecting for herbicide-resistant weed populations.

The Weed Science Society of America (wssa.net) has developed a numerical system for identifying site of action by assigning group numbers to the different sites of action. Certain sites of action (e.g. photosystem II inhibitors) have multiple numbers since different herbicides may bind at different locations on the enzyme (e.g. photosystem II inhibitors) or different enzymes in the pathway may be targeted (e.g. carotenoid synthesis). The number following the herbicide class heading is the WSSA classification. Most manufacturers are including these Herbicide Groups on herbicide labels to aid development of herbicide resistance management strategies. Prepackage mixes will contain the Herbicide Group numbers of all active ingredients.

ACCase Inhibitors – 1

The ACCase enzyme is involved in the synthesis of fatty acids. 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 – 2

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 synthaes (AHAS). These amino acids are necessary for protein synthesis and plant growth. Generally, these herbicides are absorbed by both roots and foliage and are readily translocated in the xylem and phloem. The herbicides accumulate in meristematic regions of the plant and the herbicidal effects are first observed there. Symptoms include plant stunting, chlorosis (yellowing), and tissue necrosis (death), and are evident 1 to 4 weeks after herbicide application, depending upon the dose, 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, bottle-brush roots, shortened internodes, and leaf malformations (chlorosis, window-paning). However, symptoms typically are not distinct or consistent. Factors such as soil moisture, temperature, and soil compaction can enhance 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 – 3

Dinitroaniline (DNA) herbicides inhibit cell division by interfering with the formation of microtubules through inhibition of tubulin polymerization. Dinitroaniline herbicides are soil-applied and absorbed mainly by roots. Very little herbicide translocation in plants occurs, thus the primary herbicidal effect is on root development. Soybean injury from DNA herbicides is characterized by root pruning. Roots that do develop are 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 – 4

Several chemical families cause abnormal root and shoot growth by upsetting the plant hormone (i.e. auxin) balance. This is accomplished by the herbicides binding to the auxin receptor site. These herbicides are primarily effective on broadleaf species, however some monocots are also sensitive. Uptake can occur through seeds or roots with soil-applied treatments or leaves when applied postemergence. Synthetic auxins translocate throughout plants and accumulate in meristems. 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 – 5, 6, 7

Several families of herbicide bind to a protein involved in electron transfer in Photosystem II (PSII). These herbicides inhibit photosynthesis, which may result in interveinal chlorosis of plant leaves followed by necrosis of leaf tissue. Highly reactive compounds formed due to inhibition of electron transfer result in disruption of cell membranes and 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 (5) and urea (7) herbicides generally are absorbed both by roots and foliage, whereas benzothiadiazole (6) and nitrile (6) herbicides are absorbed primarily by plant foliage. Triazine-resistant biotypes of several weed species have been confirmed in Iowa following repeated use of triazine herbicides. Although the other PSII herbicides attack the same target site, they bind on a different part of the protein and remain effective against triazine resistant weeds.

Photosystem I Inhibitors - 22

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 secondary plant compounds. Very little translocation of bipyridilium herbicides occurs due to loss of membrane structure. Injury occurs only where the herbicide spray contacts the plant. Complete spray coverage is essential for weed control. The herbicide molecules carry strong positive charges that cause them to be very tightly adsorbed by soil colloids. Consequently, bipyridilium herbicides have no significant soil activity. Injury to crop plants from paraquat drift occurs in the form of spots of dead leaf tissue wherever spray droplets contact the leaves. Typically, slight drift injury to corn, soybeans, or ornamentals from a bipyridilium herbicide does not result in significant growth inhibition.

Protoporphyrinogen Oxidase (PPO) Inhibitors – 14

Group 14 herbicides inhibit an enzyme involved in synthesis of a precursor of chlorophyll; the enzyme is referred to as PPO.   Plant death results from destruction of cell membranes due to formation of highly reactive compounds. Postemergence applied diphenyl ether herbicides (e.g., aciflurofen, lactofen) kill weed seedlings are contact herbicides with little tranlocation. 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 postemergence,diphenyl ether herbicides is cosmetic and does not affect yields. The aryl triazolinones herbicides are absorbed both by roots and foliage. Susceptible plants emerging from soils treated with these herbicides turn necrotic and die shortly after exposure to light. Soybeans are most susceptible to injury if heavy rains occur when beans are cracking the soil surface.

Carotenoid synthesis inhibitors –13, 27

Herbicides in these families inhibit the synthesis of the carotene pigments. Inhibition of the carotene pigments results in loss of chlorophyll and bleaching of foliage at sublethal doses. Plant death is due to disruption of cell membranes. Several different enzymes in the synthesis of carotenoids are targeted by herbicides. Clomozone (Command) inhibits DOXP (13), whereas the other bleaching herbicides used in corn (Callisto, Balance Flexx, Laudis, Impact) inhibit HPPD (27). The HPPD inhbiting herbicides are xylem mobile and absorbed by both roots and leaves, they are used both preemergence and postemergence.

Enolpyruvyl Shikimate Phosphate Synthase (EPSPS) Inhibitors – 9

Glyphosate is a substituted amino acid that inhibits the EPSPS enzyme. This enzyme is a component of the shikimic acid pathway, which is responsible for the synthesis of several amino acids and numerous other compounds. Glyphosate is nonselective and is tightly bound in soil, so little root uptake occurs under normal use patterns.   Applications must be made to plant foliage. Translocation occurs out of leaves to all plant parts including underground storage organs of perennial weeds. Translocation is greatest when plants are actively growing. Injury symptoms are fairly slow in appearing. Leaves slowly wilt, turn brown, and die. Sub-lethal rates of glyphosate sometimes produce phenoxy-type symptoms with feathering of leaves (parallel veins) and proliferation of vegetative buds, or in some cases cause bleaching of foliage.

Glutamine Synthetase Inhibitors – 10

Glufosinate (Liberty, Ignite) inhibits the enzyme glutamine synthetase, an enzyme that incorporates ammonium. Although glutamaine synthetase is not involved directly in photosynthesis, inhibition of this enzyme ultimately results in the disruption of photosynthesis. Glufosinate is relatively fast acting and provides effective weed control in 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 due to rapid degradation in the soil by microorganisms. Libery/Ignite is nonselective except to crops that carry the Liberty Link gene.

Fatty acid and lipid synthesis inhibitors – 8

The specific site of action for the thiocarbamate herbicides (EPTC, butylate) is unknown, but it is believed they may conjugate with acetyl coenzyme A and other molecules with a sulfhydryl component. Interference with these molecules results in the disruption of fatty acid and lipid synthesis, along with other processes. Thiocarbamate herbicides are soil applied and require mechanical incorporation due to high volatility. Leaves of grasses injured by thiocarbamates do not unroll properly from the coleoptiles, resulting in twisting and knotting. Broadleaf plants develop cupped or crinkled leaves.

Very long chain fatty acid synthesis inhibitors (VLCFA) –15

Several chemical families (acetamide, chloroacetamide, oxyacetamide and tetrazolinone) are thought to inhibit synthesis of very long chain fatty acids. VLCFA are believed to play important roles in maintaining membrane structure. These herbicides disruption the germination of susceptible weed seeds and have little effect on emerged plants. They are most effective on annual grasses, but have activity on certain small-seeded broadleaves. Soybean injury occurs in the form of a shortened mid-vein in leaflets, resulting in crinkling and a heart-shaped appearance. Leaves of grasses, including corn, damaged by these herbicides fail to unfurl properly, and may emerge underground.

Auxin Transport Inhibitors – 19

Diflufenzopyr (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.

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, Section, Arrow, others	clethodim

ALS inhibitors	
imidazolinones	
Pursuit	imazethapyr
Raptor	imazamox
Scepter	imazaquin
sulfonanilides	
FirstRate, Amplify	chloransulam
Python	flumetsulam
sulfonylureas	
Accent	nicosulfuron
Ally, Cimarron	metsulfuron
Beacon	primisulfuron
Classic	chlorimuron
Express	tribenuron
Harmony GT	thifensulfuron
Permit, Halofax	halosulfuron

Microtubule inhibitor	
dinitroanilines	
Balan	benefin
Prowl H_20, Pentagon, Pendimax, Framework, others	pendimethalin
Sonalan	ethalfluralin
Surflan	oryzalin
Treflan, Trust, others	trifluralin

Synthetic auxin	
benzoic	
Banvel, Clarity, Sterling Blue, others	dicamba
phenoxy	
many	MPCA
many	2,4-D
Butyrac, Butoxone	2,4-DB
pyridines	
Remedy Ultra, Pathfinder II, many others	triclopyr
Milestone	aminopyralid
Stinger, Transline	clopyralid
Tordon	picloram

Photosystem II inhibitors	
benzothiadiazole	
Basagran	bentazon
nitriles	
Buctril, others	bromoxynil
triazines	
AAtrex, others	atrazine
Evik	ametryn
Princep	simazine
Sencor	metribuzin
ureas	
Karmex	diuron
LInex, Lorox	linuron

Photosystem I inhibitors	
Diquat, Reward	diquat
Gramoxone Max	paraquat

Protoporphyrinogen Oxidase (PPO) inhibitors	
aryl triazolinones	
Aim	carfentrazone
Authority, Spartan	sulfentrazone
diphenyl ethers	
Blazer, UltraBlazer	acifluorfen
Cobra, Phoenix	lactofen
ET, Vida	pyraflufen
Flexstar, Reflex	fomesafen
Goal	oxyfluorfen
phenylphthalimides	
Resource	flumiclorac
Valor	flumioxazin
pyrimidinedione	
Sharpen (Kixor)	saflufenacil
other	
Cadet	fluthiacet

Enolpyruvyl shikimate phosphate synthase (EPSPS) inhibitors	
Roundup, Touchdown, others	glyphosate

Glutamine synthetase inhibitors	
Liberty, Ignite	glufosinate

Hydroxyphenyl pyruvate dioxygenase (HPPD) inhibitors	
Balance Flexx	isoxaflutole + safener
Callisto	mesotrione
Armezon/Impact	topramezone

Diterpene inhibitors	
Command	clomazone

Auxin transport inhibitors	
Distinct, Status	diflufenzopyr + dicamba

Lipid synthesis inhibitors	
amides or acetanilides	
Degree, Harness, Surpass, Warrant	acetochlor
Dual II MAGNUM, Cinch, Medal, Charger Max, others	s-metolachlor + safener
Frontier, Outlook, Commit, others	dimethenamid
Lasso, Intrro, MicroTech	alachlor
Zidua	pyroxasulfone

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

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