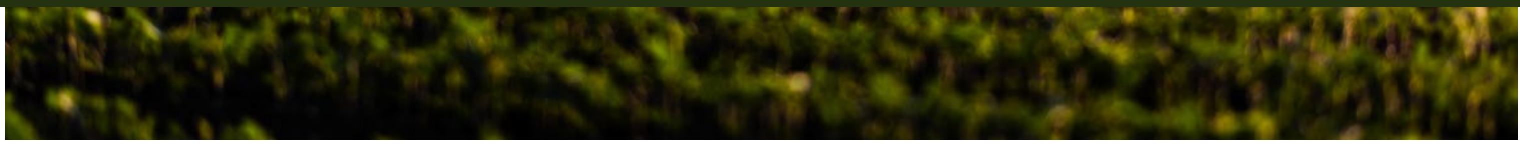
2024 Herbicide Guide: Iowa Corn and Soybean Production



Review of potential issues

In preparation for writing this introduction for the Weed Management Update for 2024, the author surveyed several individuals, and they suggested a few topics that included herbicide resistance, invasive weeds, herbicide carryover and improving herbicide performance. As the author searched for information about these topics, he found a paper he wrote for the first Proceeding of the Integrated Crop Management Conference in 1989 (Owen, 1989).

The topics that were addressed in this now 34-year-old paper included "new weed problems" and "herbicide carryover." The weeds that were described included toothed spurge (*Euphorbia dentata* Michx.), woolly cupgrass (*Eriochloa villosa* (Thunb.) Kunth), and shattercane (*Sorghum bicolor* [L.] Moench). A few years later, Asiatic dayflower (*Commelina communis* L.) was added to the list of future weed problems in Iowa. None of these weeds have become major issues in Iowa agriculture, although they may still be problems in some fields. The author's comments in 1989 about herbicide carryover were "Herbicide carryover has been a major issue in Iowa for the past three years." This comment is still appropriate today.

In 2024, there are three weeds that may be burgeoning problems: Asian copperleaf (*Acalypha australis* L.), Palmer amaranth (*Amaranthus palmeri* S. Watson) and burcucumber (*Sicyos angulatus* (L.) SIYAN.) Herbicide carryover is likely to be a problem in 2024. Apparently, some things never change in Iowa agriculture.

Invasive and "novel" weed species in Iowa

Asian copperleaf

The United States Department of Agriculture published a weed risk assessment for Asian copperleaf in 2012 and reported that the distribution of this species was limited in the United States (Anonymous, 2012). Asian copperleaf was first reported in the US in 1990. While Asian copperleaf is a major problem in the far east, the assessment for how serious the weed would become in the US suggested that it was not a major concern although individual fields might support economically significant infestations. Asian copperleaf has no adaptations for long-distance transport, so farmers can confine an infestation to specific fields if caution is practiced with equipment movement. Two reports that Asian copperleaf was resistant to glyphosate, fomesafen and ALS inhibitor herbicides were found (Li et al., 2009 and Liu et al., 2019). The article "Keep an Eye out for Asian Copperleaf," which is included in this publication, provides credible information describing the identification of this weed.

Palmer amaranth

Palmer amaranth continues to be a concern and has been found in more Iowa fields. The article included in this publication describes how to identify Palmer amaranth. Recent research currently under review (Confirmation of a four-way herbicide-resistant Palmer amaranth (*Amaranthus palmeri*) population in Iowa, Ryan Hamberg et al.) provides evidence that the Palmer amaranth populations in Iowa are likely resistant to multiple herbicides.

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Burcucumber

Burcucumber has been a minor problem in Iowa for a long time, although individual fields can have serious infestations. There are a number of publications describing the biology of burcucumber (Mann et al., 1981; Semeda and Weller, 2001) and one that provides information about how this weed responds to tillage (Messersmith et al., 2000). Burcucumber is less of a problem in no-tillage production than in reduced tillage production (Messersmith et al., 2000). As burcucumber has multiple germination events throughout the season, herbicide control can be challenging (Mann et al., 1981; Messersmith et al., 2000). Atrazine and HPPD inhibitor herbicides in combination can be effective in corn when applied preemergence but a postemergence application is likely necessary. There are no good options for controlling burcucumber in soybeans with preemergence herbicides, although chlorimuron and metribuzin may be efficacious. Dicamba products are somewhat effective when applied postemergence, but glyphosate is the best postemergence option in either corn or soybeans. However, given the lengthy emergence period of burcucumber, farmers need to use supplemental mechanical control such as cultivation.

Herbicide carryover

Herbicide carryover will again be an occasional problem in 2024. Carryover potential exists primarily for a few herbicides, specifically atrazine, HPPD inhibitor herbicides, fomesafen and clopyralid. The frequency and severity of symptoms will be dependent on the environmental conditions in 2024. Application rates and timings impact the potential for carryover, as do soil characteristics such as soil texture, organic matter, and pH. Reduce the risk of carryover in 2024 by following the rotational restrictions for the herbicides applied in 2023. Minimize stress on the 2024 crops by planting them when environmental conditions are favorable. Finally, consider avoiding herbicides that may pose a higher risk of injury to the 2024 crop due to high use rate, or that are like the 2023 herbicides. For future years, follow all label restrictions for herbicide rate and application timing based on soil characteristics. Carefully mix and apply herbicides to reduce misapplication issues. Observe crop varietal susceptibility to herbicides. If poor environmental conditions result in crops under stress, carryover may be more severe and widespread. The environmental conditions that are important include extremes in soil moisture, soil temperature, rainfall, and air temperatures. Any combination of these that results in stressed crops increases the likelihood of carryover problems.

Herbicide resistance

Herbicide resistance has been a problem in Iowa for several decades. The adapted paper (Waterhemp herbicide resistance in Iowa, Ryan Hamberg et al.) that is included in this publication provides the statistical probability of waterhemp herbicide resistance in Iowa fields. The other adapted paper (Iowa waterhemp varied susceptibility to 2,4-D, dicamba and glufosinate, Ryan Hamberg et al.) and the announcement of dicamba-resistant waterhemp in Iowa, demonstrates that Iowa is losing the battle against evolved herbicide resistance in waterhemp.

Suffice to say that unless farmers diversify management tactics, herbicide resistance will increase with higher percentages of the waterhemp population in fields demonstrating the resistance characteristics. Importantly, the use of 2,4-D, dicamba and glufosinate must be better managed to avoid the widespread evolution of resistance in waterhemp. As often repeated, there are no new effective mechanisms of herbicide action for the immediate future. Unfortunately, Illinois reports increasing waterhemp populations with resistance to herbicide group 15 (e.g., metolachlor); it is unlikely that Iowa is any different.

Improving herbicide performance

Improving herbicide performance is a function of perfecting the basics: appropriate selection of herbicides, correct rate, timely and accurate applications, and observations after application. Use all tactics including mechanical control and cultural control. Biological weed management tactics currently do not appear to be viable in Iowa row crops.

Each field is different and thus each field should have a suite of weed management tactics that are unique and appropriate for that field. While it is desirable to use a "one-size-fits-all" strategy, consider what has resulted: almost universal waterhemp resistance to glyphosate. Recognize that specific tactics may not be appropriate or needed throughout a field. Specific regions of a field may warrant cultivation. Certain fields may respond best to cover crops. Addressing the longer-term perspectives of weed management is increasingly important. Attacking the soil weed seedbank must be the focus of the program, along with finding pockets of weeds that have survived previous tactics and removing them from the field. Harvest around heavy infestations of waterhemp. so that the seeds are not dispersed by the combine. While establishing best management practices for each field requires thought and time, the benefits of a thoughtful and carefully considered approach to weed management will increase future success.

References

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Waterhemp herbicide resistance evolution in Iowa

adapted from [*Monitoring the temporal changes in herbicide-resistant Amaranthus tuberculatus: a landscape-scale probability-based estimation in Iowa*]. *Written* by Ryan C. Hamberg, Ramawatar Yadav, Philip M Dixon, Mark A. Licht and Micheal DK Owen. doi.org/10.1002/ps.7682.

Iowa soybean and corn growers are tasked with controlling waterhemp, one of the worst weeds in the United States. Waterhemp is genetically diverse and can rapidly evolve into herbicide resistance. Over the course of three decades, waterhemp populations have been confirmed resistant to seven herbicide groups (HG) including: Group 2 (ALS inhibitors, e.g., Pursuit), 4 (auxin mimics, e.g., dicamba), 5 (PS II inhibitors, e.g., atrazine), 9 (EPSPS inhibitor, e.g. glyphosate), 14 (PPO inhibitor, e.g. Blazer), 15 (VLCFAS inhibitors, e.g., Dual), and 27 (HPPD inhibitors, e.g., Impact). Often waterhemp populations will evolve resistance from multiple herbicide groups simultaneously, with 5- and 6-way multiple herbicide-resistant (MHR) populations being confirmed in Missouri and Illinois. Multiple herbicide-resistant waterhemp populations thus present major control challenges and incur increased costs to manage adequately.

Researchers use herbicide resistance surveys to better understand the frequency and distribution of herbicide-resistant weeds within a geographical region. To determine the extent of herbicide-resistant waterhemp populations in Iowa, a herbicide resistance survey funded in part by the Iowa Soybean Association was conducted across the state in 2013. The 2013 survey consisted of 97 waterhemp populations selected randomly from soybean fields across Iowa's nine crop reporting districts (Figure 1). The populations were screened with commonly used herbicide in corn and soybean including: Imazethapyr (HG2), atrazine (HG5), glyphosate (HG9), lactofen (HG14), and mesotrione (HG27) at the labeled rate and 4 times the labeled rate (Table 1). The same field sites sampled in the 2013 survey were revisited in 2019 and samples were collected again and screened with the same herbicides and rates. The goal of revisiting the survey locations was to evaluate how the waterhemp populations had changed over time.

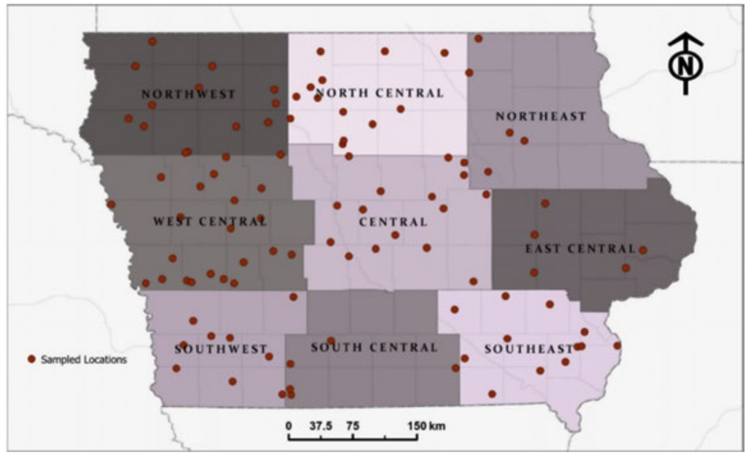

Figure 1. Field locations sampled in the 2013 and 2019 waterhemp surveys.

Results

Populations that had ≥50% survival to a herbicide and rate were classified as resistant. The waterhemp populations resistant to a 1x imazethapyr rate increased from 90% of populations in 2013 to 99% in 2019 (Figure 2). There was little to no increase in atrazine resistance at the 1x rate between 2013 and 2019 (Figure 2). However, the resistance frequency increased at the 4x atrazine rate from 55% to 68% of waterhemp populations between 2013 and 2019. Glyphosate resistance frequency was high for the 2013 and 2019 populations at the 1x rate (Figure 2). Seventy three percent of the 2013 Iowa waterhemp populations were resistant to a 1x glyphosate rate, which increased significantly to 97% in 2019. The resistance frequency to a 4x glyphosate rate increased significantly from 26% of waterhemp populations in 2013 to 66% of the populations in 2019. None of the 2013 waterhemp populations were resistant to lactofen. However, the resistance frequency increased to 16% and 4%

at 1× and 4× lactofen rates in 2019, respectively (Figure 2). Mesotrione resistance in Iowa waterhemp increased from 2013 to 2019, from 5% to 15% of the populations, respectively, however, there was little change in resistance frequency to a 4x mesotrione rate (Figure 2).

Multiple herbicide-resistance

Many Iowa waterhemp populations were resistant to more than one HG (Figure 3). From 2013 to 2019, 47 and 56 waterhemp populations evolved resistance to one or more additional HG at the 1x and 4x rates, respectively. Resistance to the ALS inhibitor herbicide imazethapyr was the most frequent HG for waterhemp populations resistant to one HG.

Two-way MHR to 1x herbicide rates decreased from 38% of Iowa waterhemp populations in 2013 to 19% in 2019 (Figure 3). In 2019, the largest proportion of two-way MHR populations were imazethapyr and glyphosate for the 1x and imazethapyr and atrazine for the 4x rates. Three-way MHR waterhemp was the most frequent for the 1x and 4x herbicide rates in 2019 with the majority resistant to imazethapyr, atrazine and glyphosate. Three-way MHR increased at 4x herbicide rates, increasing from 16% in 2013 to 44% of populations in 2019. The proportion of four-way MHR Iowa waterhemp populations resistant to imazethapyr, atrazine, glyphosate and lactofen were like those resistant to imazethapyr, atrazine, glyphosate and mesotrione in 2019. In 2013, none of the waterhemp populations demonstrated five-way

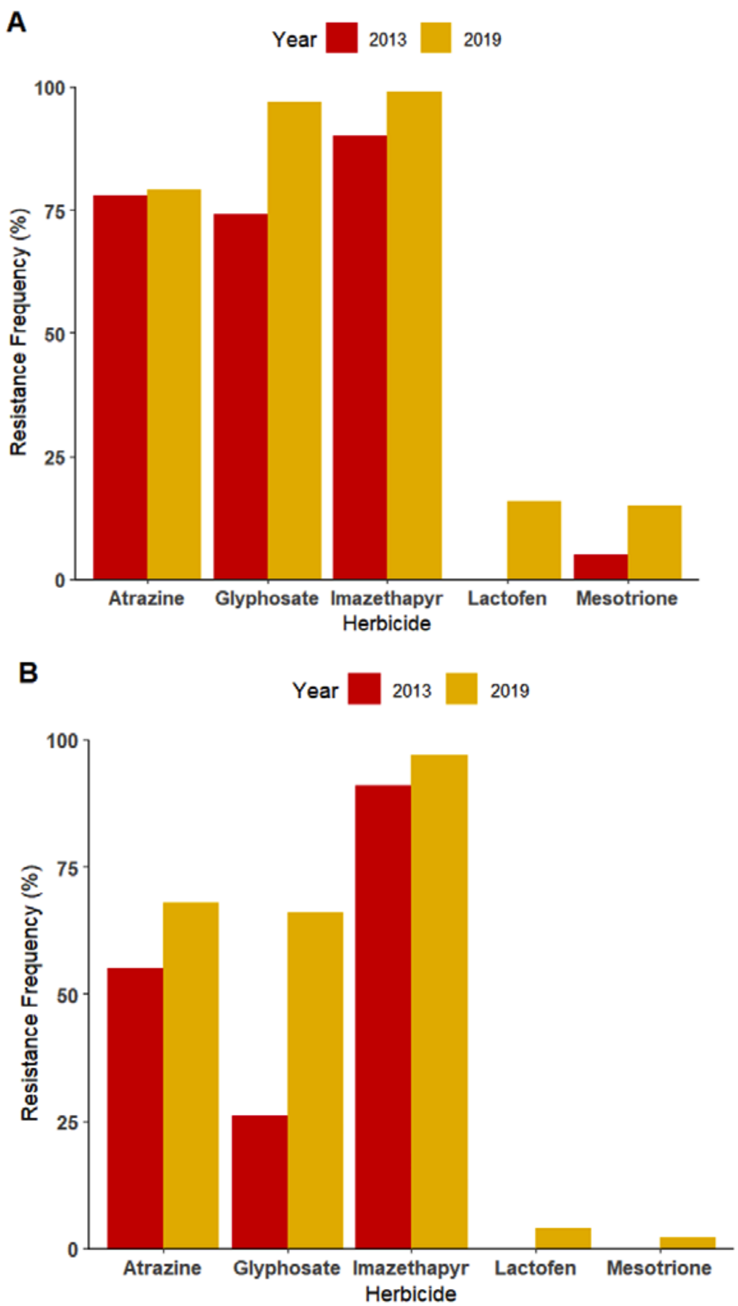

Figure 2. Resistance frequencies of waterhemp populations tested in the 2013 and 2019 surveys (A is 1x herbicide rates, B is 4x herbicide rates).

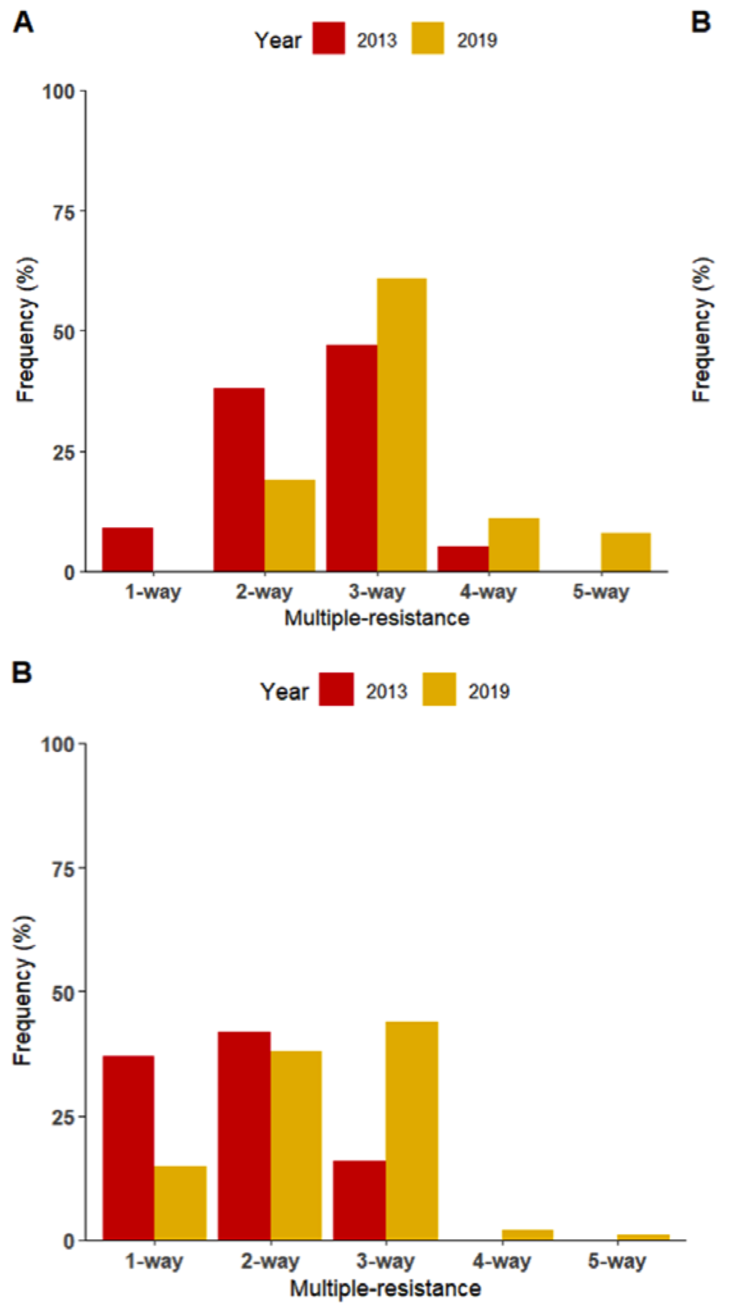

Figure 3. Resistance frequencies of multiples herbicide-resistant waterhemp populations tested in the 2013 and 2019 surveys (A is 1x herbicide rates, B is 4x herbicide rates).

MHR to 1x herbicide rates but increased to 8% of Iowa waterhemp populations in 2019. Five-way MHR at 4x herbicide rates were close to zero in both years (Figure 3). Observations from this study suggest that three-way MHR waterhemp was present in over half the Iowa waterhemp populations in 2019. Significant decreases in one- and two-way MHR populations indicated that over time, most populations have evolved resistance to more HGs.

Conclusion

The results of this study demonstrate that ALS, PS II and glyphosate resistance in Iowa waterhemp populations is frequent and resistance to lactofen and mesotrione is becoming more common. All resistance frequencies for the herbicides tested increased between 2013 and 2019 except for the 1x atrazine and 4x imazethapyr. Most Iowa waterhemp populations evolved resistance to multiple HG over the period of this study. The results of this six-year survey show the timescale by which Iowa waterhemp populations evolved herbicide resistance and suggests the rapidity with which waterhemp adapts to herbicide management tactics. Once herbicide-resistant traits have evolved in a weed population, they will likely remain regardless of the new management tactics employed in the field. Diverse weed management strategies beyond herbicides can effectively manage MHR waterhemp populations and slow the future evolution of herbicide resistance.

Iowa waterhemp varied susceptibility to 2,4-D, dicamba and glufosinate

Adapted from *Differential susceptibility of Iowa waterhemp (Amaranthus tuberculatus) populations to 2,4-D, dicamba, and glufosinate* by Ryan C Hamberg, Ramawatar Yadav, Micheal DK Owen, and Mark Licht. doi.org/10.1139/cjps-2023-0081.

The announced discovery of dicamba-resistant waterhemp in Iowa should have growers concerned. The relatively recent registration of 2,4-D, dicamba and glufosinate for use in soybean has been useful for combating herbicide-resistant waterhemp. Herbicide resistance surveys indicate the majority (>60%) of waterhemp populations in Iowa have 3-way multiple-herbicide resistance (MHR). Thus, it is understandable that growers would rely heavily on the effective herbicides left in the toolbox. In Iowa, the amount of 2,4-D, dicamba and glufosinate applied to soybeans has more than doubled between 2015 and 2020 in soybean according to the USDA NASS. With multiple-herbicide resistant waterhemp being the norm, it is likely that growers are only applying one effective postemergence mode of action herbicide to control some waterhemp populations.

A large-scale collection of waterhemp populations was conducted in 2019 in corn and soybean fields across the nine Iowa crop reporting districts. These collections were comprised of late-season waterhemp escapes that likely survived previous control tactics. The goal of these arbitrary collections was to assess the susceptibility of Iowa waterhemp to 1x label recommended rates of 2,4-D (24 fl. oz./acre), dicamba (22 fl. oz./acre) and glufosinate (29 fl. oz./acre). A total of 135, 133 and 168 waterhemp populations were collected and tested for 2,4-D, dicamba and glufosinate respectively.

Results

For each population, a total of 30 plants were treated with each herbicide and the survival frequencies were evaluated. Survival frequency was calculated for each herbicide by counting the number of surviving plants and dividing them by the total plants treated at 28 days after application. The average survival for each herbicide was calculated by dividing the total number of surviving plants for all populations by the total number of treated plants.

Glufosinate was applied to 168 waterhemp populations and 112 exhibited 0% survival frequency (Table 1). However, 56 populations had survival frequencies ranging from 0.1% to 32% (Table 1). Survival frequencies to dicamba ranged between 0% and 43%, however, 60% of the populations had 0% survival to a 1x dicamba rates (Table 1).

Table 1. Survival frequency distribution of waterhemp populations treated with 1x labeled rates.

	Survival Frequency*							
	0%	0.1%–10%	11%–20%	21%–30%	31%–40%	41%–49%	> 50%	Total
Herbicide	Number of Populations							
2,4-D	27	48	20	18	9	3	10	135
Dicamba	80	28	15	7	2	1	0	133
Glufosinate	112	33	10	11	2	0	0	168

*The survival frequency was calculated by dividing the number of resistant plants by the total number of treated plants.

The average survival to dicamba across all populations combined was 5% (Figure 4). Waterhemp susceptibility was less for 2,4-D compared to dicamba and glufosinate when averaged across the 135 waterhemp populations tested with survival frequencies ranging from 0% to >50% (Table 1). Average survival to 2,4-D was 17% across all tested populations with 10 populations exhibiting ≥50% survival frequencies.

Conclusion

The results in this study show that some Iowa waterhemp populations have reduced susceptibility to 2,4-D, dicamba, and glufosinate at field-use rates. The reduced sensitivity to group 4 herbicides is not surprising given that 2,4-D and dicamba have been used in Iowa corn production for many decades. To be clear, the recommended 2,4-D rate of application has been increased since this study was completed. However, historically, increased herbicide rates or frequency of application increases the speed that resistance evolves in weed populations.

Even though the average mortality to dicamba and glufosinate was >90%, the frequent occurrence of MHR waterhemp populations increases reliance on these herbicides for waterhemp control. The recent discovery of dicamba-resistant waterhemp populations in Iowa has validated this assessment and is yet another hard lesson that sole reliance on highly effective tools will only lead to the continued evolution of herbicide resistance.

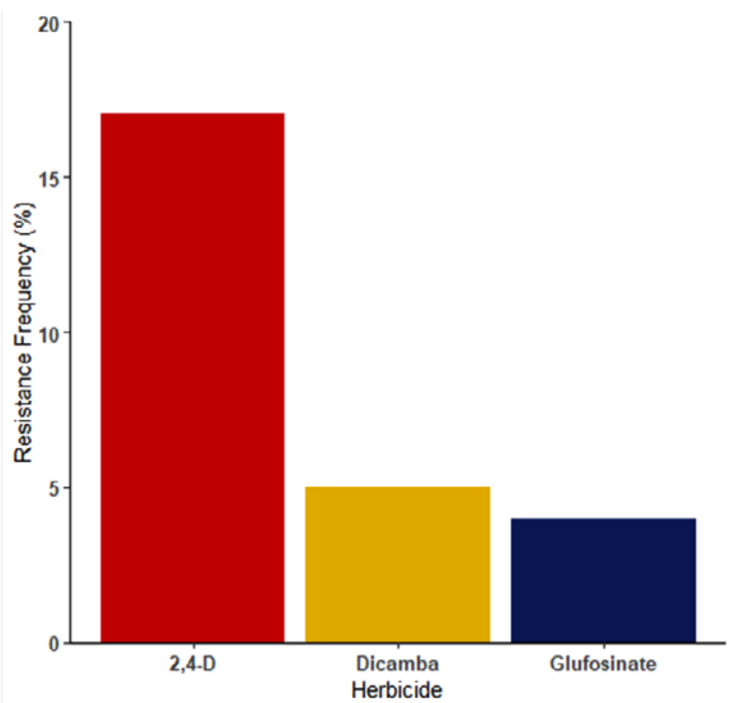

Figure 4. Overall survival of waterhemp populations to each herbicide (1x recommended label rate) tested.

Keep an eye out for Asian copperleaf

This article was originally published on September 28, 2023 by Meaghan Anderson. The information contained within may not be the most current and accurate depending on when it is accessed. (crops.extension.iastate.edu/cropnews/2023/09/keep-eye-out-asian-copperleaf)

With yet another sighting of Asian copperleaf (*Acalypha australis*) this fall, it's a good reminder to keep an eye out for this new species during harvest. Asian copperleaf (Acalypha australis) was first discovered in Iowa in 2016 in a corn field near Cedar Falls. Prior to this discovery, the only documented infestation in North America was within New York City. Since the initial discovery, it has been found in four other locations, totaling five counties across north central Iowa (Figure 5). In each field, several dense patches of the weed were present throughout the field (Figure 6), suggesting it was in the field for several years before being identified.

It is still unknown how the plant was introduced to Iowa. These discoveries are the only known cases of Asian copperleaf infesting cropland in the United States. The plant is a threat to row crops in its native range. Sources note this species has populations resistant to HG 2 (ALS inhibiting), HG 9 (glyphosate), and HG 14 (PPO inhibiting) herbicides in its native range. A USDA Risk Analysis completed in 2012 stated that the species did not show 'any strong invasive or weediness characters', but because of a high level of uncertainty the plant was classified as "High Risk" in 57% of the simulations.

Identification

Asian copperleaf is in the spurge family but lacks milky sap common in many spurges. It is an erect plant that can reach heights of 2-3 ft., but most plants found in Iowa were less than 18" in height. Leaves are 2-3" long, lanceolate with serrated (finely toothed) edges. The distinguishing characteristic of Asian copperleaf are the bracts located beneath the flowers. The bracts are circular to heart-shaped with a dentate margin (Figure 7). Virginia copperleaf and rhombic copperleaf, two other Acalypha species present in Iowa with a similar growth habit, have deeply lobed bracts (Figure 8). It is unlikely that anyone could confidently differentiate between these species prior to flowering. Asian copperleaf seems to emerge later in the season than other weed species; we found cotyledon-stage seedlings at one location on June 14. The species remains under the crop canopy throughout the growing season.

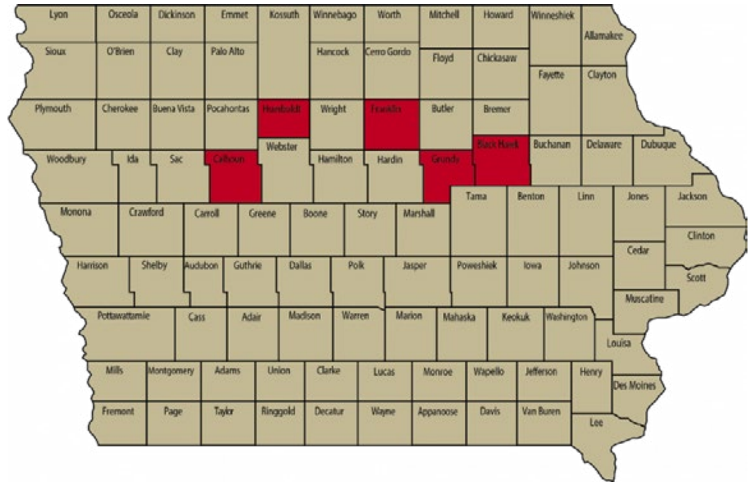

Figure 5. Map of currently known Asian copperleaf infestations in Iowa, September 2023.

Figure 6. A farmer in Franklin County noted several dense patches of Asian copperleaf at harvest.

Figure 7. Asian copperleaf has circular to heart-shaped bracts beneath flowers.

Figure 8. Deeply lobed bract like that from Virginia copperleaf and rhombic copperleaf (left) compared to a heart-shaped bract from Asian copperleaf (right).

Dicamba-resistant waterhemp in Iowa

This article was originally published on September 5, 2023 by Meaghan Anderson. The information contained within may not be the most current and accurate depending on when it is accessed. crops.extension.iastate.edu/cropnews/2023/09/dicamba-resistant-waterhemp-iowa.

While the registration of 2,4-D and dicamba products for over-the-top use in resistant-varieties has improved waterhemp control for many farmers, weed scientists warned that these herbicides would eventually select for resistant waterhemp populations. Bayer recently reported the discovery of two likely dicamba-resistant waterhemp populations in Iowa, which warrants a discussion on best management practices to slow the evolution of resistant waterhemp populations.

The particulars

On Friday, September 1, 2023 Bayer released an external communication reporting that suspected dicamba-resistant waterhemp populations were sampled in Scott County in 2021 and Marshall County in 2022. After extensive screening, the company states they are likely resistant to dicamba but will continue testing to positively confirm the resistance. This is the first case of plant growth regulator (HG 4) resistant waterhemp in Iowa, though other states have already documented HG 4 resistance in their own waterhemp populations. HG 4-resistant waterhemp were documented by university researchers in Nebraska in 2009, Illinois in 2016, and Missouri in 2018.

This discovery is not a cause for panic, but it is an important reality check for farmers who rely heavily on HG 4 herbicides or any other individual herbicide group for waterhemp control. Waterhemp is known for its ability to quickly adapt to herbicide management tactics; Iowa State University has already officially documented resistance to five HGs in Iowa waterhemp populations (Table 2).

Table 2. Herbicide resistances confirmed in Iowa prior to September 2023. (Heap, 2023).

Herbicide Group (HG) Number	Herbicide Trade Name Example	Resistance First Officially Documented
2	Pursuit, FirstRate	1993
5	Atrazine, metribuzin	1996
9	Roundup	2009
14	Flexstar, Valor	2009
27	Armezon, Callisto	2011

Best management practices to slow resistance development

While herbicides remain a primary tactic to manage many weed species, farmers can implement several best management practices to slow resistance development and better control weeds like waterhemp.

1. Choose an effective herbicide program for the weed spectrum present on a field-by-field basis.
   - **a.** Use full rates of effective residual herbicides and plant into a weed-free seedbed.
   - **b.** Include overlapping residual herbicides in postemergence applications to provide longer waterhemp control.
   - **c.** Make timely applications and follow herbicide labels to choose appropriate adjuvants, nozzles, application volume, etc.
   - **d.** Scout fields 7-10 days after postemergence herbicide applications to evaluate weed control.
2. Use a diversity of weed management tactics, including chemical, mechanical, and cultural options to better manage weeds. Narrow row spacing, cover crops, crop rotation, and tillage remain effective methods to suppress waterhemp.
3. Control weed escapes prior to seed set to reduce future weed populations and prevent resistant traits from spreading.
4. Reduce influx of weed seed into crop fields by managing field edges and cleaning equipment between movement from problematic fields to clean fields.

While some waterhemp will still survive to produce seed at the end of a growing season, farmers can reduce the spread of waterhemp seed by considering the following management recommendations:

1. Remove seed-producing waterhemp plants by hand and dispose of them outside the crop field. While a labor-intensive option, this would be very effective at reducing seed inputs in fields.
2. Avoid harvesting through drowned out spots or other heavily weed-infested areas in fields.
3. Equip harvest equipment with harvest weed seed control (HWSC) tools.
4. Prioritize fields by waiting to harvest the weediest ones last, thus reducing the weed seed spread from problem fields.
5. Implement combine clean-out practices between fields to reduce seed spread.

A new Palmer amaranth find underscores importance of scouting

This article was originally published on August 16, 2023 by Meaghan Anderson. The information contained within may not be the most current and accurate depending on when it is accessed. (crops.extension.iastate.edu/cropnews/2023/08/new-palmer-amaranth-find-underscores-importance-scouting)

While Palmer amaranth (*Amaranthus palmeri*) has been identified in more than half of Iowa's counties, new identifications have slowed since the widespread introductions on non-crop acres in 2016. A new Palmer amaranth introduction was recently identified in a crop field in central Iowa, highlighting the importance for farmers and agribusiness professionals to remain vigilant in scouting for this species.

A native of the American southwest, Palmer amaranth is more competitive than common waterhemp (*Amaranthus tuberculatus*), a pigweed native to Iowa. Both species are known for prolonged emergence, fast development of herbicide resistance, and prolific seed production (>500,000 seeds possible). In July 2017, Palmer amaranth was added to Iowa's noxious weed law, highlighting its potential threat to Iowa agriculture.

Early identification is key to eradicating this weed from fields. Eradication cannot happen without vigilance, early detection, and appropriate response soon after it invades an area. Palmer amaranth should be starting to flower, making it much easier to distinguish from waterhemp. In addition to fields where Palmer amaranth was found previously, other priority areas to scout include farms that use feed and bedding from southern states, fields receiving manure from those farms, and farms where out-of-state equipment has been used.

Palmer amaranth and waterhemp lack hair (pubescence) on stems and leaves, while other common amaranth (pigweed) species have hair on stems or leaves. Early in the growing season, Palmer amaranth is difficult to differentiate from waterhemp due to the high variability in both species. The most reliable vegetative trait to differentiate waterhemp and Palmer amaranth is that some, but not all, Palmer amaranth leaves have a petiole longer than the leaf blade. Leaves on Palmer amaranth are often clustered tightly at the top of the plant, and Palmer amaranth often has a denser canopy than waterhemp (Figure 10).

Palmer amaranth and waterhemp produce male and female flowers on separate plants (dioecious). Identifying males from females should be simple due to the small, black seed produced by female flowers and the presence of pollen on male plants. Female Palmer amaranth are easy to distinguish from waterhemp due to long, sharp bracts (Figure 11) surrounding the flowers (Figure 12). If you discover this weed, steps should be taken to remove all female plants to prevent seed production.

Figure 9. Palmer amaranth leaf with a petiole longer than the leaf blade. Folding the leaf over at the base is the fastest way to check for this trait.

Figure 10. Waterhemp's open canopy (left) compared to Palmer amaranth's denser, leafy canopy (right).

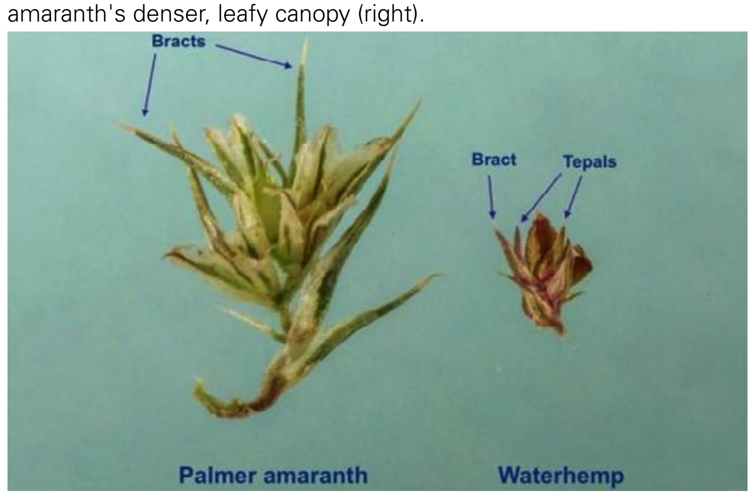

Figure 11. Comparison of a female Palmer amaranth flower and a female waterhemp flower.

Figure 12. A female Palmer amaranth with multiple, long terminal inflorescences.

Table 3. Corn herbicide effectiveness ratings.[1]

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

Weed response to selected herbicides	Herbicide Group Number	Crop tolerance	Grasses: Crabgrass	Fall panicum	Foxtail	Woolly cupgrass	Shattercane [2]	Broadleaves: Waterhemp [2, 4, 5, 6, 7, 8]	Black nightshade	Cocklebur [2]	Common ragweed	Giant ragweed [2, 4, 8]	Lambsquarter	Smartweed	Sunflower [2]	Velvetleaf	Perennials: Canada thistle	Quackgrass	Yellow nutsedge
Preplant/Preemergence																			
Atrazine	5	E	F	P	F	P	P	E	G	G	E	F-G	E	E	G	G	P	F	F
Balance Flexx (isoxaflutole)	27	E	G	F-G	G	G-E	F-G	G-E	F	P-F	F-G	P	G	G-E	F	G-E	P	P	G
Harness, Surpass NXT, etc (acetochlor)	15	E	E	E	E	F-G	F-G	G	G	P	P	P	P-F	P-F	P	P	P	P	G
Callisto (mesotrione)	27	E	P	P	P	P	P	G-E	G-E	F-G	F-G	F	E	F-G	G-E	E	P	P	P
Dual II Magnum, Outlook, Zidua, etc	15	E	E	E	E	F	F	F-G	G	P	P	P	P	P	P	P	P	P	G
Hornet WDG (flumetsulam, clopyralid)	2, 4	G	P	P	P	P	P	G-E	F-G	G	G	G	G	G-E	G-E	G	P	P	P
Linex, Lorox (linuron)	7	G	P-F	P-F	P	P	P	G-E	F	F	G	P-F	G-E	G-E	F	F	P	P	P
Pendimax, Prowl, etc (pendimethalin)	3	F-G	G-E	G-E	G-E	G	G	G	P	P	P	P	G-E	F	P	P-F	P	P	P
Python (flumetsulam)	2	G	P	P	P	P	P	E	F-G	F	G	F	F-G	G-E	F-G	G-E	P	P	P
Sharpen (saflufenacil)	14	G	P	P	P	P	P	G-E	G-E	G	G	G	G-E	G	G-E	G-E	P	P	G
Valor EZ (flumioxazin)	14	F-G	P	P	P	P	P	G-E	E	P	G	F	G-E	F	P	F	P	P	P
Postemergence																			
Accent Q, Steadfast Q (nicosulfuron, rimsulfuron)	2	G-E	P	G	G-E	G-E	E	G	P	F	P	P	P	G	P	F	F	G	F
Aim (carfentrazone)	14	G	P	P	P	P	P	F-G	G	P	P	F	G	P	P	E	P	P	P
Armezon, Impact (topramezone)	27	G-E	F-G	F	G	F	F	G-E	G-E	G-E	G	G	G	G	E	E	P	P	P
Atrazine	5	G	F	P	F	P	P	E	E	E	E	G	E	E	E	E	F*	F	G
Basagran (bentazon)	6	E	P	P	P	P	P	P	P	E	E	F	P	E	G	G-E	G*	P	G*
Basis, Basis Blend (rimsulfuron, thifensulfuron)	2	F	F	F-G	G	F	G	G	P	F	F	P	G-E	G-E	G-E	G	P	G	P
Banvel, Clarity, DiFlexx, etc. (dicamba)	4	F-G	P	P	P	P	P	G-E	G	E	G-E	E	G	E	G	F-G	G*	P	P
Beacon (primisulfuron)	2	G	P	F-G	P-F	P	E	E	G	G	G	E	P	G	G	F-G	F-G*	G	F
Buctril (bromoxynil)	6	G	P	P	P	P	P	G	G-E	E	E	G	G-E	G-E	E	G	P	P	P
Callisto (mesotrione)	27	G-E	P	P	P	P	P	E	E	G-E	F	G	G	E	G-E	E	P	P	P
Enlist One (2,4-D)[3]	4	E	P	P	P	P	P	G-E	G	E	E	E	E	F-G	G-E	G-E	F-G	P	P
Roundup (glyphosate)[3]	9	E	E	E	G-E	E	E	G-E	F-G	E	E	G-E	G	E	E	G	G	G-E	F
Hornet WDG (flumetsulam, clopyralid)	2, 4	G	P	P	P	P	P	G-E	F	E	E	G-E	F	G-E	E	G-E	G	P	P
Liberty (glufosinate)[3]	10	E	E	G	G-E	E	E	G	E	E	E	G	G	E	E	E	F-G	G	P
Laudis (tembotrione)	27	G-E	F-G	F	G-E	F-G	F-G	E	G-E	G-E	G	G	G	G	E	E	P	P	P
Permit, Halomax, etc. (halosulfuron)	2	G	P	P	P	P	P	E	P	G-E	G-E	G	P	G-E	E	E	P	P	G
Resolve (rimsulfuron)	2	F	F	F-G	G	F	G	G	P	F	F	P	G-E	G	P	F-G	F	G	F
Resource (flumiclorac)	14	G-E	P	P	P	P	P	G	P	F	F-G	P	F	P	P	E	P	P	P
Shieldex (tolpyralate)	27	G-E	F-G	P	G	P	G	E	E	F-G	G	G	G	F-G	E	E	P	P	P
Status (dicamba, diflufenzopyr)	4, 19	F-G	P	F	F	P	F	G-E	G	E	G-E	G	G	E	G	G	G*	P	P

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

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.

Table 4. Soybean herbicide effectiveness ratings.[1]

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

Herbicide	Herbicide Group Number	Crop tolerance	Grasses: Crabgrass	Fall panicum	Foxtail	Woolly cupgrass	Shattercane [2]	Waterhemp [2,4,5,6,7,8]	Broadleaves: Black nightshade	Cocklebur [2]	Common ragweed	Giant ragweed [2,4,8]	Lambsquarter	Smartweed	Sunflower [2]	Velvetleaf	Perennials: Canada thistle	Quackgrass	Yellow nutsedge
Preplant/Preemergence																			
Authority, Spartan, Zone (sulfentrazone)	14	G	P-F	P	P-F	P	P	E	E	F	F	F	G-E	F	P	F-G	P	P	F-G
Breakfree, Harnness, Surpass NXT, etc. (acetochlor)	15	E	E	E	E	F	F	F-G	G	P	P	P	P	P	P	P	P	P	P
Dual II Magnum, Outlook, Warrant, Zidua, etc. (S-metolachlor, pyroxasulfone)	15	E	E	E	E	F	F	F-G	G	P	P	P	P	P	P	P	P	P	P
Command (clomazone)	13	E	G-E	G-E	E	F	F	P	F	F	G	P	G-E	G	F	E	P	P	P
Engenia, Xtendimax w/ VGT (dicamba)[3]	4	F-G	P	P	P	P	P	F	G	G	G	G-E	G	G	G	F-G	G*	P	P
FirstRate, Amplify (cloransulam)	2	G-E	P	P	P	P	P	F-G	P	G	G-E	G-E	G	G-E	G	F-G	P	P	F-G
Linex, Lorox (linuron)	7	F	P-F	P-F	P	P	P	G-E	F	F	G	P-F	G-E	G-E	F	F	P	P	P
Prowl, Treflan, etc (pendimethalin, trifluralin)	3	G-E	E	E	E	E	G-E	G	P	P	P	P	G	F	P	P	P	P	P
Pursuit (imazethapyr)	2	G	F-G	F	F-G	P-F	G	F-E	G-E	F	G	F	G	G-E	F-G	G	P	P	P
Python (flumetsulam)	2	E	P	P	P	P	P	E	F	F	F	P	F-G	G-E	F	E	P	P	P
Metribuzin, TriCor, Mauler, etc	5	F-G	P	P	P-F	P	P	E	F	F	E	P	E	E	F-G	G-E	P	P	P-F
Sharpen (saflufenacil)	14	G	P	P	P	P	P	F	F	F	F	F	F	F	F	F	P	P	P
Valor EZ (flumioxazin)	14	F-G	P	P	P	P	P	G-E	E	P	G	F	G-E	F	P	F	P	P	P
Postemergence																			
Assure II, Fusilade DX, Poast Plus, Select Max (quizalofop, fluazifop, sethoxydim, clethodim)	1	E	E	E	E	E	E	P	P	P	P	P	P	P	P	P	P	G-E*	P
Basagran (bentazon)	6	E	P	P	P	P	P	P-F	P-F	E	E	F	P	E	G	G-E	G*	P	G*
Blazer (aciflurofen)	14	F-G	P	P	F	P	F	E	G	F	G	F	F	E	F	F	F	P	P
Classic (chlorimuron)	2	G	P	P	P	P	P	E	P	E	G-E	F	P	G-E	E	G-E	F	P	G-E
Cobra, Phoenix (lactofen)	14	F-G	F	P	P	P	P	E	G	G-E	E	F-G	F	G	G	F	F	P	P
Engenia, Xtendimax with VGT (dicamba)[3]	4	E	P	P	P	P	P	G-E	G	E	G-E	E	G	E	G	F-G	G*	P	P
Enlist One (2,4-D)[3]	4	E	P	P	P	P	P	G-E	G	E	E	E	E	F-G	G-E	G-E	F-G*	P	P
FirstRate, Amplify (cloransulam)	2	G	P	P	P	P	P	P	P	G-E	E	E	P	G	E	G	P	P	P
Roundup (glyphosate)[3]	9	E	E	G-E	E	E	E	G-E	F-G	E	E	G-E	G	E	E	G	G	G-E	F
Harmony (thifensulfuron)	2	F	P	P	P	P	P	E	P	F	F	P	G-E	G-E	G-E	G	P	P	P
Liberty (glufosinate)[3]	10	E	E	G	G-E	E	E	G	E	E	E	G	G	E	E	E	F-G	G	F
Pursuit (imazethapyr)	2	G	G	G	F-G	F	E	F-G	E	G-E	G	F	P-F	E	G	G-E	F	P	P
Beyond Xtra (imazamox)	2	G	G-E	G-E	G-E	G	E	F-G	E	G-E	G	G	G	E	E	G-E	F	F	F
Reflex, Flexstar (fomesafen)	14	F-G	P	P	P	P	P	E	F-G	F	G	G	F	G-E	F	F	P-F	P	P
Resource (flumiclorac)	14	G-E	P	P	P	P	P	G	P	F	F-G	P	F	P	P	E	P	P	P

[1]Ratings in this table are based on full label rates. Premix products containing ingredients marketed as single a.i. products may not be included in this table.
[2]ALS-resistant biotypes have been identified in Iowa. These biotypes may not be controlled by all ALS products.
[3]Use only on appropriate resistant varieties.
[4]Glyphosate-resistant biotypes of these weeds have been identified in Iowa. These biotypes may not be controlled by glyphosate.
[5]PPO-resistant biotypes of common waterhemp have been identified in Iowa. These biotypes may not be controlled by PPO inhibitor herbicides.
[6]HPPD-resistant biotypes of common waterhemp have been identified in Iowa. These biotypes may not be controlled by HPPD herbicides.
[7]PSII-resistant biotypes of these weeds have been identifed in Iowa. These biotypes may not be controlled by PSII inhibitor herbicides.
[8]Biotypes of this weed with resistance to multiple sites of herbicide action have been identified in Iowa.
*Degree of perennial weed control is often a result of repeated applications.

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.

Table 5. Grazing and haying restrictions for herbicides used in grass pastures.

				Beef and Non-Lactating Animals			Lactating Dairy Animals	
Herbicide	**A. I.**	**HG**	**Rate/A**	**Grazing**	**Hay harvest**	**Removal before slaughter**	**Grazing**	**Hay harvest**
2,4-D	2,4-D	4	1.5 to 2.0 lb. a.e.		7 days	0	0	7 days
Clarity and many others	dicamba	4	Up to 1 pt.	0	0	30 days	7 days	37 days
			1 - 2 pt.	0	0	30 days	21 days	51 days
			2 - 4 pt.	0	0	30 days	40 days	70 days
Chaparral	aminopyralid + metsulfuron methyl	4, 2	1 - 3.3 oz.	0	0	0	0	0
Cimarron Max (co-pack)	metsulfuron methyl + dicamba + 2,4-D	2, 4, 4	0.25-1 oz. A + 1-4 pt. B	0	0	30 days	7 days	37 days
Cimarron X-Tra	metsulfuron methyl + chlorsulfuron	2, 2	0.1 - 1.0 oz.	0	0	0	0	0
Crossbow	triclopyr + 2,4-D	4, 4	1 - 6 qt.	0	14 days	3 days	Growing season	Growing season
Curtail	clopyralid + 2,4-D	4, 4	2 - 4 qt.	0	7 days	7 days*	14 days	7 days
Duracor	aminopyralid + florpyrauxifen-benzyl	4, 4	12 - 20 oz.	0	14 days	0	0	14 days
Escort XP	metsulfuron methyl	2	Up to 1.7 oz.	0	0	0	0	0
ForeFront HL, GrazonNext HL	aminopyralid + 2,4-D	4, 4	1.2 - 2.1 pt.	0	7 days	0	0	7 days
Grazon P&D	picloram + 2,4-D	4, 4	3 - 4 pt.	0	30 days	3 days	7 days	30 days
Milestone	aminopyralid	4	3 - 7 oz.	0	0	0	0	0
Outrider	sulfosulfuron	2	0.75-2.0 oz.	0	0	0	0	0
Overdrive	dicamba + diflufenzopyr	4, 19	4 - 8 oz.	0	0	0	0	0
PastureGard HL	triclopyr + fluroxypyr	4, 4	1 - 1.5 pt.	0	14 days	3 days	1 year	1 year
Rave	dicamba + triasulfuron	4, 2	2 - 5 oz.	0	37 days	30 days	7 days	37 days
Redeem R&P	triclopyr + clopyralid	4, 4	1.5 - 4 pt.	0	14 days	3 days	Growing season	Growing season
Remedy Ultra	triclopyr	4	1 - 2 qt.	0	14 days	3 days	Growing season	Growing season
Surmount	picloram + fluroxypyr	4, 4	1.5 - 6 pt.	0	7	3	14	7
Tordon 22K	picloram	4	< 2 pt.	0	0	3	14	14
			> 2 pt.	0	14	3	14	14
Weedmaster	dicamba + 2,4-D	4, 4	1-4 pt.	0	7 days	30 days	7 days	7 days

"a.e." stands for acid equivalent.

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

Table 6. Corn herbicide premixes or co-packs and equivalents.

Herbicide	Group	Components (a.i./ gal or % a.i. or a.e.)	If you apply (per acre)	You have applied (a.i. or a.e.)
Acuron	15	2.14 lb. S-metolachlor	3 qt.	1.6 lb. S-metolachlor
	5	1.0 lb. atrazine		0.75 lb. atrazine
	27	0.24 lb. mesotrione		2.9 oz. mesotrione
	27	0.06 lb. bicyclopyrone		0.72 oz. bicyclopyrone
Acuron Flexi	27	0.08 lb. bicyclopyrone	2.25 qt.	0.72 oz. bicyclopyrone
	27	0.32 lb. mesotrione		2.9 oz. mesotrione
Acuron GT	15	2.00 lb. S-metolachlor	3.75 pt.	0.94 lb. S-metolachlor
	9	2.00 lb. a.e. glyphosate		0.94 lb. a.e. glyphosate
	27	0.20 lb. mesotrione		1.5 oz. mesotrione
	27	0.095 lb. bicyclopyrone		0.7 oz. bicyclopyrone
Alluvex WSG	2	16.7% rimsulfuron	1.5 oz.	0.25 oz. rimsulfuron
	2	16.7% thifensulfuron		0.25 oz. thifensulfuron
Anthem	15	2.087 lb. pyroxasulfone	10 fl. oz.	2.6 oz. pyroxasulfone
	14	0.063 lb. fluthiacet-methyl		0.08 oz. fluthiacet-methyl
Anthem Maxx	15	4.174 lb. pyroxasulfone	5 fl. oz.	2.6 oz. pyroxasulfone
	14	0.126 lb. fluthiacet-methyl		0.08 oz. fluthiacet-methyl
Anthem ATZ	5	4 lb. atrazine	2 pt.	1.0 lb. atrazine
	15	0.485 lb. pyroxasulfone		1.9 oz. pyroxasulfone
	14	0.014 lb. fluthiacet-methyl		0.06 oz. fluthiacet-methyl
Armezon Pro	15	5.25 lb. dimethenamid-P	20 fl. oz.	0.82 lb. dimethenamid-P
	27	0.1 lb. topramezone		0.25 oz. topramezone
Basis Blend	2	20% rimsulfuron	0.825 oz.	0.167 oz. rimsulfuron
	2	10% thifensulfuron		0.083 oz. thifensulfuron
Bicep II MAGNUM, Charger Max ATZ	15	2.4 lb. S-metolachlor	2.1 qt.	1.26 lb. S-metolachlor
	5	3.1 lb. atrazine		1.63 lb. atrazine
Bicep Lite II MAGNUM, Charger Max ATZ Lite	15	3.33 lb. S-metolachlor	1.5 qt.	1.25 lb. S-metolachlor
	5	2.67 lb. atrazine		1.0 lb. atrazine
Calibra	15	2.82 lb. S-metolachlor	2 qt.	1.41 lb. S-metolachlor
	27	0.28 lb. mesotrione		0.14 lb. mesotrione
Callisto GT	9	3.8 lb. a.e. glyphosate	2 pt.	0.95 lb. a.e. glyphosate
	27	0.38 lb. mesotrione		1.52 oz. mesotrione
Callisto Xtra	27	0.5 lb. mesotrione	24 fl. oz.	1.5 oz. mesotrione
	5	3.2 lb. atrazine		0.6 lb. atrazine
Capreno	2	0.57 lb. thiencarbazone	3.0 fl. oz.	0.16 oz. thiencarbazone
	27	2.88 lb. tembotrione		1.09 oz. tembotrione
Corvus	27	1.88 lb. isoxaflutole	5.6 fl. oz.	1.3 oz. isoxaflutole
	2	0.75 lb. thiencarbazone		0.5 oz. thiencarbazone
Coyote	15	3.34 lb. S-metolachlor	2.4 qt.	2.0 lb. S-metolachlor
	27	0.33 lb. S-metolachlor		3.2 oz. S-metolachlor
Crusher 50 WDF	2	25% rimsulfuron	1 oz.	0.25 oz. rimsulfuron
	2	25% thifensulfuron		0.25 oz. thifensulfuron
Degree Xtra	15	2.7 lb. acetochlor	3 qt.	2.0 lb. acetochlor
	5	1.34 lb. atrazine		1.0 lb. atrazine
DiFlexx Duo	27	0.27 lb. tembotrione	32 fl. oz.	1.1 oz. tembotrione
	4	1.86 lb. dicamba a.e.		0.31 lb. dicamba a.e.
Distinct 70WDG	19	21.4% diflufenzopyr	6 oz	1.3 oz. diflufenzopyr
	4	55.0% dicamba		3.3 oz. dicamba
Enlist Duo	4	1.6 lb. a.e. 2,4-D	4.75 pt	0.95 lb. a.e. 2,4-D
	9	1.7 lb. a.e. glyphosate		1.0 lb. a.e. glyphosate

"a.i." stands for active ingredient.
"a.e." stands for acid equivalent.

Table 6. Corn herbicide premixes or co-packs and equivalents. (continued)

Herbicide	Group	Components (a.i./ gal or % a.i. or a.e.)	If you apply (per acre)	You have applied (a.i. or a.e.)
Fierce EZ	14	1.34 lb. flumioxazin	6 fl. oz.	1.0 oz. flumioxazin
	15	1.7 lb. pyroxasulfone		1.28 oz. pyroxasulfone
Fierce MTZ	5	1.5 lb. metribuzin	16 fl. oz.	0.187 lb. metribuzin
	14	0.5 lb. flumioxazin		1.0 oz. flumioxazin
	15	0.64 lb. pyroxasulfone		1.28 oz. pyroxasulfone
FulTime NXT	15	2.7 lb. acetochlor	3 qt.	2.0 lb. acetochlor
	5	1.34 lb. atrazine		1.0 lb. atrazine
Halex GT	15	2.09 lb. S-metolachlor	3.6 pt.	0.94 lb. S-metolachlor
	27	0.209 lb. mesotrione		1.44 oz. mesotrione
	9	2.09 lb. a.e. glyphosate		0.94 lb. a.e. glyphosate
Harness MAX	15	3.52 lb. acetochlor	75 fl. oz.	2.05 lb. acetochlor
	27	0.33 lb. mesotrione		3.1 oz. mesotrione
Harness Xtra, Confidence Xtra, Keystone LA NXT	15	4.3 lb. acetochlor	2.3 qt.	2.5 lb. acetochlor
	5	1.7 lb. atrazine		0.98 lb. atrazine
Harness Xtra 5.6L , Confidence Xtra 5.6, Keystone NXT	15	3.1 lb. acetochlor	3 qt.	2.325 lb. acetochlor
	5	2.5 lb. atrazine		1.875 lb. atrazine
Hornet WDG	2	18.5% flumetsulam	5 oz.	0.924 oz. flumetsulam
	4	50% clopyralid		2.5 oz. clopyralid
Impact Core	15	7.08 lb. acetochlor	30 fl. oz.	1.66 lb. acetochlor
	27	0.07 lb. topramezone		0.26 oz. topramezone
Instigate	2	4.17% rimsulfuron	6.0 oz.	0.25 oz. rimsulfuron
	27	41.67% mesotrione		2.5 oz. mesotrione
Katagon	2	1.00 lb. nicosulfuron	2.3 fl. oz.	0.3 oz. nicosulfuron
	27	1.00 lb. tolpyralate		0.3 oz. tolpyralate
Kyro	4	0.247 lb. clopyralid	45 fl. oz.	1.4 oz. clopyralid
	15	2.78 lb. acetochlor		0.977 lb. acetochlor
	27	0.046 lb. topramezone		0.26 oz. topramezone
Lexar EZ	15	1.74 lb. S-metolachlor	3.5 qt.	1.52 lb. S-metolachlor
	5	1.74 lb. atrazine		1.52 lb. atrazine
	27	0.224 lb. mesotrione		3.1 oz. mesotrione
Lumax EZ	27	0.249 lb. mesotrione	3 qt.	3.0 oz. mesotrione
	15	2.49 lb. S-metolachlor		2.0 lb. S-metolachlor
	5	0.935 lb. atrazine		1.6 oz. atrazine
Maverick Corn Herbicide	4	0.693 lb. clopyralid	18 fl. oz.	1.56 oz. clopyralid
	15	0.693 lb. pyroxasulfone		1.6 oz. pyroxasulfone
	27	0.829 lb. mesotrione		1.9 oz. mesotrione
Panoflex 50 WSG	2	40% tribenuron	0.5 oz.	0.2 oz. tribenuron
	2	10% thifensulfuron		0.05 oz. thifensulfuron
Perpetuo	14	0.59 lb. flumiclorac	8 fl. oz.	0.037 lb. flumiclorac
	15	1.71 lb. pyroxasulfone		1.7 oz. pyroxasulfone
Prequel 45% DF	2	15% rimsulfuron	2 oz.	0.3 oz. rimsulfuron
	27	30% isoxaflutole		0.6 oz. isoxaflutole
Preview 2.1 SC	5	2.23 lb. metribuzin	14 fl. oz.	0.25 lb. metribuzin
	14	1.12 lb. sulfentrazone		0.13 lb. sulfentrazone
Realm Q	2	7.5% rimsulfuron	4 oz.	0.3 oz. rimsulfuron
	27	31.25% mesotrione		1.25 oz. mesotrione
Resicore	15	2.8 lb. acetochlor	2.5 qt.	1.75 lb. acetochlor
	27	0.3 lb. mesotrione		3.0 oz. mesotrione
	4	0.19 lb. clopyralid		1.9 oz. clopyralid

"a.i." stands for active ingredient.
"a.e." stands for acid equivalent.

Table 6. Corn herbicide premixes or co-packs and equivalents. (continued)

Herbicide	Group	Components (a.i./ gal or % a.i. or a.e.)	If you apply (per acre)	You have applied (a.i. or a.e.)
Resicore XL	4	0.19 lb. clopyralid	2.5 qt.	1.9 oz. clopyralid
	15	2.8 lb. acetochlor		1.75 lb. acetochlor
	27	0.27 lb. mesotrione		2.7 oz. mesotrione
Resolve Q	2	18.4% rimsulfuron	1.25 oz.	0.23 oz. rimsulfuron
	2	4.0% thifensulfuron		0.05 oz. thifensulfuron
Restraint	15	6.4 lb. acetochlor	30 fl. oz.	1.5 lb. acetochlor
	27	0.09 lb. tolpyralate		0.35 oz. tolpyralate
Revulin Q	27	36.8% mesotrione	4 oz.	1.5 oz. mesotrione
	2	14.4% nicosulfuron		0.58 oz. nicosulfuron
Scorch	4	1 lb. dicamba a.e.	1.5 pt.	0.187 lb. dicamba a.e.
	4	3.02 lb. a.e. 2,4-D		0.57 lb. a.e. 2,4-D
	4	0.75 lb. fluroxypyr		0.14 lb. fluroxypyr
Sequence	9	2.25 lbs. a.e. glyphosate	4 pt.	1.12 lb. a.e. glyphosate
	15	3 lbs. S-metolachlor		1.5 lb. S-metolachlor
Sinate	10	2.47 lb. glufosinate	28 fl. oz.	0.54 lb. glufosinate
	27	0.1 lb. topramezone		0.35 oz. topramezone
Solstice	27	3.78 lb. mesotrione	3.15 fl. oz.	1.49 oz. mesotrione
	14	0.22 lb. fluthiacet-methyl		0.08 oz. fluthiacet-methyl
Spirit 57WG	2	14.25% prosulfuron	1 oz.	0.1425 oz. prosulfuron
	2	42.75% primisulfuron		0.4275 oz. primisulfuron
Spitfire	4	0.5 lb. a.e. dicamba	2 pt.	0.12 lb. a.e. dicamba
	4	3.07 lb. a.e. 2,4-D		0.77 lb. a.e. 2,4-D
Status 56WDG	19	17.1 % diflufenzopyr	5 oz.	0.8 oz. diflufenzopyr
	4	44% dicamba		0.125 lb. dicamba
Steadfast Q	2	25.2% nicosulfuron	1.5 oz.	0.37 oz. nicosulfuron
	2	12.5% rimsulfuron		0.19 oz. rimsulfuron
Storen	15	2.69 lb. S-metolachlor	2.1 qt.	1.41 lb. S-metolachlor
	15	0.15 lb. pyroxasulfone		1.3 oz. pyroxasulfone
	27	0.31 lb. mesotrione		2.6 oz. mesotrione
	27	0.075 lb. bicyclopyrone		0.63 oz. bicyclopyrone
Surestart II, Tripleflex II, Trisidual	15	3.75 lb. acetochlor	2.0 pt.	0.94 lb. acetochlor
	4	0.38 lb. clopyralid		1.5 oz. clopyralid
	2	0.12 lb. flumetsulam		0.48 oz. flumetsulam
Tough R	6	2.5 lb. pyridate	32 fl. oz.	0.625 lb. pyridate
	27	0.75 lb. mesotrione		3.0 oz. mesotrione
Tripzin ZC	3	2.9 lb. pendimethalin	29 fl. oz.	0.66 lb. pendimethalin
	5	1.1 lb. metribuzin		0.25 lb. metribuzin
Trivolt	2	0.23 lb. thiencarba-zone-methyl	20 fl. oz.	0.036 lb. thiencarba-zone-methyl
	15	2.85 lb. flufenacet		0.445 lb. flufenacet
	27	0.57 lb. isoxaflutole		1.4 oz. isoxaflutole
Verdict	14	0.57 lb. saflufenacil	14 fl. oz.	1.0 oz. saflufenacil
	15	5 lb. dimethenamid-P		0.55 lb. dimethenamid-P
WideMatch 1.5EC	4	0.75 lb. fluroxypyr	1.3 pt.	0.125 lb. fluroxypyr
	4	0.75 lb. clopyralid		1.95 oz. clopyralid
Yukon	2	12.5% halosulfuron	4 oz.	0.5 oz. halosulfuron
	4	55% dicamba		0.125 lb. dicamba

"a.e." stands for acid equivalent.

Table 7. Soybean herbicide premixes or co-packs and equivalents.

Herbicide	Group	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)
Afforia	14	40.8% flumioxazin	3 oz.	1.22 oz. flumioxazin
	2	5.0% thifensulfuron		0.15 oz. thifensulfuron
	2	5.0% tribenuron		0.15 oz. tribenuron
Anthem Maxx	15	4.174 lb. pyroxasulfone	5 fl. oz.	2.6 oz. pyroxasulfone
	14	0.126 lb. fluthiacet-methyl		0.08 oz. fluthiacet-methyl
Authority Assist, Zone Assist	14	33.3% sulfentrazone	10 oz.	0.21 lb. sulfentrazone
	2	6.67% imazethapyr		0.67 oz. imazethapyr
Authority Edge	14	2.73 lb. sulfentrazone	10 fl. oz.	0.21 lb. sulfentrazone
	15	1.52 lb. pyroxasulfone		1.9 oz. pyroxasulfone
Authority Elite, Broad-Axe XC, Zone Elite	14	0.7 lb. sulfentrazone	25 fl. oz.	0.14 lb. sulfentrazone
	15	6.3 lb. S-metolachlor		1.23 lb. S-metolachlor
Authority First	14	62.1% sulfentrazone	8.0 oz.	0.31 lb. sulfentrazone
	2	7.96% cloransulam-methyl		0.64 oz. cloransulam-methyl
Authority MAXX, Zone Maxx	14	62.12% sulfentrazone	7 oz.	0.27 lb. sulfentrazone
	2	3.88% chlorimuron		0.28 oz. chlorimuron
Authority MTZ	14	18% sulfentrazone	16 oz.	0.18 lb. sulfentrazone
	5	27% metribuzin		0.27 lb. metribuzin
Authority Supreme	14	20.66% sulfentrazone	10 oz.	0.13 lb. sulfentrazone
	15	20.66% pyroxasulfone		0.13 lb. pyroxasulfone
Authority XL	14	62.2% sulfentrazone	8 oz.	0.31 lb. sulfentrazone
	2	7.8% chlorimuron		0.6 oz. chlorimuron
Boundary 7.8EC, Presidual	15	5.2 lbs. S-metolachlor	2.1 pt.	1.4 lb. S-metolachlor
	5	1.25 lbs. metribuzin		0.3 lb. metribuzin
BroadAxe XC	15	6.3 lb. S-metolachlor	26.5 fl. oz.	1.302 lb. S-metolachlor
	14	0.7 lb. sulfentrazone		0.145 lb. sulfentrazone
Canopy 75DF	2	10.7% chlorimuron-ethyl	6 oz.	0.5 oz. chlorimuron
	5	64.3% metribuzin		3 oz. metribuzin
Canopy EX	2	22.7% chlorimuron	1.5 oz .	0.34 oz. chlorimuron
	2	6.8% tribenuron		0.10 oz. tribenuron
Cheetah Max	10	2 lb. glufosinate	34 fl. oz.	0.53 lb. glufosinate
	14	1 lb. fomesafen		0.27 lb. fomesafen
Crusher	2	25% rimsulfuron	1 oz.	0.25 oz. rimsulfuron
	2	25% thifensulfuron		0.25 oz. thifensulfuron
Enlist Duo	4	1.6 lb. a.e. 2,4-D choline salt	4 pt.	0.8 lb. a.e. 2,4-D
	9	1.7 lb. a.e. glyphosate		0.85 lb. a.e. glyphosate
Enlite 47.9DG	14	36.2% flumioxazin	2.8 oz.	1.0 oz. flumioxazin
	2	8.8% thifensulfuron		0.25 oz. thifensulfuron
	2	2.8% chlorimuron ethyl		0.08 oz. chlorimuron ethyl
Envive 41.3DG	14	29.2% flumioxazin	3.5 oz.	1.0 oz. flumioxazin
	2	2.9% thifensulfuron		0.10 oz. thifensulfuron
	2	9.2% chlorimuron ethyl		0.32 oz. chlorimuron ethyl
Extreme	2	0.17 lb. imazethapyr	3 pt.	1.02 oz. imazethapyr
	9	1.48 ib. a.e. glyphosate		0.75 lb. a.e. glyphosate
Fierce EZ	14	1.34 lb. flumioxazin	6 fl. oz.	1.0 oz flumioxazin
	15	1.75 lb. pyroxasulfone		1.28 oz. pyroxasulfone
Fierce MTZ	5	1.5 lb. metribuzin	16 fl. oz.	0.187 metribuzin
	14	0.64 lb. pyroxasulfone		1.28 oz. pyroxasulfone
	15	0.5 lb. flumioxazin		1.0 oz. flumioxazin

"a.e." stands for acid equivalent.

Table 7. Soybean herbicide premixes or co-packs and equivalents. (continued)

Herbicide	Group	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)
Fierce XLT	14	24.57% flumioxazin	4 oz.	1.0 oz. flumioxazin
	15	31.17% pyroxasulfone		1.25 oz. pyroxasulfone
	2	6.67% chlorimuron		0.25 oz. chlorimuron
Flexstar GT 3.5	14	0.56 lb. fomesafen	3.5 pt.	0.245 lb. fomesafen
	9	2.26 lb. a.e. glyphosate		1.0 lb. a.e. glyphosate
Harrow	2	50% rimsulfuron	0.5 oz.	0.25 oz. rimsulfuron
	2	25% thifensulfuron		0.12 oz. thifensulfuron
Intermoc	10	1.07 lb. glufosinate	64 fl. oz.	0.54 lb. glufosinate
	15	2.5 lb. metolachlor		1.25 lb. metolachlor
Latir	14	31.5% flumioxazin	3.2 oz.	1.0 oz. flumioxazin
	2	23.5% imazethapyr		0.75 oz. imazethapyr
Marvel	14	1.2% fluthiacet-methyl	5 oz.	0.075 oz. fluthiacet-methyl
	14	30.08% fomesafen		0.09 lb. fomesafen
Matador	15	4 lb. metolachlor	2 pt.	1.0 lb. metolachlor
	5	0.56 lb. metribuzin		2.25 oz. metribuzin
	2	0.13 lb. imazethapyr		2.0 oz. imazethapyr
Moccason MTZ	5	1.116 lb metribuzin	4 pt.	0.558 lb. metribuzin
	15	3.35 lbs. metolachlor		1.675 lb. metolachlor
OpTill	14	17.8% saflufenacil	2 oz.	0.35 oz. saflufenacil
	2	50.2% imazethapyr		1.0 oz. imazethapyr
Panoflex 50% WSG	2	40% tribenuron	0.5 oz.	0.2 oz. tribenuron
	2	10% thifensulfuron		0.05 oz. thifensulfuron
Panther Pro	14	0.67 lb. flumioxazin	12 fl. oz.	1.0 oz. flumioxazin
	2	0.56 lb. imazethapyr		0.84 oz. imazethapyr
	5	3 lb. metribuzin		0.28 lb. metribuzin
Perpetuo	14	0.59 lb. flumiclorac	8 fl. oz.	0.037 lb. flumiclorac
	15	1.71 lb. pyroxasulfone		1.7 oz. pyroxasulfone
Prefix	15	46.4% S-metolachlor	2 pt.	1.09 lb. S-metolachlor
	14	10.2% fomesafen		0.238 lb. fomesafen
Preview 2.1 SC	5	2.23 lb. metribuzin	14 fl. oz.	0.25 lb. metribuzin
	14	1.12 lb. sulfentrazone		0.13 lb. sulfentrazone
Sequence 5.25L	15	3.0 lb. S-metolachlor	3 pt.	1.13 lb. S-metolachlor
	9	2.25 lb. a.e. glyphosate		0.84 lb. a.e. glyphosate
Sonic	14	62.1% sulfentrazone	8.0 oz.	0.361 lb. sulfentrazone
	2	7.9% cloransulam-methyl		0.64 oz. cloransulam-methyl
Statement	15	4.22 lb. metolachlor	2 pt.	1.1 lb. metolachlor
	14	0.91 lb. fomesafen		0.23 lb. fomesafen
Storm 4S	6	2.67 lb. bentazon	1.5 pt.	0.50 lb. bentazon
	14	1.33 lb. acifluorfen		0.25 lb. acifluorfen
Surveil	14	51% flumioxazin	3.6 oz.	1.5 oz. flumioxazin
	2	84% chloransulam		0.5 oz. cloransulam
Synchrony NXT	2	21.5% chlorimuron	0.5 oz.	0.11 oz. chlorimuron
	2	6.9% thifensulfuron		0.034 oz. thifensulfuron
Tailwind	15	5.25 lb. metolachlor	2 pt.	1.3 lb. metolachlor
	5	1.25 lb. metribuzin		0.31 lb. metribuzin
Tavium plus VGT	4	1.12 lb. dicamba a.e.	56.5 fl. oz.	0.5 lb. dicamba a.e.
	15	2.26 lb. S-metolachlor		1.0 lb. s-metolachlor
Tendovo	15	3.74 lb. S-metolachlor	1.75 qt.	1.518 lb. S-metolachlor
	2	0.065 lb. cloransulam-methyl		0.454 oz. cloransulam-methyl
	5	0.642 lb. metribuzin		0.2809 lb. metribuzin

"a.e." stands for acid equivalent.

Table 7. Soybean herbicide premixes or co-packs and equivalents. (continued)

Herbicide	Group	Components (a.i./gal or % a.i.)	If you apply (per acre)	You have applied (a.i.)
Torment	14	2.0 lb. fomesafen	1 pt.	0.25 lb. fomesafen
	2	0.5 lb. imazethapyr		1.0 oz. imazethapyr
Tripzin ZC	3	2.9 lb. pendimethalin	29 fl. oz.	0.66 lb. pendimethalin
	5	1.1 lb. metribuzin		0.25 lb. metribuzin
Trivence WDG	2	3.9% chlorimuruon-ethyl	6 oz.	0.23 oz. chlorimuron
	14	12.8% flumioxazin		0.77 oz. flumioxazin
	5	44.6% metribuzin		0.17 lb. metribuzin
Valor XLT	14	30.0% fluioxazin	2.5 oz.	0.75 oz. flumioxazin
	2	10.3% chlorimuron ethyl		0.25 oz. chlorimuron
Varisto	6	4.0 lb. bentazon	27 fl. oz.	0.84 lb. bentazon
	2	0.187 lb. imazamox		0.64 oz. imazamox
Verdict	14	0.57 lb. saflufenacil	5 fl. oz.	0.36 oz. saflufenacil
	15	5 lb. dimethenamid-P		0.195 lb. dimethenamid-P
Warrant Ultra	15	2.82 lb. acetochlor	50 fl. oz.	1.1 lb. acetochlor
	14	0.63 lb. fomesafen		0.25 lb. fomesafen
Zidua Pro	14	0.48 lb. saflufenacil	4.5 fl. oz.	0.26 oz. saflufenacil
	2	1.33 lb. imazethapyr		0.75 oz. imazethapyr
	15	2.28 lb. pyroxasulfone		1.28 oz. pyroxasulfone
ZoneDefense	14	62% sulfentrazone	5 oz.	0.19 lb. sulfentrazone
	14	15% flumioxazin		0.8 oz. flumioxazin

Herbicide Site of Action

Table 8. Herbicide classification by group number and site of action.

Group No.	Site of Action (mode of action)	Examples
1	ACC-ase (lipid synthesis)	Poast, Select MAX
2	ALS (amino acid synthesis)	Pursuit, Classic, Accent
3	Tubulin (cell division)	Treflan, Prowl
4	Auxin binding site (synthetic auxin)	2,4-D; Clarity
5	D1 protein (Photosystem II inhibition)	atrazine, metribuzin
6	D1 protein (Photosystem II inhibition)	Basagran, Tough
7	D1 protein (Photosystem II inhibition)	linuron
9	EPSPS (shikimic acid pathway inhibition)	Roundup, glyphosate
10	Glutamine synthetase (photosynthesis inhibition)	Liberty
13	DPX synthase (carotene synthesis)	Command
14	PPO (chlorophyll synthesis)	Cobra, Flexstar, Valor, Authority
15	Unknown (auxin transport disruption)	Dual II Magnum, Harness, Zidua
19	Photosystem I (cell membrane disruption)	N/A
22	Photosystem I	Paraquat
27	HPPD (carotene synthesis)	Callisto, Balance, Impact

Table 9. Active ingredients and group numbers of single ingredient products.

Trade name	Herbicide Group No.	Active ingredient
2,4-D, Enlist One and others	4	2,4-D
Accent Q	2	nicosulfuron
Aim	14	carfentrazone
Assure II	1	quizalofop
atrazine	5	atrazine
Autumn	2	iodosulfuron
Balance Flexx	27	isoxaflutole
Banvel/Clarity/DiFlexx/Xtendimax/Engenia	4	dicamba
Basagran	6	bentazon
Beacon	2	primisulfuron
Beyond Xtra	2	imazamox
Buctril	6	bromoxynil
Cadet	14	fluthiacet-ethyl
Callisto	27	mesotrione
Classic	2	chlorimuron
Cobra	14	lactofen
Command	13	clomazone
Dual Magnum/EverpreX	15	S-metolachlor
Express	2	tribenuron
FirstRate	2	cloransulam-methyl
FlexStar/Reflex	14	fomesafen
Fusilade DX	1	fluazifop
Gramoxone SL	22	paraquat
Harmony	2	thifensulfuron
Harness/Surpass/Warrant	15	acetochlor
Impact/Armezon	27	topramezone
Laudis	27	tembotrione
Liberty	10	glufosinate
Lorox/Linex	7	linuron

Table 9. Active ingredients and group numbers of single ingredient products. (continued)

Trade name	Herbicide Group No.	Active ingredient
Metribuzin/TriCor/Sencor	5	metribuzin
Option	2	foramsulfuron
Outlook	15	dimethenamid-P
Peak	2	prosulfuron
Permit	2	halosulfuron
Poast	1	sethoxydim
Prowl	3	pendimethalin
Pursuit	2	imazethapyr
Python	2	flumetsulam
Resolve/Bestow	2	rimsulfuron
Resource	14	flumiclorac
Roundup	9	glyphosate
Scepter	2	imazaquin
Select MAX	1	clethodim
Sharpen	14	saflufenacil
Shieldex	27	tolpyralate
Sonalan	3	ethalfluralin
Spartan/Authority	14	sulfentrazone
Stinger HL	4	clopyralid
Tough	6	pyridate
Treflan/Thrust	3	trifluralin
UltraBlazer	14	acifluorfen
Valor EZ/Panther SC	14	flumioxazin
Warrant	15	acetochlor
Zidua SC	15	pyroxasulfone
Only sold in premix	2	thiencarbazone
Only sold in premix	19	diflufenzopyr
Only sold in premix	1	fenoxaprop
Only sold in premix	27	bicyclopyrone

Table 10. Active ingredients and group numbers of herbicide premixes.

Trade name	Herbicide Group No.	Active ingredient
Acuron	5, 15, 27, 27	atrazine, S-metolachlor, mesotrione, bicyclopy-rone
Acuron Flexi	15, 27, 27	S-metolachlor, mesotrione, bicyclopyrone
Acuron GT	15, 27, 27, 9	S-metolachlor, mesotrione, bicyclopyrone, glyphosate
Afforia	2, 2, 14	thifensulfuron, tribenuron, flumioxazin
Alluvex	2, 2	rimsulfuron, thifensulfuron
Anthem	14, 15	fluthiacet, pyroxasulfone
Anthem ATZ	5, 14, 15	atrazine, fluthiacet, pyroxasulfone
Anthem Maxx	14, 15	fluthiacet, pyroxasulfone
Armezon Pro	15, 27	dimethenamid-P, topramezone
Authority Assist	2, 14	imazethapyr, sulfentrazone
Authority Edge/Authority Supreme	14, 15	sulfentrazone, pyroxasulfone
Authority Elite	14, 15	sulfentrazone, S-metolachlor
Authority MTZ	5, 14	metribuzin, sulfentrazone
Authority XL	2, 14	chlorimuron, sulfentrazone
Autumn Super	2, 2	iodosulfuron, thiencarbazone
Basis Blend	2, 2	rimsulfuron, thifensulfuron
Bicep II Magnum, Bicep Lite II Magnum	5, 15	atrazine, S-metolachlor
Boundry	15, 5	S-metolachlor, metribuzin
BroadAxe	14, 15	sulfentrazone, S-metolachlor
Calibra	15, 27	S-metolachlor, mesotrione
Callisto GT	9, 27	glyphosate, mesotrione
Callisto Xtra	5, 27	atrazine, mesotrione
Canopy	2, 5	chlorimuron, metribuzin
Canopy EX	2, 2	chlorimuron, tribenuron
Capreno	2, 27	thiencarbazone, tembotrione
Charger Max ATZ	5, 15	atrazine, S-metolachlor
Cheetah Max	10, 14	glufosinate, fomesafen
Cinch ATZ	15, 5	S-metolachlor, atrazine
Confidence Xtra	5, 15	atrazine, acetochlor
Corvus	2, 27	thiencarbazone, isoxaflutole
Coyote	15, 27	metolachlor, mesotrione
Crusher	2, 2	rimsulfuron, thifensulfuron
Degree Xtra	5, 15	atrazine, acetochlor
DiFlexx	4, 27	dicamba, isoxaflutole
Diflexx Duo	4, 27	dicamba, tembotrione
Enlist Duo	4, 9	2,4-D, glyphosate
Enlite	2, 2, 14	chlorimuron, thifensulfuron, flumioxazin
Envive	2, 2, 14	chlorimuron, thifensulfuron, flumioxazin
Extreme	2, 9	imazethapyr, glyphosate
Fierce EZ	14, 15	flumioxazin, pyroxasulfone
Fierce MTZ	5, 14, 15	metribuzin, flumioxazin, pyroxasulfone
Fierce XLT	2, 14, 15	chlorimuron, flumioxazin, pyroxasulfone
Flexstar GT	9, 14	glyphosate, fomesafen
FulTime NXT	5, 15	atrazine, acetochlor
Halex GT	9, 15, 27	glyphosate, S-metolachlor, mesotrione
Harness MAX	15, 27	acetochlor, mesotrione
Harness Xtra	5, 15	atrazine, acetochlor
Harrow	2, 2	rimsulfuron, thifensulfuron
Hornet WDG	2, 4	flumetsulam, clopyralid

Table 10. Active ingredients and group numbers of herbicide premixes. (continued)

Trade name	Herbicide Group No.	Active ingredient
Impact Core	15, 27	acetochlor, topramezone
ImpactZ	5, 27	atrazine, topramezone
Instigate	2, 27	rimsulfuron, mesotrione
Intermoc	10, 15	glufosinate, metolachlor
Keystone NXT, Keystone LA NXT	5, 15	atrazine, acetochlor
Kyro	4, 15, 27	clopyralid, acetochlor, topramezone
Latir	2, 14	imazethapyr, flumioxazin
Lexar EZ	5, 15, 27	atrazine, S-metolachlor, mesotrione
Lumax EZ	5, 15, 27	atrazine, S-metolachlor, mesotrione
Marksman	4, 5	dicamba, atrazine
Marvel	14,14	fluthiacet, fomesafen
Maverick Corn Herbicide	4, 15, 27	clopyralid, pyroxasulfone, mesotrione
Moccasin MTZ	5, 15	metribuzin, metolachlor
Optill	2, 14	imazethapyr, saflufenacil
Panoflex	2, 2	tribenuron, thifensulfuron
Panther Pro	2, 5, 14	imazethapyr, metribuzin, flumioxazin
Perpetuo	14, 15	flumiclorac, pyroxasulfone
Permit Plus	2, 2	halosulfuron, thifensulfuron
Prefix	14, 15	fomesafen, S-metolachlor
Presidual	5, 15	metribuzin, S-metolachlor
Prequel	2, 27	rimsulfuron, isoxaflutole
Preview 2.1 SC	5, 14	metribuzin, sulfentrazone
Priority	2, 14	halosulfuron, carfentrazone
Pummel	2, 15	imazethapyr, metolachlor
Realm Q	2, 27	rimsulfuron, mesotrione
Require Q	2, 4	rimsulfuron, dicamba
Resicore, Resicore XL	4, 15, 27	clopyralid, acetochlor, mesotrione
Resolve Q	2, 2	rimsulfuron, thifensulfuron
Revulin Q	2, 27	nicosulfuron, mesotrione
Scorch	4, 4, 4	2,4-D, dicamba, fluroxypyr
Sinate	10, 27	glufosinate, topramezone
Sequence	9, 15	glyphosate, S-metolachlor
Sinate	10, 27	glufosinate, topramezone
Solstice	14, 27	fluthiacet, mesotrione
Sonic	2, 14	cloransulam, sulfentrazone
Spitfire	4, 4	2,4-D, dicamba
Statement	15, 14	metolachlor, fomesafen
Status	4, 19	dicamba, diflufenzopyr
Steadfast Q	2, 2	nicosulfuron, rimsulfuron
Storen	15, 15, 27, 27	S-metolachlor, pyroxasulfone, mesotrione, bicyclopyrone
Surpass NXT	5, 15	atrazine, acetochlor
Surestart II	2, 4, 15	flumetsulam, clopyralid, acetochlor
Surveil	2,14	cloransulam, flumioxazin
Synchrony	2, 2	chlorimuron, thifensulfuron
Tailwind	5, 15	metribuzin, metolachlor
Tavium plus VGT	4, 15	dicamba, S-metolachlor
Tendovo	15, 2, 5	S-metolachlor, cloransulam-methyl, metribuzin
Torment	2, 14	imazethapyr, fomesafen
Tough R	6, 27	pyridate, mesotrione
TripleFLEX II	2, 4, 15	flumetsulam, clopyralid, acetochlor
Tripzin ZC	3, 5	pendimethalin, metribuzin
Trisidual	2, 4, 15	flumetsulam, clopyralid, acetochlor

Table 10. Active ingredients and group numbers of herbicide premixes. (continued)

Trade name	Herbicide Group No.	Active ingredient
Trivence	2, 5, 14	chlorimuron, metribuzin, flumioxazin
Trivolt	2, 15, 27	thiencarbazone-methyl, flufenacet, isoxaflutole
Valor XLT	2, 14	chlorimuron, flumioxazin
Varisto	2, 6	imazamox, bentazon
Verdict	14, 15	saflufenacil, dimethenamid
Warrant Ultra	14, 15	fomesafen, acetochlor
Weedmaster	4, 4	2,4-D, dicamba
Yukon	2, 4	halosulfuron, dicamba
Zidua Pro	2, 14, 15	imazethapyr, saflufenacil, pyroxasulfone
Zone Defense	14, 14	sulfentrazone, flumioxazin
Zone Assist	2, 14	imazethapyr, sulfentrazone
Zone Elite	14, 15	sulfentrazone, S-metolachlor
Zone Maxx	2, 14	chlorimuron, sulfentrazone

Herbicide site of action and typical injury symptoms

Herbicides kill plants by disrupting essential physiological processes. This normally is accomplished by the herbicide specifically binding to a single protein. The target protein is referred to as the herbicide "site of action". Herbicides in the same chemical family (e.g. triazine, phenoxy, etc.) generally have the same site of action. The mechanism by which an herbicide kills a plant is known as its "mode of action". For example, triazine herbicides interfere with photosynthesis by binding to the D1 protein which is involved in photosynthetic electron transfer. Thus, the site of action for triazines is the D1 protein, whereas the mode of action is the disruption of photosynthesis. An understanding of herbicide mode of action is essential for diagnosing crop injury or off-target herbicide injury problems, whereas knowledge of the site of action is needed for designing weed management programs with a low risk of selecting for herbicide-resistant weed populations.

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

ACCase Inhibitors – 1

The ACCase enzyme is involved in the synthesis of fatty acids. Three herbicide families attack this enzyme although there are two commonly associated with this site of action. Aryloxyphenoxypropanoate (referred to as "fops") and cyclohexanedione (referred to as "dims") herbicides are used postemergence, although some have limited soil activity (e.g., fluazifop). ACCase inhibitors are active only on grasses, and selectivity is due to differences in sensitivity at the site of action, rather than differences in absorption or metabolism of the herbicide. Most herbicides in this class are translocated within the phloem of grasses. The growing points of grasses are killed and rot within the stem. At sublethal rates, irregular bleaching of leaves or bands of chlorotic tissue may appear on affected leaves. Resistant weed biotypes have evolved following repeated applications of these herbicides. An altered target site of action and metabolism of these herbicides have been determined as responsible for the resistance.

ALS Inhibitors – 2

A number of chemical families interfere with acetolactate synthase (ALS), an enzyme involved in the synthesis of the essential branched chain amino acids (e.g., valine, leucine, and isoleucine). This enzyme is also called acetohydroxyacid synthase (AHAS). These amino acids are necessary for protein biosynthesis and plant growth. Generally, these herbicides are absorbed by both roots and foliage and are readily translocated in the xylem and phloem. The herbicides accumulate in meristematic regions of the plant and the herbicidal effects are first observed there. Symptoms include plant stunting, chlorosis (yellowing), and tissue necrosis (brown, dead tissue), and are evident 1 to 4 weeks after herbicide application, depending upon the herbicide dose, plant species and environmental conditions. Soybeans and other sensitive broad-leaf plants often develop reddish veins visible on the undersides of leaves. Symptoms in corn include reduced secondary root formation, stunted, "bottle-brush" roots, shortened internodes, and leaf malformations (chlorosis, window-pane appearance). However, symptoms typically are not distinct or consistent. Factors such as soil moisture, temperature, and soil compaction can enhance injury or can mimic the herbicide injury. Some ALS inhibiting herbicides have long soil residual properties and may carry over and injure sensitive rotational crops. Herbicide-resistant weed biotypes possessing an altered site of action have evolved after repeated applications of these herbicides. Resistance to the ALS inhibitor herbicides attributable to metabolism has also been identified in weeds. Some weed species have both target-site and metabolic resistances.

Microtubule Inhibitors – 3

Dinitroaniline (DNA) herbicides inhibit cell division by interfering with the formation of microtubules by inhibiting tubulin polymerization. Dinitroaniline herbicides are soil-applied and absorbed mainly by roots. Very little herbicide translocation in plants occurs, thus the primary herbicidal effect is on root development. Soybean injury from DNA herbicides is characterized by root pruning. Roots that do develop are typically thick and short. Hypocotyl swelling also occurs and the hypocotyl may be brittle and easily snapped at the ground level. The inhibited root growth causes tops of plants to be stunted. Corn injured by DNA carryover demonstrates root pruning and short, thick roots. Leaf margins may have a reddish color. Since DNAs are subject to little movement in the soil, such injury is often spotty due to localized concentrations of the herbicide. Early-season stunting from DNA herbicides typically does not result in significant yield reductions.

Synthetic Auxins – 4

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

Photosystem II Inhibitors – 5, 6, 7

Several families of herbicide bind to a protein involved in electron transfer in Photosystem II (PSII). These herbicides inhibit photosynthesis, which may result in inter-veinal yellowing (chlorosis) of plant leaves followed by necrosis (brown, dead) of leaf tissue. Highly reactive compounds formed due to inhibition of electron transfer cause the disruption of cell membranes and ultimately plant death. When PSII inhibitors are applied to the leaves, uptake occurs into the leaf but very little movement out of the leaf occurs. Injury to corn may occur as yellowing of leaf margins and tips followed by browning, whereas injury to soybean occurs as yellowing or burning of outer leaf margins. The entire leaf may turn yellow, but veins usually remain somewhat green (inter-veinal chlorosis). Lower leaves are first and most affected, and new leaves may be unaffected. Triazine (Group 5) and urea (Group 7) herbicides generally are absorbed both by roots and foliage, whereas benzothiadiazole (Group 6) and nitrile (Group 6) herbicides are absorbed primarily by plant foliage. Triazine-resistant biotypes of several weed species have been confirmed in Iowa following repeated use of triazine herbicides. Although the other PSII herbicides attack the same target site, they bind on a different part of the protein and remain effective against triazine-resistant weeds. Triazine resistance is due to an altered target site and examples of metabolic resistance also have been identified.

Photosystem I Inhibitors – 22

Herbicides in the bipyridilium family rapidly disrupt cell membranes, resulting in wilting, necrosis, and tissue death. They capture electrons moving through

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

Protoporphyrinogen Oxidase (PPO) Inhibitors – 14

Group 14 herbicides inhibit an enzyme involved in synthesis of a precursor of chlorophyll; the enzyme is referred to as PPO. Plant death results from destruction of cell membranes due to formation of highly reactive compounds. There are several herbicide families that are classified as PPO inhibitors. Postemergence applied diphenyl ether herbicides (e.g., aciflurofen, lactofen) are contact herbicides with little translocation. Thorough plant coverage by the herbicide spray is required. Applying the herbicide prior to prolonged cool periods or during hot, humid conditions will result in significant crop injury. Injury symptoms range from speckling of foliage to necrosis of whole leaves. Under extreme situations, herbicide injury has resulted in the death of the terminal growing point, which produces short, bushy soybean plants. Most injury attributable to postemergence diphenyl ether herbicides is cosmetic and does not affect yields. The aryl triazolinones herbicides are absorbed both by roots and foliage. Susceptible plants emerging from soils treated with these herbicides turn necrotic and die shortly after exposure to light. Soybeans are most susceptible to injury if heavy rains occur when beans are cracking the soil surface.

Carotenoid Synthesis Inhibitors – 13, 27

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

Enolpyruvyl Shikimate Phosphate Synthase (EPSPS) Inhibitors – 9

Glyphosate is a substituted amino acid (glycine) that inhibits the EPSPS enzyme. This enzyme is a component of the shikimic acid pathway, which is responsible for the synthesis of the essential aromatic amino acids and numerous other compounds. Glyphosate is nonselective and is tightly bound in soil, so little root uptake occurs under normal use patterns. Applications must be made to plant foliage. Translocation occurs out of leaves to all plant parts including underground storage organs of perennial weeds. Translocation is greatest when plants are actively growing. Injury symptoms are fairly slow in appearing. Leaves slowly wilt, turn brown, and die. Sub-lethal rates of glyphosate sometimes produce phenoxy-type symptoms with feathering of leaves (parallel veins) and proliferation of vegetative buds, or in some cases cause bleaching of foliage. Resistance to glyphosate has evolved in a number of important weed species (e.g., waterhemp, giant ragweed, horseweed/marestail, Palmer amaranth). Several mechanisms have been identified that confer resistance to glyphosate in weeds.

Glutamine Synthetase Inhibitors – 10

Glufosinate (Liberty) inhibits the enzyme glutamine synthetase, known to incorporate ammonium in plants. Although glutamine synthetase is not involved directly in photosynthesis, inhibition of this enzyme ultimately results in the disruption of photosynthesis. Glufosinate is relatively fast acting and provides effective weed control in 3-7 days. Symptoms appear as chlorotic lesions on the foliage followed by necrosis. There is limited translocation of glufosinate within plants. Glufosinate has no soil activity due to rapid degradation in the soil by microorganisms. Liberty is nonselective except to crops that carry the Liberty Link gene. To date, there are only two weed species with evolved resistance to glufosinate and resistance has not been identified in Iowa.

Fatty Acid and Lipid Synthesis Inhibitors – 8

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

Very Long Chain Fatty Acid Synthesis Inhibitors (VLCFA) – 15

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

Auxin Transport Inhibitors – 19

Diflufenzopyr (Status) has a unique mode of action in that it inhibits the transport of auxin, a naturally occurring plant-growth regulator. Diflufenzopyr is sold only in combination with dicamba and is primarily active on broadleaf species, but it may suppress certain grasses under favorable conditions. Diflufenzopyr is primarily active through foliar uptake, but it can be absorbed from the soil for some residual activity. Injury symptoms are similar to other growth regulator herbicides. Status (dicamba + diflufenzopyr) includes a safener to improve crop safety.

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