SDSU Extension

iGrow Corn

BEST MANAGEMENT PRACTICES

Chapter: 43

Identification and Control of Herbicide-resistant Weeds

Sharon A. Clay (Sharon.Clay@sdstate.edu)

This chapter discusses herbicide-resistant weeds, often found in corn, that have been confirmed in South Dakota and the surrounding states of North Dakota, Minnesota, Iowa, and Nebraska (Table 43.1). According to the International Survey of Herbicide Resistant Weeds (www.weedscience.org), which allows self-reporting of confirmed cases, 9 herbicide-resistant weed biotypes have been reported and confirmed in South Dakota, as of 2015. In the surrounding region, Minnesota reported 19 herbicide-resistant biotypes, Iowa 17, North Dakota 14, and Nebraska 13. These are mentioned because weeds do not recognize state boundaries and growers must be diligent to prevent or confine these problematic species.

Since the 1960s, when the first triazine-resistant weed was reported, there has been a steady increase of herbicide-resistant biotypes, with over 250 incidents of herbicide resistance reported in the U.S. in 2015. The frequent use of single site-of-action herbicides across multiple crops and years has been reported to accelerate herbicide-resistance selection in weed populations. Using application rates below the label recommended rates may also reduce herbicide effectiveness and promote herbicide resistance. Often the problem is first observed as a few scattered plants that survive herbicide applications. However, due to the ability of these weeds to produce thousands (and, in some cases, millions) of seeds per plant, the survival of even a few plants allows the biotype to quickly become a widespread infestation. Herbicide resistance is a inheritable trait, passed from one generation to the next. This means that once the trait is in the population, other methods of control are needed to control the remaining plants. In addition, some herbicide-resistant biotypes show resistance to different herbicides that have different sites of action.

To reduce selection for herbicide-resistant biotypes, it is necessary to diversify weed-management programs, crop rotations, and the types of herbicide chemistries and sites of action that are used. The best time to take action against pesticide resistance is BEFORE the resistance is in your field or area. Unfortunately, most action is taken as a REACTION to the problem when it occurs, rather than before it is seen. Programs for herbicide-resistance management should include cultural, mechanical, sanitation, herbicide mode-of-action rotations, and crop rotations.

Herbicide-resistant Biotypes in South Dakota

Kochia biotypes resistant to ALS herbicides (WSSA Group 2) (Table 43.2) were first reported in South Dakota in 1998. The problem was noted in northeastern SD after only three consecutive seasons of ALS herbicide use. In 2007, a common ragweed biotype was the first glyphosate-resistant (WSSA Group 9)

Table 43.1 Weed species, reporting state, and resistance sites of action and designated WSSA group number (see Chapter 42 for more details). Herbicide examples by WSSA group number are reported in Table 43.2. (Modified from International Survey of Herbicide Resistant Weeds; www.weedscience.org)

Weed Species	State	Resistance Sites of Action and WSSA Group Number
Kochia *(Kochia scoparia)*	SD, MN, ND	ALS inhibitors (WSSA Group 2)
	IA, ND, NE	Photosystem II inhibitors (WSSA Group 5)
	ND, NE	Synthetic auxins (WSSA Group 4)
	SD, NE, ND	EPSPS inhibitors (WSSA Group 9)
	ND	Multiple resistance (2 sites of action): Photosynthesis inhibitors (WSSA Groups 5 and 6)
Common sunflower *(Helianthus annuus)*	SD, IA	ALS inhibitors (WSSA Group 2)
Common ragweed *(Ambrosia artemisiifolia)*	SD, ND, MN, NE	EPSPS inhibitors (WSSA Group 9)
	MN	ALS inhibitors (WSSA Group 2)
	MN	Multiple resistance (2 sites of action): ALS (WSSA Group 2); EPSPS inhibitors (WSSA Group 9)
Giant ragweed *(Ambrosia trifida)*	NE, MN, IA	EPSP inhibitors (WSSA Group 9)
	IA	ALS inhibitors (WSSA Group 2)
	MN	Multiple resistance (2 sites of action): ALS inhibitor (WSSA Group 2); EPSPS inhibitors (WSSA Group 9)
Wild oat *(Avena fatua)*	SD, MN, ND	ACCase inhibitors (WSSA Group 1)
	SD, ND	ALS inhibitor (WSSA Group 2)
	SD	Multiple Resistance (2 sites of action): ACCase inhibitors (WSSA Group 1); ALS inhibitors (WSSA Group 2)
Tall (common) Waterhemp *(Amaranthus tuberculatus (=A. rudis)*	SD, NE, MN, IA, ND	EPSPS inhibitors (WSSA Group 9)
	IA, MN	ALS inhibitors (WSSA Group 2)
	IA, NE	Photosystem II inhibitor (WSSA Group 5)
	IA	PPO inhibitor (WSSA Group 14)
	NE	Synthetic auxins (WSSA Group 4)
	NE	HPPD (WSSA Group 13)
	MN	Multiple Resistance (2 sites of action): ALS inhibitors (WSSA Group 2); EPSPS inhibitors (WSSA Group 9)
	IA	Multiple Resistance (3 sites of action): ALS inhibitors (2); HPPD (13); Photosystem II inhibitor (5)
	IA	Multiple Resistance (4 sites of action): ALS inhibitors (WSSA Group 2); HPPD (WSSA Group 13); Photosystem II inhibitor (WSSA Group 5); EPSP synthase inhibitor (WSSA Group 9)
Redroot pigweed *(Amaranthus retroflexus)*	MN	Photosystem II inhibitor (WSSA Group 5)
	ND	ALS inhibitor (WSSA Group 2)
Palmer amaranth *(Amaranthus palmeri)*	NE	Photosystem II inhibitor (WSSA Group 5)
	NE	HPPD (WSSA Group 13)
Horseweed *(Conyza canadensis)*	SD, NE, IA	EPSPS inhibitors (WSSA Group 9)
Common lambsquarters *(Chenopodium album)*	MN, IA	Photosystem II inhibitor (WSSA Group 5)
Velvetleaf *(Abutilon theophrasti)*	MN	Photosystem II inhibitor (WSSA Group 5)
Common cocklebur *(Xanthium strumarium)*	IA, MN	ALS inhibitors (WSSA Group 2)

Table 43.1 Weed species, reporting state, and resistance sites of action and designated WSSA group number (see Chapter 42 for more details). Herbicide examples by WSSA group number are reported in Table 43.2. (Modified from International Survey of Herbicide Resistant Weeds; www.weedscience.org)

Weed Species	State	Resistance Sites of Action and WSSA Group Number
Marshelder *(Iva xanthifolia)*	ND	ALS inhibitors (WSSA Group 2)
Shattercane *(Sorghum bicolor)*	NE, IA	ALS inhibitors (WSSA Group 2)
Wild mustard *(Sinapis arvensis)*	ND	ALS inhibitors (WSSA Group 2)
Eastern black nightshade *(Solanum ptycanthum)*	ND	ALS inhibitors (WSSA Group 2)
Pennsylvania smartweed *(Polygonum pensylvanicum)*	IA	Photosystem II inhibitor (WSSA Group 5)
Giant foxtail *(Setaria faberi)*	IA	Photosystem II inhibitor (WSSA Group 5)
	IA	ACCase inhibitors (WSSA Group 1)
	MN	ALS inhibitors (WSSA Group 2)
Yellow foxtail *(Setaria pumila)*	MN	ALS inhibitors (WSSA Group 2)
Giant green foxtail *(Setaria viridis var. major)*	MN	ALS inhibitors (WSSA Group 2)
	MN	ACCase inhibitor (WSSA Group 1)

Table 43.2 WSSA group number, herbicide site of action (Modified from http://www.wssa.net/Weeds/Resistance/WSSA-Mechanism-of-Action.pdf) and herbicide example(s). Herbicide labels often highlight the WSSA group number(s) for the herbicide(s) site(s) of action found in the formulation.

WSSA group number	Site of action	Examples
1	ACCase inhibitor	Clethodim, quizalofop
2	ALS inhibitor	Imazethapyr, cloransulam
3	Microtubule inhibitor	Pendimethalin, trifluralin
4	Growth regulator (synthetic auxin)	2,4-D, clopyralid, dicamba
5	Photosynthesis inhibitor (PSII inhibitor) (triazine)	Atrazine, Metribuzin
6	Photosynthesis inhibitor (contact)	Bentazon
9	EPSPS inhibitor	Glyphosate
10	Glutamine synthetase inhibitor	Glufosinate
13	HPPD inhibitor or “Bleacher”	Clomazone
14	Cell membrane disrupter (PPO inhibitor)	Carfentrazone, lactofen
15	Seedling shoot inhibitor (Very Long-Chain Fatty Acid inhibitor) (VLCFA)	Acetochlor, metolachlor
22	Cell membrane disrupter (Photosystem (PS)1 inhibitor)	Paraquat

weed identified in South Dakota. Since then, glyphosate-resistant biotypes of waterhemp, kochia, and horseweed have been confirmed and grass weeds, particularly wild oat, have been reported to be resistant to ALS (WSSA Group 2) and ACCase (WSSA Group 1) herbicides. Among all the resistant biotypes reported, kochia and waterhemp appear to be the most widespread and problematic. Figure 43.1 shows where glyphosate-resistant biotypes of several weed species have been confirmed, but unconfirmed populations maybe much more extensive.

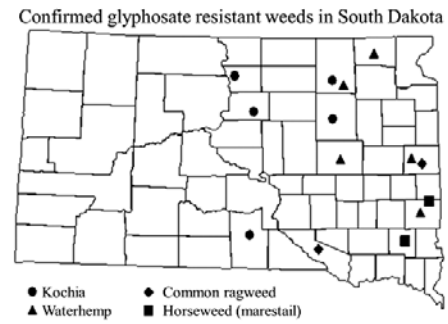

Figure 43.1 Approximate locations of confirmed glyphosate-resistant weed species in South Dakota (2013 map).

How and Why do Herbicide-resistant Weeds Develop?

Weeds become resistant to an herbicide when offspring from a once-controlled weed develops a characteristic that makes it less susceptible to an herbicide. Resistance may occur from a biochemical change, such as enhanced production of a sensitive enzyme, or a physical change (e.g., thicker cuticle) that reduces herbicide uptake or reduces movement of an herbicide within a plant (e.g., isolates the herbicide in vacuoles, sheds herbicide-treated leaves). Glyphosate-resistant biotypes have been reported to have seven different and distinct mechanisms of resistance, including hypersensitivity (leaf drop) that does not allow the herbicide to translocate; changed site of action caused by one or two amino acid changes in the sensitive region of the enzyme; and multiple (40-fold or greater) copies of the gene targeted by the herbicide. These mechanisms of resistance can cause the biotype to have 3 to 100 times less sensitivity to glyphosate than the wild, sensitive types. Repeated use of herbicides with the same mode-of-action allows any offspring that possesses these new characteristics to survive, produce seed, and develop increased densities after a few years.

Management to Prevent Resistance

Preventing herbicide resistance requires a diversified and integrated weed-control program. Field-scale changes in weed species composition occur slowly. Utilize a diverse management system that conscientiously and proactively selects methods to minimize the chances of resistant weeds becoming a problem. This management tactic is more practical than responding after resistance has occurred. By the time the problem has been noticed, populations often have become widespread across one or multiple fields and weed seed banks have increased. It should be noted that using ANY single method of management continuously can produce problems. For example, tillage at the same time every year reduces the weeds that emerge at that time but may favor early emerging species that are now too large to control, or encourage late-emerging species that are missed by the tillage implement.

Diversified weed-management programs should include biological, mechanical, cultural, sanitation, and herbicide options. Such management programs should:

- Practice using a mix of pre-emergence herbicides, and herbicide tank mix partners that contain herbicides that have several sites of action. The HERBICIDE RESISTANCE ACTION COMMITTEE (HRAC) within the Weed Science Society of America (WSSA, www.wssa.net) has developed a numbering system to help producers select chemicals with different sites of action (Table 43.2). For example, one formulation may contain several different active ingredients, but all may act as Group 2 (ALS inhibitor) herbicides, whereas a different formulation may have two active ingredients and be listed as a Group 2 + Group 4 (an ALS inhibitor + an auxin growth regulator).
- Rotate crops that do not require the use of the same herbicides year after year.
- Use mechanical weed-control options when appropriate.
- Practice good sanitation for equipment (planters, combines), seeds, manure spreading, and areas around fields.

Crop Rotation: Crop rotations may include different crop species, such as wheat, soybean, or crops that require different herbicide programs, such as conventional or LibertyLink® varieties. Rotating crops with different life cycles, such as winter annuals (e.g., winter wheat), annuals (e.g., corn or sunflowers), or short-season annuals (e.g., spring wheat, field pea, or millet), also can disrupt weed life cycles and enable different control options. Note that to minimize problems of not matching herbicides with crop characteristics or rotating to crops where carryover may be a problem, excellent field records are required. In addition, always follow labeled instructions including rate, herbicide compatibility, surfactant addition, application timing, use frequency, and maximum allowable rate in a season.

Scout Fields: Always scout the field to understand what weeds are present prior to an herbicide application and choose the chemical solutions with the best efficacy for the weed spectrum present. Scouting after application and recording weed escapes is vital information for future planning. Poor herbicide efficacy could be caused by a number of issues, including faulty equipment, skips, incorrect mixing, and climate issues (e.g., rain soon after application, cold conditions, etc.). These problems must be ruled out before claiming that herbicide resistance was the cause.

Use Pre-emergence Herbicides: Pre-emergence herbicide application is recommended to ensure consistent weed control. Pre-emergence and postemergence herbicides should be chosen with different sites of action to avoid selecting for resistance to another herbicide site of action. In addition, it is also important to avoid using herbicides with similar sites of action during two consecutive years.

If Herbicide-resistant Biotypes are Present

When controlling herbicide-resistant biotypes always include herbicides that have a different site of action than the confirmed (or suspected) resistance. In no-till fields, added challenges associated with managing herbicide-resistant biotypes have caused some people to abandon no-till practices. However, tilling fields may prolong the persistence of herbicide-resistant weed seed banks. South Dakota State University research has demonstrated that common ragweed seed left on the soil surface in a no-tillage field may cause greater weed densities the following year, but if emerged plants are controlled, the seed bank becomes depleted in just a few years, compared with densities in tilled fields where seeds may be dormant and persist for a longer period of time (Moechnig et al., 2012).

Figure 43.2 Corn stubble can trap tumbling kochia plants. (Howard F. Schwartz, Colorado State University, Bugwood.org).

As herbicide-resistant biotypes become more common, it will become increasingly important to minimize weed seed movement among fields. It is always important to clean equipment before entering different fields to prevent the spread of weed species. It is commonly believed that new infestations of glyphosate-resistant weeds are most often caused by independent selection within that field rather than movement of seeds between fields. However, some weeds may be adapted particularly well to movement into different fields. "Tumbleweed" species, such as kochia, may roll to adjacent fields, while spreading weed seeds (Figs. 43.2, 43.3).

Figure 43.3 Kochia shoots can be trapped by a roadside vegetation (Photo courtesy of authors)

Other weed species may be so problematic that preventing new infestations may justify the time required to clean equipment. Palmer amaranth *(Amaranthus palmeri)* is an annual weed that looks similar to waterhemp, but may have a slightly faster growth rate and may adapt to herbicides more quickly (see

Chapter 38). In the Southern U.S., Palmer amaranth has proven to be a very challenging weed to control in fields. Some biotypes have developed resistant to formulations that contain single, as well as multiple modes-of-action, including glyphosate (Group 9), ALS (Group 2) and PPO (Group 14) herbicides (Table 43.2). There is concern that Palmer amaranth has moved to South Dakota and other Northern states as a contaminant of cotton seed used as livestock feed, with livestock manure, or through unclean harvesting equipment. This has already occurred in Michigan and Nebraska. As of 2015, there are confirmed patches of Palmer amaranth in Sully, Douglas, and Bennett counties of SD. In one case, manure from animals fed in the Southern states was spread, along with Palmer amaranth.

Avoiding Selection for Additional Herbicide-resistant Weed Biotypes

Diversifying weed-management programs to control a particular resistant-biotype in a field does not mean that another species will not be selected in the future. Most herbicides are effective only on a limited number of weed species. There are many weeds that are not resistant to glyphosate but are difficult to control because they are less sensitive to glyphosate. If not carefully managed, these weeds could produce glyphosate-resistant biotypes.

It is important to consider other challenging weed species when developing a management plan to control herbicide-resistant species. For example, adding fomesafen with glyphosate may effectively control glyphosate-resistant biotypes of waterhemp but would provide only limited control of common lambsquarters or velvetleaf. Therefore, it will be important to monitor populations of these other difficult species, make management adjustments when necessary, and be sure to use effective management programs for these species in rotational crops.

South Dakota Glyphosate-resistant Weeds

Due to the changing herbicide formulations, rates, and restrictions, specific herbicides for control are not reported here but can be found at the annually updated extension.sdstate.edu website in the Corn Pest Management Guidelines.

Kochia (Kochia scoparia)

Herbicide-resistant kochia *(Kochia scoparia)* is a challenging weed in corn (Figs. 43.2 – 43.4). ALS-resistant kochia was first seen in the mid-1990s in wheat and soybean fields of northeastern SD (Wolf, 1998) after just 3 years of ALS inhibitor herbicide applications. In some fields, over 1000 seedlings per ft^2 were present early in the season. Glyphosate-resistant kochia was confirmed near Gettysburg, SD in 2009. Since then, scouting reports suggest that infestations have been expanding.

Figure 43.4 Kochia growing in a production field. (Howard F. Schwartz, Colorado State University, Bugwood.org)

Kochia is a very prolific seed producer as plants may produce approximately 500 seeds/g shoot biomass (Nyamusamba et al., 2012), which is nearly three times as much as common lambsquarters and five times as much as giant foxtail (Moechnig et al., 2003). Seed spreads very rapidly to form new infestations because of the plant's tumbleweed tendencies when it becomes mature, which scatters plants across fields and in mats along fence lines.

Pre-emergence herbicides such as atrazine may be very effective in controlling kochia infestations, but care must be taken as triazine-resistant kochia has been reported in neighboring states. There are several broadleaf herbicides available for kochia control in corn. However, consecutive use of the same site of action and even mixtures with herbicides having multiple sites of action may contribute to resistance.

In no-till fields, kochia may be one of the first weeds to emerge in the spring. Therefore, an effective burn-down herbicide program prior to corn planting may eliminate much of the kochia infestation. However, effective burn-down herbicide options are not well-known as glyphosate has previously been the standard herbicide. 2,4-D is a common burn-down herbicide but will not likely be effective on many kochia populations. Indeed, some auxin-resistant biotypes have been reported in North Dakota, so care must be taken to rotate out of this herbicide family as well. Potentially effective options could be paraquat (Gramoxone®), glufosinate (Liberty®), or lactofen (Cobra®). Since kochia emerges very early in spring, a late-fall application of a soil residual herbicide may provide suppression or control in early spring.

LibertyLink® corn may be an alternative option. Since Liberty® acts like a contact herbicide with limited mobility in plants, the first application must be applied to small weeds (less than 4 inches tall) with few growing points. Like contact herbicides, glufosinate requires the use of more water per acre (15 gallons) than glyphosate, but this will be necessary for any postemergence herbicide for glyphosate-resistant kochia.

The lack of kochia seed dormancy may be a characteristic that could be exploited to minimize densities in soybeans. Recent research at SDSU and elsewhere indicates that less than 10% of kochia seed may survive in soil for longer than a year. Therefore, it may be possible to reduce kochia densities by aggressively managing it in corn or wheat. However, the prolific seed production potential of kochia will require nearly complete control in order to deplete the seed bank. In addition, since the kochia shoot acts as a tumbleweed, fencerows can have extremely high densities of seedlings that could result in over 10 mature plants/ft^2 by the end of the growing season (Wolf, 1998). Treating these areas with a selective herbicide may reduce one potential source of future kochia infestations.

Waterhemp (Amaranthus tuberculatus)

A glyphosate-resistant biotype of the annual weed waterhemp *(Amaranthus tuberculatus)* was confirmed in 2010 in South Dakota (Fig. 43.5). Since then, field surveys suggest that glyphosate-resistant waterhemp is common. Table 43.1 indicates that in surrounding states, waterhemp biotypes have been found that are resistant to five other site-of-action chemistries, with some biotypes having multiple resistances. In most cases, effective management requires both pre-emergence and postemergence herbicide applications to ensure consistent waterhemp control. To avoid selecting for additional herbicide-resistant weed biotypes, herbicides with different sites of action should be used when possible. Most of the waterhemp in SD is also resistant to WSSA Group 2 herbicides (ALS inhibitors), so those herbicides will not control the ALS-resistant waterhemp. It has not been shown that waterhemp resistant to both chemicals is present in South Dakota fields.

Figure 43.5 Waterhemp single plant and patch of waterhemp following germination. (Photo courtesy Ohio State Weed Lab , The Ohio State University, Bugwood.org and Aaron Hager, USDA Agricultural Research Service, Bugwood.org).

However, no matter which herbicide program is followed, best control of waterhemp results when the application is applied to small (less than 4 inches tall) plants and uses enough water per acre to ensure thorough herbicide coverage of the weeds. Auxin herbicides (WSSA Group 4; e.g., Banvel, Clarity) in corn may give excellent control, but care must to taken to apply at these herbicides at the correct corn growth stage to avoid green snap or brace root problems.

Waterhemp can produce upwards of 100,000 seeds per plant, if the plant emerges early (Uscanga-Mortera et al., 2007). Later emerging waterhemp may produce only 100 seeds. This emphasizes the importance of early season control. Waterhemp seed may survive in the soil for 4 to 5 years (Buhler and Hartzler 2001; Steckel et al., 2007), so seed bank depletion may require aggressive control for several years. Aggressive control would require pre-emergence and postemergence herbicides, at labeled use rates, in corn and rotational crops, such as soybean. In addition, field edges may be treated with selective herbicides (those that do not injure grasses) to control waterhemp plants that may be a seed source for future infestations.

Horseweed (marestail) (Conyza canadensis)

Glyphosate-resistant horseweed *(Conyza canadensis)* has become relatively common in eastern South Dakota no-till fields (Figs. 43.6, 43.7). Horseweed is generally a winter annual species that emerges in the fall and continues growth in the spring, but some plants may emerge in the spring after burn-down applications. Consequently, fall herbicide applications may reduce horseweed densities the following year. Spring burn-down herbicide programs may require herbicides that have foliar and soil residual activity. Herbicides with foliar activity include 2,4-D, or saflufenacil (Sharpen®). Soil residual herbicides include saflufenacil, atrazine, or flumetsulam (Python®).

Figure 43.6 Horseweed has become more common in no-tillage fields. (Photo courtesy of Joseph M. DiTomaso, Univ. Cal. Davis, Bugwood.org)

Postemergence herbicide options are limited and should be applied while horseweed is small (less than 4 – 6 inches). However, the goal should always be to control horseweed prior to corn emergence.

Figure 43.7 Horseweed seedlings in the fall may be very small and difficult to see. (Photo courtesy of J.A. Dille, Kansas State University)

Common Ragweed (Ambrosia artemisiifolia)

Glyphosate-resistant common ragweed *(Ambrosia artemisiifolia)* was first confirmed in 2007 and was the first confirmed glyphosate-resistant weed in South Dakota (Fig. 43.8). However, occurrences of resistance seem to be expanding much more slowly than kochia and waterhemp. There are a number of pre-emergence and postemergence herbicides that can provide good to excellent control of common ragweed in corn.

Figure 43.8 Common ragweed in a corn field. (Photo courtesy Barbara Tokarska-Guzik, University of Silesia, Bugwood.org)

If fields contain herbicide-resistant biotypes, they should be closely monitored for resistant common ragweed as seed bank depletion may require aggressive control for several years. SDSU research indicates approximately 5% – 10% of the seed may germinate each year for the first 4 years after production, but less than 1% may emerge thereafter. However, maintaining no-till practices that leave seed on the soil surface can hasten the decline of the seed bank (Moechnig et al., 2012). Therefore, part of a long-term strategy to control glyphosate-resistant common ragweed may be to maintain no-till practices. In tilled fields, emergence may occur over a longer period of time than in no-till fields, so including a soil active residual herbicide may be even more important to maintain consistent control.

Controlling Volunteer Crops

Although volunteer crops are often not considered typical weeds, they do reduce yields. In addition they may be herbicide resistant (Fig. 43.9). Volunteer corn in hybrid corn and volunteer soybean in corn can be problematic. Low densities (1 plant/ft^2) of volunteer corn can reduce hybrid corn yield by about 3% with higher densities reducing yield up to 30%. Grain from volunteer corn can be harvested, but it may be of lower quality, be at an incorrect moisture content, or be a bridge to insect and disease problems. Even partial control of volunteer corn can increase corn yields. Hybrid selection is crucial to successfully control corn from past corn crops. For example, if the recent past hybrid corn was glyphosate-resistant, conventional hybrids, of ALS-resistant or glufosinate-resistant hybrid corn may be selected.

Figure 43.9 Volunteer corn in a soybean field. (Photo courtesy of Howard F. Schwartz, Colorado State University, Bugwood.org).

In most instances, volunteer soybean has not been thought of as a weedy species. However, Alms et al. (2016) reported that volunteer glyphosate-resistant soybean at low densities (1-5 plants/ft^2) can reduce corn yield 10%. This corn yield reduction is similar to reductions that can be observed with similar densities of velvetleaf or redroot pigweed. At high densities, volunteer soybean can reduce corn yield by 50% or more. Volunteer soybean, at present, can be managed using common corn herbicides, however, as new herbicide-tolerant varieties are introduced, control may become more difficult.

References and Additional Information

Websites

Weed Science Society of America: http://wssa.net/ (accessed 5 November 2015)

The glyphosate, weeds, and crops website: http://www.glyphosateweedscrops.org/ (accessed 5 November 2015)

International survey of herbicide resistant weeds at: www.weedscience.org (accessed 5 November 2015)

Papers

Alms, J., S.A. Clay, D. Vos, and M. Moechnig. 2016. Corn yield loss due to volunteer soybean. Weed Sci. 64: 495-500.

Buhler, D. D., and R. G. Hartzler. 2001. Emergence and persistence of seed of velvetleaf, common waterhemp, woolly cupgrass, and giant foxtail. Weed Science 49:230-235.

Moechnig, M. J., C. M. Boerboom, D. E. Stoltenberg, and L. K. Binning. 2003. Growth interactions in communities of common lambsquarters (Chenopodium album), giant foxtail (Setaria faberi), and corn. Weed Science 51:363-370.

Moechnig, M., R. Nyamusamba, D. Deneke, D. Vos, and J. Alms. 2012. The influence of seed burial depth on common ragweed seed bank persistence. Proceedings of the Weed Science Society of America. Available at: http://wssaabstracts.com/public/index.php. (accessed 5 November 2015).

Nyamusamba, R. P., M. J. Moechnig, D. A. Vos, J. K. Alms, and D. L. Deneke. 2012. Crop canopy effect on kochia seed production. Proceedings for the North Central Weed Science Society. http://wssaabstracts.com/public/index.php. (accessed 5 November 2015).

Krupke, C., S. Weller, S. Conley, P. Marquardt, and W. Johnson. 2009. Volunteer corn presents new challenges for insect resistance management. Agron. J. 101:797-799.

Steckel, L. E., C. L. Sprague, E. W. Stoller, L. M. Wax, and F. W. Simmons. 2007. Tillage, cropping system, and soil depth effects on common waterhemp (Amaranthus rudis) seed-bank persistence. Weed Sci. 55:235-239.

Uscanga-Mortera, E., S. A. Clay, F. Forcella, and J. Gunsolus. 2007. Common waterhemp growth and fecundity as influenced by emergence date and competing crop. Agron. J. 99:1265–1270

Wolf, R. 1998. Management strategies for controlling ALS-resistant kochia in wheat and soybean. M.S. Thesis. South Dakota State University. 64 pg.

Acknowledgements

Support for this document was provided by South Dakota State University, SDSU Extension, South Dakota Agricultural Experiment Station and the South Dakota Corn Utilization Council.

Clay. S. 2016. Chapter 43: Identification and Control of Herbicide-resistant Weeds. In Clay, D.E., C.G. Carlson, S.A. Clay, and E. Byamukama (eds). iGrow Corn: Best Management Practices. South Dakota State University.

The preceding is presented for informational purposes only. SDSU does not endorse the services, methods or products described herein, and makes no representations or warranties of any kind regarding them.