SDSU Extension

iGrow Soybean

BEST MANAGEMENT PRACTICES

Chapter 33: Herbicide-Resistant Weeds in Soybeans

Michael Moechnig
Sharon A. Clay (Sharon.Clay@sdstate.edu)
Darrell Deneke

Widespread planting of Roundup Ready® crops and the use of glyphosate have been linked to reduced herbicide costs and improved profitability. However, continued used of a limited weed control strategy has resulted in increased herbicide resistance. To reduce selection for herbicide-resistant weeds, weed management programs must be diversified. The purpose of this chapter is to discuss herbicide sites of action and glyphosate-resistant weeds confirmed in South Dakota.

Glyphosate-resistant weeds in South Dakota soybeans

Weeds become resistant to an herbicide when offspring from a 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 that reduces herbicide uptake or translocation within the plant.

Repeated use of that herbicide allows the offspring that possesses these characteristics to survive, produce seed, and develop noticeable densities after approximately three years. Therefore, preventing herbicide resistance requires a diversified weed control program so that weeds that tolerate or adapt to one control method are at least suppressed by an additional control method used in the management program.

Since field-scale changes in weed species composition may occur slowly over several years, it may be more practical to utilize a diverse management program that proactively minimizes selection for resistance rather than respond after the resistance has occurred, populations have become widespread across the field, and the weed seed bank has increased.

Diversified weed management programs may include pre-emergence herbicides, herbicide tank-mix partners with glyphosate, and rotating to crops that do not require the use of glyphosate for weed control. Crop rotation may include different crop species, such as wheat, or crops that require different herbicide programs, such as conventional or LibertyLink® varieties (Problem 33.1).

Controlling glyphosate-resistant weeds requires the use of herbicides with different sites of action. In Roundup Ready® soybeans, a pre-emergence herbicide and a post-emergence tank-mix partner will likely be required for complete control of moderate to high weed densities. Although low weed densities may be controlled with only a post-emergence application of glyphosate plus an herbicide tank-mix partner, a pre-

Problem 33.1. An herbicide program that routinely relies on glyphosate has been effective and has reduced my costs. What is an alternative program that rotates herbicide site of action on my farm?

Answer: One successful mamagement strategy may include rotating Roundup Ready® soybeans with LibertyLink® corn. Glufosinate (Libery®) may be less consistent than glyphosate, particularly during dry conditions, but two post-emergence herbicide applications per season or pre- and post-emergence herbicide applications can result in very good weed control. 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), can disrupt weed life cycles and enable different control options.

Note: To minimize problems of not matching herbicides with crop characteristics, good field records are required. In addition always follow labeled instructions.

emergence herbicide is still recommended to ensure consistent weed control.

When using a pre-emergence and post-emergence herbicide, it is best to use herbicides 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. The Weed Science Society of America (WSSA, http://www.wssa.net/) has developed a numbering system to distinguish herbicides with different sites of action (Table 33.1).

In no-till fields, added challenges associated with managing herbicide-resistant weeds have caused some people to abandon no-till practices. However, tilling fields may prolong the persistence of herbicide-resistant weed seed banks. SDSU research has demonstrated that common ragweed seed left on the soil

Table 33.1. WSSA group numbers associated with different soybean herbicide sites of action.
(Modified from http://www.wssa.net/wp-content/uploads/WSSA-Mechanism-of-Action.pdf)

WSSA Group Number	Site of Action	Examples
1	ACCase inhibitor	Cletodim, quizalofop
2	ALS inhibitor	Imazethapyr, cloransulam
3	Microtubule inhibitor	Pendimethalin, trifluralin
4	Growth regulator	2,4-D
5	Photosynthesis inhibitor (triazine)	Metribuzin
6	Photosynthesis inhibitor (contact)	Bentazon
9	EPSP 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 (VLCFA inhibitor)	Acetochlor, metolachlor
22	Cell membrane disrupter (PS1 inhibitor)	Paraquat

surface may cause greater weed densities the following year relative to tilled fields, but the seed bank may be depleted more rapidly in subsequent years. These results indicate that herbicide-resistant weed seed banks may be depleted most rapidly by maintaining no-till practices and modifying herbicide programs and/or crop rotations (Moechnig et al., 2012).

As herbicide-resistant biotypes become more common in a region, it will become increasingly important to minimize movement of weed seed among fields. It is always important to clean tillage and harvesting equipment before entering different fields to prevent the spread of weed species. However, it is commonly believed among many weed scientists that new infestations of glyphosate-resistant weeds are mostly caused by independent selection within that field rather than movement of seed among fields. Nevertheless, 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 (Fig. 33.1 and Fig. 33.2). Other weed species may be so problematic that preventing new infestations may justify the time required to clean equipment.

Figure 33.1. Corn stubble near a road that trapped tumbling kochia shoots from an adjacent field.
(Photo courtesy of Michael Moechnig, SDSU)

Figure 33.2. Tumbling kochia shoots trapped by a roadside fence.
(Photo, Michael Moechnig, SDSU)

Palmer amaranth *(Amaranthus palmeri)* is an annual weed that may appear very similar to waterhemp, but may have a slightly faster growth rate and may adapt to herbicides more quickly. Glyphosate-resistant Palmer amaranth has been a very challenging weed to control in soybean and cotton fields in the southern U.S. Now there is a concern that it may move to South Dakota and other northern states as a contaminant of cottonseed used as livestock feed. This has already occurred in Michigan. Palmer amaranth is already established in Great Plains states from Nebraska and south, so harvesting equipment that migrates north could also transfer Palmer amaranth seed. There has been at least one confirmed patch of Palmer amaranth in Sully County, S.D., but it is not known if that patch has survived or spread.

Management recommendations for glyphosate-resistant weeds

In 2007, a common ragweed biotype was the first glyphosate-resistant weed identified in South Dakota. Since then, glyphosate-resistant biotypes of waterhemp, kochia, and horseweed have been confirmed. Among these, kochia and waterhemp have become the most problematic. Figure 33.3 shows the locations of where glyphosate-resistant biotypes have been confirmed, but unconfirmed populations are much more extensive. Herbicide-resistant weeds in South Dakota and other states are also reported on the Internet at www.weedscience.org.

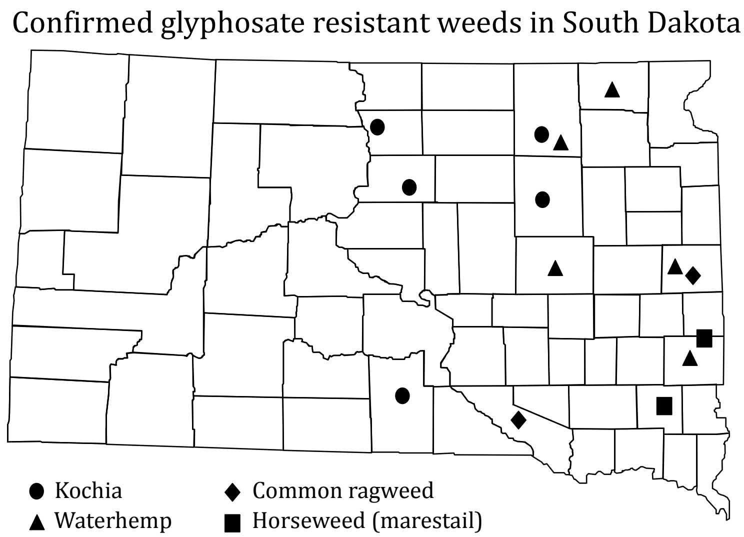

Figure 33.3. Approximate locations of confirmed glyphosate-resistant weed species in South Dakota.

Waterhemp

A glyphosate-resistant biotype of the annual weed waterhemp *(Amaranthus tuberculatus)* (Fig. 33.4) was confirmed in 2010. Since then, field surveys suggest that glyphosate-resistant waterhemp is becoming more common. In many cases, effective management may require pre-emergence and post-emergence 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 South Dakota is also resistant to Group 2 herbicides (ALS inhibitors), so those herbicides will not control glyphosate-resistant waterhemp.

Figure 33.4. Waterhemp. (Photo, Michael Moechnig, SDSU)

The most effective post-emergence herbicides include Group 14 herbicides (PPO inhibitors) such as fomesafen (Flexstar®) and lactofen (Cobra®). Some of the most effective pre-emergence herbicides are also Group 14 herbicides, such as sulfentrazone and flumioxazin. Group 15 herbicides, such as acetochlor (Warrant®) and pyroxasulfone, and Group 5 herbicides, such as metribuzin, may also provide good residual waterhemp control while diversifying herbicides with different sites of action. Glyphosate-resistant waterhemp may also be controlled with glufosinate (Liberty®) in LibertyLink® soybeans.

Like Group 14 herbicides (PPO herbicides), glufosinate is a contact herbicide that primarily desiccates weeds, so it must be applied to small (less than four inches tall) waterhemp and may require using more water per acre as a carrier to ensure thorough herbicide coverage on the weeds. Waterhemp seed may survive in the soil for 4-5 years (Buhler and Hartzler 2001 and Steckel et al., 2007), so seed bank depletion may require aggressive control for several years.

Aggressive control would require pre- and post-emergence herbicides, at labeled use rates, in soybeans and rotational crops, such as corn. 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.

Kochia

Glyphosate-resistant kochia *(Kochia scoparia)* (Fig. 33.5) may be one of the most challenging weeds to control in soybeans. Glyphosate-resistant kochia was first confirmed near Gettysburg in 2009. Since then, scouting reports suggest that it has been expanding. 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 lambsquarters and five times as much as giant foxtail (Moechnig et al., 2003).

Figure 33.5. Kochia one of the most challenging weeds to control in soybeans. (Photo, Michael Moechnig, SDSU)

Post-emergence herbicide options in soybeans are limited. Lactofen (Cobra®) or acifluorfen (Blazer®) may be some of the most effective options, but these are Group 14 herbicides, so they must be applied to small (less than two inches tall) plants, they require at least 20 gallons per acre as a carrier, and they may stress soybeans during adverse growing conditions. With these herbicides, it will become increasingly important to control weeds like kochia early in the growing season. A pre-emergence herbicide, such as sulfentrazone or flumioxazin, will likely be necessary to minimize dependence on a post-emergence herbicide.

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 soybean planting may eliminate much of the kochia population. However, effective burn-down herbicide options are not as well known as glyphosate, which has previously been the standard herbicide. 2,4-D is common burn-down herbicide, but that will not likely be effective on many kochia populations. Potentially effective options could be paraquat (Gramoxone®), glufosinate (Liberty®), or lactofen (Cobra®). Since kochia emerges very early in the spring, a late fall application of a soil residual herbicide, such as flumioxazin or sulfentrazone, may provide suppression or control in early spring.

LibertyLink® soybeans may be an alternative option. Since Liberty® is somewhat like a contact herbicide as it has limited mobility in plants, the first application must be applied to small weeds (less than four 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 post-emergence 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 in soybeans by aggressively managing it in rotational crops, such as corn or wheat, making it possible to control kochia in soybeans with a well-timed burn-down application and/or a pre-emergence herbicide application.

The prolific seed production potential of kochia will require nearly complete control in the rotational crops 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.

Horseweed (marestail)

Glyphosate-resistant horseweed *(Conyza canadensis)* (Figs. 33.6 and 33.7) has become relatively common in eastern South Dakota no-till fields. 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, saflufenacil (Sharpen®), or cloransulam (FirstRate®). Soil residual herbicides include saflufenacil, products containing cloransulam and Group 14 herbicides (Sonic®, Authority First®, or Gangster®), or flumetsulam (Python®).

Figure 33.6. Horseweed has become more common in no-tillage fields.
(Photo, Michael Moechnig, SDSU)

Post-emergence herbicide options are limited and they must be applied while horseweed is small (less than 4-6 inches). In spring to early summer, cloransulam (FirstRate®) may be the only herbicide that can be applied after soybean emergence that will provide horseweed suppression. However, the goal should always be to control horseweed prior soybean emergence.

Figure 33.7. Horseweed seedlings in the fall may be very small and difficult to see.
(Photo, Michael Moechnig, SDSU)

Common ragweed

Glyphosate-resistant common ragweed (Ambrosia artemisiifolia) (Fig. 33.8) was first confirmed in 2007, which was the first confirmed glyphosate-resistant weed in South Dakota. However, occurrences of resistance seem to be expanding much more slowly than kochia and waterhemp. Effective post-emergence herbicides include cloransulam (FirstRate®) or fomesafen (Flexstar®). However, a pre-emergence herbicide will also likely be required to manage glyphosate-resistant common ragweed. Effective soil residual herbicides include those that contain cloransulam (Sonic®, Authority First®, Gangster®), metribuzin (Authority MTZ®), fomesafen (Prefix®), or flumioxazin (Valor®).

Figure 33.8. Common ragweed in a South Dakota soybean field.
(Photo, Michael Moechnig, SDSU)

Fields 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 four years after production, but less than 1% may emerge thereafter.

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 (Fig. 33.9). In addition, they may be glyphosate resistant. Volunteer corn is perhaps the most common volunteer crop weed in soybeans. It can cause yield loss, inhibit harvesting, contaminate soybean seed, and act as a host for insect (Krupke et al., 2009) or diseases that may infest the subsequent corn crop. Volunteer corn may be effectively controlled with Group 1 herbicides (ACCase-inhibiting), such as clethodim,

Figure 33.9. Volunteer corn in a soybean field. (Photo, Michael Moechnig, SDSU)

quizalofop, sethoxydim, and others. Figure 33.9 demonstrates the potential soybean yield loss that may occur from volunteer corn in South Dakota.

Volunteer canola may be more difficult to control than corn in soybeans. Although canola is generally not grown in South Dakota, seed may enter a field as a fertilizer contaminant or by other means. It often occurs at very low densities and is likely more of an aesthetic problem rather than a yield loss concern. Herbicides containing imazethapyr (Pursuit®, Extreme®, etc.) may be most effective.

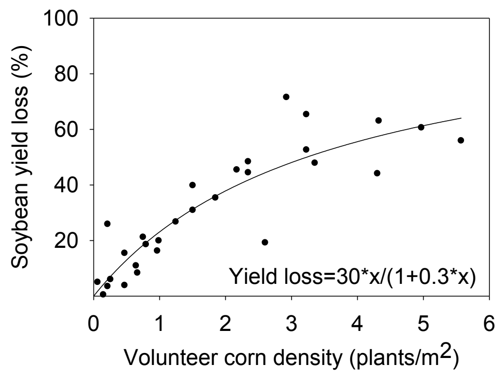

Figure 33.10. Soybean yield loss associated with volunteer corn density (x = volunteer corn density as plants/m^2).

Avoiding selection for additional herbicide-resistant weeds biotypes

Diversifying weed management programs to control one glyphosate-resistant weed biotype in a field does not mean that another species will not be selected in the future. Most herbicides are effective on only 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 (Chapter 31). 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 glyphosate-resistant species. For example, adding fomesafen with glyphosate may effectively control glyphosate-resistant waterhemp, but would provide only limited additional control of common lambsquarters or velvetleaf, which means resistant biotypes could be selected. Therefore, it will be important to monitor populations of these other difficult species, make management adjustments if necessary, and be sure to use effective management programs for these species in rotational crops. Weed species and densities changes may be evaluated over time by entering this information into your field records annually (Chapter 2).

References and additional information

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.J., 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 (http://wssaabstracts.com/public/index.php).

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 (in press).

Krupke, C., S. Weller, S. Conley, P. Marquardt, and W. Johnson. 2009. Volunteer corn presents new challenges for insect resistance management. Agronomy Journal 101(4):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 Science 55:235-239.

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

Websites

Weed Science Society of America: http://www.wssa.net

The glyphosate, weeds, and crops web site: http://www.glyphosateweedscrops.org/

International survey of herbicide-resistant weeds: http://www.weedscience.org

Acknowledgements

Funding for developing this chapter was provided by the South Dakota Soybean Research and Promotion Council, USDA-IPM, and South Dakota State University.

Moechnig, M., S.A. Clay, and D. Deneke. 2013. Herbicide-resistant weeds in soybeans. In Clay, D.E., C.G. Carlson, S.A. Clay, L. Wagner, D. Deneke, and C. Hay (eds). iGrow Soybeans: Best Management Practices for Soybean Production. South Dakota State University, SDSU Extension, Brookings, SD.