NebGuide
University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources
Know how. Know now.

G1484
(Revised February 2010)

Use of Herbicide-Tolerant Crops as Part of an Integrated Weed Management Program

Stevan Z. Knezevic, Extension Integrated Weed Management Specialist

Recommendations for using herbicide-tolerant crops as part of an integrated weed management (IWM) effort that incorporates preventive, cultural, mechanical, and chemical tools to keep weed pressure below yield-robbing levels.

Herbicide-tolerant crops represent weed control technology that can be combined with preventive, cultural, mechanical, and chemical measures as part of an integrated weed management (IWM) strategy. Herbicide-tolerant crops have been widely adopted by growers in the U.S. and Canada and offer enhanced weed control; however, they should be considered as just one component of an IWM approach that helps ensure the long-term benefits of a profitable and environmentally sound weed management program. Widespread use and over-reliance on herbicide-tolerant crops, without the benefit of an integrated weed management program, can result in:

- the development of herbicide-tolerant weeds,
- a shift to weed species or biotypes that are more tolerant of the herbicide in question, and
- species that emerge after postemergence herbicide has been applied.

This NebGuide provides general guidelines for using herbicide-tolerant crops in an IWM program with emphasis on ensuring the long-term viability and profitability of this technology while protecting natural resources.

Integrated Weed Management

Integrated weed management is commonly described as a combination of mutually supportive technologies that control weeds. In practical terms, it means developing a weed management program using a combination of preventive, cultural, mechanical and chemical practices. It does not mean abandoning chemical weed control, but rather, using it with many mutually supportive weed management options. This can lead to reduced herbicide use.

IWM advocates the use of all available weed control options. These might include:

- selection of a well adapted crop variety or hybrid with good early-season vigor and appropriate disease and pest resistance
- appropriate planting patterns and optimal plant density
- improved timing, placement, and amount of nutrient application
- crop rotation
- tillage practices
- cover crops
- mechanical cultivation
- biological and chemical control methods

A single weed control measure is not feasible due to the number of weed species which may be present, as well as their different life cycles and survival strategies. In addition, controlling weeds with only one or two methods allows them to adapt to those practices. The IWM toolbox allows growers to select from many options and vary the weed control tools they use from year to year.

Herbicide-tolerant crops are a powerful tool in this toolbox. Their use has grown steadily since they became commercially available a decade ago. Currently more than 90 percent of the 70 million acres of soybean grown in the U.S. annually are cultivars genetically engineered to be tolerant to glyphosate, a broad spectrum herbicide. In some regions as much as 70 percent of the corn crop has been planted to glyphosate-tolerant hybrids. Herbicide-tolerant crops offer many important advantages to an IWM program, but there also are risks associated with their use. This NebGuide provides a short overview of benefits and concerns of using herbicide-tolerant crops as part of a successful IWM program in order to help those involved in weed management at the field level.

Herbicide-Tolerant Crops

Herbicide-tolerant crops can be produced by either insertion of a "foreign" gene from another organism into a crop, or by regenerating herbicide-tolerant mutants from existing crop germplasm. The first process produces what is commonly known as a genetically modified organism or GMO, while the second process produces a non-GMO variety or hybrid. Examples of GMO herbicide-tolerant crops include canola and soybean varieties or corn hybrids tolerant to glyphosate and glufosinate herbicides. Examples of non-GMO herbicide-tolerant crops include sulfonylurea-tolerant soybeans (STS) and Clearfield corn and wheat.

Industry continues to develop new herbicide-tolerant crops, including ones that use several genes in a single hybrid or variety, commonly referred to as stacked genes or stacked traits. For example, some corn hybrids and cotton varieties have been genetically engineered to contain several foreign genes for insect-tolerance and herbicide tolerance and new corn varieties may have as many as eight traits, further extending the control options they provide.

Benefits of Planting Herbicide-Tolerant Crops

Given that as much as 90 percent of soybean and 50 percent of corn fields in some U.S. states are planted to glyphosate-tolerant varieties, those producers must clearly realize benefits from this technology. The most commonly cited benefits to producers include:

- broader spectrum of weeds controlled
- reduced crop injury
- reduced herbicide carry-over
- use of herbicides that are more environmentally friendly
- new mode of action for resistance management
- crop management flexibility and simplicity

Some of these factors contribute to IWM because they are mutually supportive of other weed management tools such as reduced tillage and crop rotation, while others can help protect yields and profit.

Broader Spectrum of Weeds Controlled. Non-selective herbicides such as glyphosate and glufosinate aid in broadening the spectrum of weeds controlled. The systemic activity of glyphosate also helps with the control of perennial weeds and their perennial vegetative structures such as stolons and rhizomes. Such broad spectrum control is particularly important in no-till systems and in weedy fields.

Reduced Crop Injury. Crop injury in general is reduced with the use of herbicide-tolerant crops. Both glyphosate and glufosinate cause almost no crop injury compared to some traditional herbicides (e.g. lactofen, clorimuron), especially on soybean.

Reduced Herbicide Carry-Over. Glyphosate and glufosinate have almost no soil residual activity because they are tightly bound to the organic particles in the soil. Hence, there are few restrictions for planting or replanting intervals and few injuries to subsequent crops. This trait facilitates crop rotation by providing flexibility in selection of potential rotation crops.

Use of Herbicides That Are More Environmentally Friendly. In general, glyphosate and glufosinate have lower toxicity to humans and animals compared to some other herbicides. Since they are readily absorbed by the organic particles in the soil and decompose rapidly, they pose little danger for leaching and contamination of groundwater or toxicity to wildlife.

New Mode of Action for Resistance Management. Glyphosate and glufosinate provide a new mode of action that can aid in resistance management in an IWM program. Weed resistance is a serious problem in some areas of the U.S. and Canada; herbicide-tolerant crops can reduce problems with weed resistance.

Crop Management Flexibility and Simplicity. The technology associated with herbicide-tolerant crops is simple to use. It requires neither special skills nor training. The technology is flexible and does not have major restrictions, which is probably one reason why it's been so widely adopted by producers. In particular, crops tolerant to broad spectrum herbicides, such as glyphosate, extend the period of herbicide application for effective weed control, which is helpful in dealing with rainy and windy days during the optimal periods for weed control measures. In contrast, poor weather during the critical period for weed control can greatly limit the effectiveness of more selective herbicides.

Concerns with Planting Herbicide-Tolerant Crops

A number of concerns should be considered when deciding whether to use herbicide-tolerant crops as part of an IWM program. These include:

- yield performance
- single selection pressure and weed resistance
- shifts in weed species
- gene escape
- gene flow and contamination of organic crops
- drift and non-target movement

Yield Performance. Herbicide-tolerant crop varieties or hybrids must achieve yields comparable to conventional varieties to ensure an adequate economic return. Some researchers have identified "yield drag" and "yield lag" as two potential concerns. Yield drag is a yield reduction due to the addition of foreign genes. Yield lag is the potential yield depression due to the age of the variety in which the gene is inserted. University of Nebraska–Lincoln research published in 2001 concluded that soybean varieties with the glyphosate-tolerant gene yielded 5 percent less than sister lines without the foreign gene, indicating yield drag. In the same study, glyphosate-tolerant varieties yielded 10 percent less than the best high-yielding varieties that were not herbicide-tolerant, indicating yield lag. While companies try to incorporate new traits into elite varieties, there can be a time lag in this process. Also, as GMO varieties become widely used, as in the case with Roundup-Ready® soybean, it is likely yield lag will diminish. In most cases, public scientists do not have access to the breeding materials of private companies. Such access would allow for independent studies of whether yield lag or yield drag is occurring in genetically modified crops.

Single Selection Pressure and Weed Resistance. Widespread use of the same herbicide-tolerant crops may result in repeated use of same herbicide, creating a single selection pressure on a weed population. Repeated use of the same herbicides is the main reason for herbicide resistance worldwide. Properly managing the use of herbicide-tolerant crops can help deter the development of herbicide-resistant weed populations.

Before glyphosate-tolerant crops were introduced, only three weed species in the world were known to have developed resistance to glyphosate. Such resistance resulted from repeated glyphosate applications in species such as rigid ryegrass (*Lolium rigidum*) in Australia and California and goosegrass (*Eleusine indica*) in Malaysia. Following the introduction of Roundup-Ready crops and repeated use of glyphosate, the number increased to 15 species worldwide with nine in the U.S. Glyphosate-resistant weeds found in the U.S. include common waterhemp (*Amaranthus rudis* Sauer), horseweed, giant ragweed (*Ambrosia trifida* L.), common ragweed (*Ambrosia artemisiifolia* L.), palmer amaranth (*Amaranthus palmeri* S. Wats.), hairy fleabane [*Conyza bonariensis* (L.) Cronq.], Italian ryegrass [*Lolium perenne* L. ssp. *multiflorum* (Lam.) Husnot], rigid ryegrass, and johnsongrass [*Sorghum halepense* (L.) Pers.]. These weeds are primarily found in the Midwest, the main region for corn and soybean production. Glyphosate-resistant horseweed has been confirmed in Nebraska and there are documented instances where common broadleaf weeds such as waterhemp, velvetleaf, or lambsquarters are not being controlled as well as they were six or seven years ago with the label rate of glyphosate.

Shifts in Weed Species. Weed shifts have happened since humans began cultivating land and growing crops. These shifts can occur both within a population of a certain species (e.g. surviving mutants), and within a plant community (e.g. certain species). Weedy and invasive species can easily adapt to changes in production practices to take advantage of the available niche. Species that do not adapt to management changes will decrease in number. While glyphosate controls many weed species, it does not control all plant species. Similarly, while glyphosate controls many grasses, certain broadleaf species in major Midwest cropping systems are naturally tolerant to label rates of glyphosate. Repeated use of glyphosate can result in a shift in weed species from those easily controlled by glyphosate to those more tolerant to this herbicide. Furthermore, weeds can survive in crop production systems using herbicide-tolerant crops because of natural tolerance to glyphosate and because of growth types or life cycles that help them avoid being treated.

As a result of repeated use of glyphosate in Nebraska, there is a slow shift in weed species 1) from those weeds easily controlled by glyphosate to those more tolerant to this herbicide, and 2) to those weed species that have growth types, or life cycles, that help them avoid being treated by glyphosate, such as some winter annual weed species.

UNL researchers compiled a list of problematic weed species based on extension phone calls and questions from producers, crop consultants, and agronomists. This list included wild buckwheat (*Polygonum convolvulus*); Pennsylvania smartweed (*P. pensilvanicum*); lady's thumb (*P. lapathifolium*); ivyleaf morningglory (*Ipomea hederacea*); venice mallow (*Hibiscus trionum*); horseweed (*Conyza canadensis*); yellow sweet clover (*Melilotus officinalis*); and field bindweed (*Convolvulus arvensis*). Control of these species increased weed control costs, even with the use of herbicide-tolerant crops. In an experimental setting, the researchers defined a dose response curve for glyphosate for control of these problem weed species. Except for morningglory and sweet clover, most weeds up to 10 cm tall were controlled well with the label rate of glyphosate. Taller weeds required 1.5 to 4 times the label rate. About 1.5 to 2 times the rate was needed to control 10-20 cm tall wild buckwheat, Venice mallow, velvetleaf, waterhemp, sweet clover, ivyleaf morningglory, and bindweed. About three to four times the rate was needed to control 30-40 cm tall ivyleaf morningglory and sweetclover. These results suggest that these species had a high level of natural tolerance to glyphosate, especially as they increased in size. If these weed shift trends continue, glyphosate used alone will no longer be a viable tool for weed control in glyphosate-tolerant crop systems. Producers will need to mix glyphosate with other postemergence broadleaf herbicides or use soil-applied herbicides after planting to effectively control these species, increasing the overall cost of weed control.

UNL research in western Nebraska found that repeated use of glyphosate caused a shift in the local weed population. After six years the local population shifted from kochia (*Kochia scoparia*) and proso millet (*Panicum miliaceum* L.) to predominately common lambsquarters. In addition, researchers reported that the local common lambsquarters population exhibited a higher level of tolerance to glyphosate, both in field and growth chamber studies.

An increase in the occurrence of winter annual weeds also was reported in Nebraska for cropping systems based on glyphosate-tolerant crops. It is believed that the increase in winter annual species likely resulted from the reduced use of preemergence herbicides and the use of herbicides with residual activity in glyphosate-tolerant crops. The list of common winter annuals included field pennycress (*Thlaspi arvense* L.), shepherdspurse (*Capsella bursa-pastoris*), henbit (*Lamium amplexicaule*), and tansy mustard (*Descurainia pinnata* Walt. Britt). These species are commonly found in the fall (October, November) and early spring (March, April) throughout eastern Nebraska and western Iowa. Management strategies need to include control of these winter annuals, which is likely to increase the overall cost of weed control.

Gene Escape. The potential for the "escape" of herbicide-resistant genes via pollen to other plant species is another major concern, especially with wild species closely related to the herbicide-tolerant ones. Gene escapes are not a new phenomenon. A USDA researcher reported in 1998 that a resistance gene had been naturally transferred via pollen from herbicide-tolerant imidazolinone-resistant wheat to jointed goatgrass (*Aegilops cylindrica*) in the northwestern

U.S. A Canadian study identified pollen transfer as the main means for the development of Canola (*Brassica napus*) with naturally occurring, multiple resistance to three commonly used herbicides — glyphosate, glufosinate, and imazethapyr. The probability of gene flow increases further if the plant species are closely related (i.e. same genus) due to the possibility of cross-pollination. The list of so-called "high risk crops" and their weedy relatives includes:

- sorghum — shattercane and johnsongrass
- canola — mustards
- wheat — jointed goatgrass and quackgrass
- rice — red rice
- sunflower — wild sunflower

Gene Flow and Contamination of Organic Crops. Gene flow results when pollen from GMO crops contaminate non-GMO crops. Organic crops can become contaminated by glyphosate-resistant or Bt genes via cross-pollination from neighboring fields planted with glyphosate-tolerant crops. This is especially a concern for organic crops. For example, widespread use of glyphosate-tolerant soybean and an increase in glyphosate-tolerant corn and alfalfa acres are causing problems for the production of organic soybeans, corn, and alfalfa. Various field tests can detect very small quantities of cross-contamination. This can limit marketing options for organic crops which cannot contain GMO seeds or any trace of foreign genes.

Drift and Non-Target Movement. Spray drift and non-target movement are a concern with the use of any herbicide; however, the concern becomes greater with use of non-selective herbicides such as glyphosate and glufosinate. Misidentification of fields planted with herbicide-tolerant crops and misapplications of herbicides can lead to unintended contamination of conventional crops.

Conclusion

Integrated weed management can optimize profit by maintaining weed density below threshold levels. Herbicide-tolerant crops are a powerful part of this strategy and should be used with other weed management practices as part of a mutually supportive, integrated weed management plan. In essence, the development of an IWM program is based on a few general rules that can be used on any farm.

- Use agronomic practices that limit the introduction and spread of weeds. (Prevent weed problems before they start.)
- Help the crop compete with weeds. (Healthy fields can help "choke out" weeds.)
- Adjust or change practices so weeds are kept "off balance" and can't adapt.

Combining agronomic practices based on these rules will allow producers to design an IWM program for any farm. IWM is not a single strategy, but rather a group of options that can be changed and adjusted to a particular farming operation. The goal is to manage, not eradicate weeds.

Other IWM Applications

Regardless of whether conventional or herbicide-tolerant crops are used, producers can help give their crops an advantage over weeds by:

- changing fertilizer placement
- adjusting crop row spacing
- planting more competitive varieties
- varying planting dates
- rotating crops
- rotating herbicides with different modes of action
- rotating tolerant crops with those with different modes of actions
- scouting fields
- applying the critical period of weed control to determine weed control timing
- keeping careful records of weed populations and problems

Specific details about these rules for implementing an integrated weed management strategy are in the *Nebraska Guide for Weed Management* (EC130), which is updated annually.

Proper use of herbicide-tolerant crops as part of an IWM program will help preserve the long-term benefits of this technology while avoiding many of the concerns about its use. With both conventional and herbicide-tolerant crops, there is no single, "silver bullet" for weed control. In the long term, careful management of the available technologies will provide for more options to be available longer.

This publication has been peer reviewed.

Disclaimer

Reference to commercial products or trade names is made with the understanding that no discrimination is intended of those not mentioned and no endorsement by University of Nebraska–Lincoln Extension is implied for those mentioned.

UNL Extension publications are available online at *http://extension.unl.edu/publications*.

Index: Weeds
Field and Pasture
2002, Revised February 2010

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

University of Nebraska–Lincoln Extension educational programs abide with the nondiscrimination policies of the University of Nebraska–Lincoln and the United States Department of Agriculture.

© 2010, The Board of Regents of the University of Nebraska on behalf of the University of Nebraska–Lincoln Extension. All rights reserved.