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Use of Herbicide Tolerant Crops as a Component of an Integrated Weed Management Program

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This NebGuide provides general guidelines for using herbicide tolerant crops in an integrated weed management program to ensure the long-term viability and profitability of this technology while protecting natural resources.

Integrated weed management (IWM) advocates the use of a combination of preventive, cultural, mechanical, and chemical tools to keep weed pressure below threshold levels that reduce yields and profits. Herbicide tolerant crops (HTCs) represent a relatively new weed control technology that can be used in an integrated weed management program. These crops, which enhance weed control options and greatly expand market demand for some herbicides, have been readily adopted by farmers in the United States and Canada. They provide many benefits to producers and to the companies that own the intellectual property rights to this technology. However, HTCs should be considered as one component of an integrated weed management approach that uses other management tools to ensure the long-term benefits of a profitable and environmentally sound weed management program. Widespread use and overreliance on herbicide tolerant crops, without the benefit of an integrated weed management program, can result in:

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

This NebGuide provides general guidelines for using herbicide tolerant crops in an integrated weed management program to ensure the long-term viability and profitability of this new technology as well as the protection of natural resources.

Integrated Weed Management

Integrated weed management commonly has been described as “a combination of mutually supportive technologies in order to control weeds.” Some have also called it “a multi-disciplinary approach to weed control utilizing the application of numerous alternative control measures.” 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 altogether. Instead, chemical control is considered to be one of many mutually supportive weed management options. Implementing this approach, however, can result in reduced herbicide use. An IWM approach advocates the use of all available weed control options, such as: selection of a well adopted 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; and biological and chemical control methods. A single weed control measure is not feasible due to the number of weed species, their highly differing life cycles and survival strategies. In addition, controlling weeds with one or two methods gives the weeds a chance to adapt to those practices. Therefore, instead of relying on only one or two management tools, the IWM toolbox includes many options.

Herbicide tolerant crops are a powerful new tool in this toolbox. Since they became commercially available less than a decade ago, growers have readily integrated them into their crop production practices. For example, currently more than 80 percent of 65 million acres of soybean grown in the United States annually are cultivars genetically engineered to be tolerant to glyphosate, a broad spectrum herbicide. In some regions as much as 90 percent of planted soybeans are glyphosate tolerant varieties. Although herbicide tolerant crops may offer many advantages, there also are risks associated with their use. The objective of this publication is to provide a short overview of benefits and concerns regarding the use of herbicide tolerant crops in a successful integrated weed management program in order to help those involved in weed management at the field level.

Herbicide Tolerant Crops[1]

Herbicide tolerant crops can be produced by either inserting a "foreign" gene from some organism into a crop or by regenerating herbicide tolerant mutants from existing crop germplasm. The first type is also commonly known as a genetically modified organism, or GMO, while the second type is referred to as 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 STS-soybeans[2]; Clearfield corn[3] and Clearfield wheat[4]. Herbicide tolerant crops have become a common weed control tool in North American cropping systems, and their use is steadily growing, especially for soybean. For example, use of glyphosate tolerant soybean has grown from 41 percent of all U.S. soybean planted in 1998 to 54 percent, 70 percent, and 80 percent in 1999, 2000 and 2001, respectively. A similar increase in use of HTCs has occurred in U.S. canola and cotton. About 26 percent of cotton grown in 1998 was glyphosate tolerant, with an increase to 35 percent, 46 percent and 57 percent in 1999, 2000 and 2001, respectively. The rate of increase in the use of herbicide-tolerant corn (eg. Roundup-Ready[5], Liberty-Link[6] and Clearfield) has been much slower than that for soybean or cotton. Only about 7 percent of U.S. corn was in herbicide tolerant hybrids in 1998, compared to 8 percent, 12 percent, and 15 percent in 1999, 2000, and 2001. Overall, the most common HTC in the United States is glyphosate tolerant soybean.

Industry continues to work on the development of new herbicide tolerant crops. For example, it is likely that glyphosate tolerant spring wheat will be available in 2004 in Canada and in 2005 in the United States. In addition, Clearfield winter wheat, which is tolerant primarily to imazamox herbicide, is likely to be released for the South and Central Great Plains in 2002 or 2003. Glyphosate tolerant alfalfa is currently being evaluated in variety testing trials, indicating potential for release within a few years.

The trend toward the use of several genes in a single hybrid or variety, commonly referred to as "stacked genes" or "stacked traits" is also under development. For example, some corn hybrids and cotton varieties have been genetically engineered to contain two foreign genes, one for insect tolerance and another for herbicide tolerance (eg. Bt/glyphosate, or Bt/liberty). Furthermore, some corn hybrids have three traits, of which two are for herbicide tolerance and one is for insect tolerance (eg. Liberty, Clearfield and Bt). In contrast, several types of HTCs likely may be withdrawn from the market for various reasons.

Benefits

Considering that as much as 90 percent of the soybean crop in some states is planted to glyphosate tolerant varieties, soybean producers must clearly realize benefits from this technology. The most commonly cited benefits to the producers include: 1) broader spectrum of weeds controlled, 2) reduced crop injury, 3) less herbicide carryover, 4) price reduction for "conventional herbicides", 5) use of herbicides that are more environmentally friendly, 6) new mode of action for resistance management, and 7) crop management flexibility and simplicity, especially in no-till systems. Some of these factors contribute to integrated weed management because they are mutually supportive of other weed management tools such as reduced tillage and crop rotation, while others can help improve 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 control perennial weeds and their perennial vegetative structures such as stolons and rhizomes. Such broad spectrum control is particularly important in no-till systems and "weedy" fields.

Reduced crop injury. Generally, there is less crop injury with the use of herbicide tolerant crops. Both glyphosate and glufosinate cause little or no crop injury, compared to some traditional herbicides (e.g. lactofen, clorimuron), especially on soybean.

Less herbicide carryover. 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 or injuries to the subsequent crops. This trait facilitates crop rotation by providing flexibility in selection of potential rotation crops.

Price reduction for 'conventional herbicides.' Introduction of HTCs resulted in a price reduction for conventional herbicides. For example, just a few years ago the cost of weed control with conventional herbicides in soybeans ranged from $30 to $60 per acre compared to the current $20 to $30. The price reduction is the result of the market adjustment and an attempt by companies to remain competitive with herbicides used on non-herbicide tolerant 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 due to leaching and contamination of ground water or toxicity to wildlife.

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[1]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.
[2]STS-Soybean® by DuPont de Nemours & Co, Inc. 1007 Market Street, Wilmington, DE, 19898.
[3]Clearfield® corn by BASF Corporation, 26 Davis Drive, Research Triangle Park, NC, 27709.
[4]Clearfield® wheat by BASF Corporation, 26 Davis Drive, Research Triangle Park, NC, 27709.
[5]Roundup Ready® by Monsanto Company, 800 N. Linberg Boulevard, St. Louis, MO, 63167.
[6]Liberty Link® by Bayer CropScience, P.O. Box 121014, Research Triangle Park, NC, 27709.

New mode of action for resistance management. Glyphosate and glufosinate provide a new mode of action that can aid in resistance management. Single or multiple weed resistance is a serious problem in certain parts of the United States and Canada, thus the use of 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 does not have major restrictions and it is flexible, which is probably one of the reasons for its wide adoption. 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 (Peterson et al. 2002).

Concerns

A number of concerns should be considered when deciding whether to use herbicide tolerant crops as a component of an integrated weed management program. These concerns include:

1) yield performance,
2) single selection pressure and weed resistance,
3) shifts in weed species,
4) gene escape,
5) gene flow and contamination of organic crops,
6) drift and non-target movement, and
7) marketing and food labeling in global markets.

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. Recent University of Nebraska research (Elmore et al. 2001) concluded that soybean varieties with the glyphosate tolerant gene yielded 5 percent less than the 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 non-HTCs indicating yield lag. While companies try to incorporate new traits into elite varieties, there can be a time lag in this process. However, as GMO varieties become widely used, as in the case of Roundup- Ready soybean, it is likely the yield lag will diminish.

Single selection pressure and weed resistance. Widespread use of the same HTCs may result in repeated use of the same herbicide, creating a single selection pressure on the weed population. Repeated use of the same herbicides is the main reason for herbicide resistance worldwide (Holt, 1992). Therefore special attention should be given to proper management of HTCs to avoid the development of herbicide resistant weed populations. Indeed repeated use of glyphosate can result in weed resistance, such as happened with several weed species: rigid ryegrass (*Lolium rigidum*) in Australia (Powles et al. 1998), goosegrass *(Eleusine indica*) in Malaysia, ryegrass in California, and horseweed (*Conyza canadensis*), commonly known as marestail, in Delaware and Tennessee (VanGessel, 2001). Resistance in the above cases resulted from repeated use of glyphosate in the absence of an IWM program.

Shifts in weed species. Despite the fact that glyphosate and glufosinate control many weed species, they do not control all plant species. There is no herbicide that controls all plants. While it is well known that glyphosate controls many grasses, certain broadleaf species in major U.S. and Canadian cropping systems are tolerant to label rates of glyphosate. Therefore, repeated use of glyphosate can result in a shift in weed species from those easily controlled by glyphosate to those more tolerant of this herbicide. Examples of such species include: wild buckwheat (*Polygonum convolvulus*), Pennsylvania smartweed (*P. pensilvanicum*), lady's thumb (*P. lapathifolium*), ivyleaf morning glory (*Ipomea hederacea*), venice mallow (*Hibiscus trionum*), horseweed (*Conyza canadensis*), yellow sweetclover (*Melilotus officinalis*), and field bindweed (*Convolvulus arvensis*) (VanGessel, 2001). Shifts in weed populations to more tolerant weeds will result in increased weed control costs, even with HTCs.

Gene escape. Another major concern is the potential for the "escape" of genes for herbicide resistance via pollen from HTCs to other plant species, especially from HTCs to closely related wild relatives. Gene escapes from HTCs are not a new phenomenon. Seefeldt et al. (1998) reported that a resistance gene had been naturally transferred via pollen from herbicide tolerant IMI wheat to jointed goatgrass (*Aegilops cylindrica*) in the northwestern United States. Hall et al (2000) also demonstrated that pollen flow was the main reason for naturally occurring multiple resistance of canola (*Brassica napus*) to three commonly used herbicides such as glyphosate, glufosinate and imazethapyr in Alberta, Canada. 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: a) sorghum and its weedy relatives shattercane and johnsongrass; b) canola and mustards; c) wheat and jointed goatgrass and quackgrass; d) rice and red rice; and e) sunflower and wild sunflower.

Gene flow and contamination of organic crops. Gene flow is the contamination of non-GMO crops, especially organically grown crops, by pollen from GMO crops. For example, organic soybean and organic corn are grown in Nebraska and are good sources of income for some producers. However, widespread use of glyphosate tolerant crops (e.g. Roundup Ready soybean and corn) can cause problems for organic growers if glyphosate-resistant genes cross-pollinate with organic crops in neighboring fields. Because certain tests can detect very small quantities of cross-contamination, organic farmers are concerned that such cross-contamination will limit their ability to market organic soybean, which must contain no GMO seeds.

Drift and non-target movement: Drift and non-target movement is a general concern with use of any herbicide. However, the concern becomes greater with use of non-selective herbicides such as glyphosate and glufosinate. Misapplication and misidentification of fields planted with non-HTCs can occur unless care is taken to identify such fields and to avoid drift onto nearby fields with conventional crops.

World markets and food labeling. Current anti-biotech sentiment in Europe and Japan has caused a reduction in grain imports from the United States to these countries. There is already an estimated 30 percent reduction in U.S. exports of various products related to glyphosate tolerant soybeans, mostly due to opposition toward biologically engineered crops in these countries. In addition, many countries are considering or have implemented labeling regulations for GMO crops and grain products.

Conclusion

An IWM approach is required to optimize profit by maintaining weed density below threshold levels. Herbicide tolerant crops are a relatively new and powerful tool in the IWM toolbox, but they must be used in a mutually supportive fashion with other weed management practices. Therefore, HTCs should be used in accordance with the principles of IWM.

In essence, the development of an integrated weed management program is based on a few general rules that can be used at any farm. They include:

1) using agronomic practices that limit the introduction and spread of weeds (preventing weed problems before they start),
2) helping the crop compete with weeds (helping “choke out” weeds), and
3) using practices that keep weeds “off balance” (not allowing weeds to adapt).

Combining agronomic practices based on the above rules will allow producers to design an IWM program for any farm. An IWM program is not a ‘recipe’, it needs to be changed and adjusted to a particular farming operation. The goal is to manage not eradicate weeds. Regardless whether HTCs or conventional crops are used, there are several things that can be done to give crops the advantage over weeds and to keep weeds “off balance”:

1) fine-tune fertilizer placement and timing,
2) adjust crop row spacing,
3) plant more competitive varieties,
4) vary planting dates,
5) rotate crops,
6) rotate herbicides with different modes of action,
7) rotate HTCs that are tolerant to herbicides with different modes of actions,
8) scout fields,
9) use the concept of critical period of weed control to determine timing of weed control, and
10) maintain documentation and record keeping.

Specific details about these guidelines can be found in the “Nebraska Weed Management Guide” (EC130), which is updated annually.

To conclude, proper use of herbicide tolerant crops technology as a component of an IWM program is the key to preserving the long-term benefits of this technology while avoiding many of the concerns about its use. And remember, there is no such a thing as a “silver bullet” when it comes to weed control, regardless of whether the production system is based on conventional or herbicide tolerant crops.

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