2º PAINEL – CULTURAS RESISTENTES AOS HERBICIDAS

HERBICIDE TOLERANT CROP: BENEFITS, CONCERNS AND RISKS

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Abstract

Herbicide tolerant crops (HTC) represent relatively new weed control technology that was readily integrated into crop production practices in US and Canada. HTC can be produced by either the insertion of a foreign gene or by regenerating herbicide tolerant mutants. The first ones are also commonly known as genetically modified organisms or GMOs, while the second ones are usually referred to as the non-GMOs. Examples of GMO crops include soybean, corn and canola tolerant to glyphosate and glufosinate. Examples of non-GMO crops include STS-soybean, Clearfield-corn and Clearfield-wheat. Glyphosate and glufosinate can also be used as an alternative tool for weed control thus playing an important role in the development of integrated weed management systems. HTC enhanced weed control options and greatly expanded the market demand for these herbicides. HTC provided many benefits to the producers and the companies that own this technology. However, the wide spread and repeated use of HTCs created many concerns about their impact on the environment and sustainability of cropping systems. Benefits, concerns and risks with widespread use of HTC-s are discussed.

Introduction

Herbicide tolerant crops (HTC) represent relatively new weed control technology. Since introduction, less than a decade ago, their use has been steadily growing. Examples of HTC include soybean, corn and canola tolerant to glyphosate and glufosinate (Moll 1997; Rasche and Gadsby 1997). Growers have readily integrated HTC into their crop production practices. For example, currently more than 60% of 25 million hectares of soybeans grown in the U.S. annually are glyphosate tolerant cultivars (USDA/NASS 2000). In some regions as much as 90% of soybeans are glyphosate tolerant varieties. Even though the use of herbicide tolerant crops may have advantages over regular herbicide programs, there are risks

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associated with their use. Therefore the objective of this paper is to provided a short overview of benefits, risks and concerns with widespread and repeated use of HTC.

HTC can be produced by either the insertion of a foreign gene or by regenerating herbicide tolerant mutants. The first ones are also commonly known as genetically modified organisms or GMOs, while the second ones are referred to as the non-GMOs. Examples of GMO crops include canola, soybeans and corn tolerant to glyphosate and glufosinate herbicides. Examples of non-GMO crops include [2]STS-soybeans, [3]Clearfield corn and [4]Clearfield wheat. HTC is a common weed control tool in the North American cropping systems and their usage is steadily growing, especially in soybean crops. It is estimated that in the year 2001 more than 80% of soybeans planted in the United States were glyphosate tolerant varieties, compared to 70%, 54%, and 41% in 2000, 1999 and 1998, respectively. Similar increase in use was observed in canola and cotton. About 26% of cotton grown in 1998 was glyphosate tolerant, with an increase to 35%, 46% and 57% for 1999, 2000 and 2001, respectively (USDA/NASS, 2002). However, there is a much slower trend on the use of herbicide tolerant corn (eg. [5]Roundup-Ready, [6]Liberty-Link and Clearfield) than for soybean or cotton. It is estimated that only about 7% of corn hybrids planted in 1998 were herbicide tolerant hybrids compared to 8%, 12% and 15% in 1999, 2000 and 2001. Overall, the most common HTC in the United States is soybean tolerant to glyphosate. (USDA/NASS 2002). Since the HTC are a common part of our cropping system, it brings the question, "What is the next HTC?".

Development of new HTC is the goal of industry's research programs. For example, speculations are that glyphosate tolerant spring wheat will be available in 2004 and 2005 for Canadian and US market, respectively. The Clearfield winter wheat, which is tolerant primarily to imazamox herbicide, is likely to be released for South Central US in 2002 or 2003. Glyphosate tolerant alfalfa is currently being evaluated in the field variety testing trials, indicating potential for release within a few years, or sooner.

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[2]STS-Soybean® by du Pont 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 Aventis CropScience, P.O. Box 12014, Research Triangle Park, NC, 27709.

The trend is also growing towards the use of several genes in a single hybrid or variety, as commonly referred as "stacked genes or stacked traits". There are also corn and cotton hybrids containing two genes, (eg. Bt/glyphosate, or Bt/liberty). As well as corn hybrids with three genes (Bt, liberty and Clearfield). In contrary, there are also several types of HTC that may likely be withdrawn from the market due to various reasons. Speculations are that these HTC may include: Liberty-Link corn (Star-Link), STS-soybean, Liberty-Link soybean, SR-Corn, as well as a High-Oil corn.

Benefits associated with the use of htc

Considering the fact that some US states have as much as 90% of soybean fields planted to glyphosate tolerant varieties, there must be benefits that the producers see from this technology. The list of most common benefits to the producers may include: (1) broadening the spectrum of weeds controlled, (2) increased margin of crop safety, (3) less herbicide carry over, (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.

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.

Crop safety in general is also improved with the use of HTC. Both glyphosate and glufosinate provide almost no crop injury, compared to some of traditional herbicides (eg. lactofen, clorimuron), especially in soybean crop.

Both compounds also have almost no soil residual activity, because they are tightly bound to the organic particles in the soil. This provides no restrictions for planting or replanting intervals nor injuries to the subsequent crops.

Introduction of HTC also resulted in a price reduction for conventional herbicides. For example, just few years ago the cost of weed control in soybeans ranged from $100-140 per hectare compared to the current $50-70. The price reduction is the result of the market adjustment and an attempt for companies to remain competitive with their herbicides.

Glyphosate and glufosinate also provide a new mode of action that can aid in resistance management. A single or multiple weed resistance is a serious problem in certain parts of the US and Canada, thus the use of HTC can help with this issue.

The technology associated with HTC is simple to use. It does not require special skills nor training. The technology does not have major restrictions and it is flexible, which is probably one of the reasons for such wide adoption by producers.

Finally the companies that own this technology have benefitted financially though the sales of their herbicides and seeds. Also, the companies save funds by breeding HTC, which is much cheaper than developing new herbicides.

Concerns about the widespread use of htc:

Major concerns with widespread use of HTC includes: (1) A shift in the philosophy of breeding programs (eg. breeding for herbicide resistance versus yields), (2) performance and quality of yields, (3) cost of planting HTC seeds (4) farming contracts, and (5) privacy of farmland.

With the introduction of HTC it seems that there is a shift in basic philosophy of many breeding programs. It looks like that the "driving force" is not the increased crop yield but the addition of specialty traits. In general, the traditional objective of a breeding program was to breed for higher yielding hybrids or varieties. However, most of the current breeding programs are actually "bio-tech driven" programs that produce new HTC, both the GMO and non-GMO types. The point is that the addition of these genes does not enhance yields. This raises simple questions: "Who breeds for higher yielding varieties?" and "Are the current corn/soybean yields at its maximum?" There was an overall yield increase of 1-3% per year from 1960-1990 in dryland corn and soybean. However, there was almost no yield increase in the past decade. It is likely the result of a shift in breeding philosophy, not breeding for higher yields but for specialty traits.

Performance and quality of crop yield is also of concern. In fact this resulted in new terms such as "yield drag" and "yield lag". Yield drag is a yield reduction due to addition of foreign genes. Yield lag is the potential yield depression due to the age of the variety in which the gene is inserted. The University of Nebraska study by Elmore at al. 2001 concluded that soybean varieties with glyphosate-tolerant gene yielded 5 % less that the sister lines without the foreign gene indicating the yield drag. In the same study the glyphosate tolerant varieties yielded 10% less than the high yielding non-HTC indicating the yield lag. Public scientists, in most cases, do not have access to the private breeding programs, which is needed in order to conduct independent studies to determine if there is a yield lag or yield drag. This also raises a major public concern and the issue of trust (eg. can we trust large corporations).

There is also a higher cost for seeds of HTC compared to conventional hybrids, which raises the cost of crop production. Also, in order to plant HTC in US and Canada producers must sign contracts, which interferes with the privacy of the farm and it is against the principles of freedom to farm.

Risks associated with the widespread use of htc

Potential risks (ecological and economic) associated with the widespread use of HTC includes: (1) single selection pressure, (2) shifts in weed species, (3) gene escape, (4) gene flow and contamination of organic crops, (5) HTC as weeds, (6) promotion of chemical weed control mentality,

(7) drift and mis-application, (8) attitudes of world market and food labeling and (9) ethics.

One of the major ecological concerns with wide spread use of the same HTC and repeated use of same herbicide creates a single selection pressure on weed population. This has been reported as the main reason for herbicide resistance. Examples include atrazine and ALS resistance in the US and Canada. The risk is that repeated use of glyphosate can result in weed resistance. There are already several weed species that are resistant to glyphosate. Examples include: rigid ryegrass (*Lolium rigidum*) in Australia (Powels 1994), goosegrass *(Eleusine indica*) in Malaysia, ryegrass in California, and horseweed (*Conyza canadensis*) in Delaware and Tennessee (VanGessel, 2001). Resistance in the above cases resulted from repeated use of glyphosate.

Furthermore, despite the fact that glyphosate and glufosinate control many weed species, they do not control all plant species. It is well known that glyphosate controls many grasses. However, certain broadleaf species in field crops of US and Canada have shown tolerance to the label rates of glyphosate. Therefore repeated use of glyphosate can result in the shift of weed species. 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*).

Another risk with HTC is the potential for escape of resistant gene via pollen from HTC to other plant species, especially to closely related wild relatives. Gene escapes from HTC is not a new phenomenon, it has occurred before. Seefeldt (1998) reported that resistance gene was naturally transferred via pollen from herbicide tolerant IMI-wheat to jointed goatgrass (*Aegilops cylindrica*). Hall (2000) reported pollen flow as the main reason for naturally occurring multiple resistance of canola (*Brassica napus*) to glyphosate, glufosinate and imazethapyr. Recently, the Nature magazine recently reported that the *Bacillus thuringiensis* (Bt) and glyphosate resistant genes are contaminating wild corn in Mexico, which has > 60 of indigenous (wild) corn used as the "gene library". More than 80 scientists from 12 countries urged the Mexican government to stop genetic contamination of natural library of corn genes which reduces natural diversity. The chance 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: (1) sorghum and its weedy relatives shattercane and johnsongrass; (2) canola and mustards; (3) wheat and jointed goat-grass and quackgrass; (4) rice and red rice; (5) sunflower and wild sunflower.

Another concern related to gene flow is the contamination of non-GMO crops, especially
organically grown crops. For example, organic soybean is a common crop in Nebraska and a good source of income to organic producers. However, the wide spread use of glyphosate tolerant soybean created major problems for the production of organic soybeans due to contamination by glyphosate resistant genes via pollination. Another risk is the control of HTC as volunteer crops. For example, glyphosate does not control volunteer glyphosate tolerant corn in glyphosate tolerant soybean, which requires additional herbicides and is an economic burden.

Eventhough the HTCs present a new weed control technology, in reality it is just another way of chemical weed control. Therefore the wide spread use of HTC represents a risk of promoting and continuing the same "chemical mentality" that has been around for the last 40 years, and made weed management rely exclusively on herbicides. Drift and non-target movement of non-selective herbicides such as glyphosate is also a risk, as well as misapplication and misidentification of fields planted with HTC compared to non-HTC.

Another risk to US producers is potential for losing part of the world's food market, due to current anti-biotech sentiment in Europe and Japan. There is already an estimated 30% reduction in US exports of various products related to glyphosate tolerant soybeans, mostly due to worlds market opposition towards biologically engineered crops.

Biotechnology and biologically engineered crops also raised the issues of ethics in science (Zimdahl 1998, Radosevic 1998). In essence, there is a strong opposition around the world about the potential for gene transfer from one species to another. Some are asking if it is unnatural to genetically engineer the plants while others are concerned about using gene transfer for even animal and human research (Comstock 1998). Currently there are no international regulations on those issues.

Producers in the US have also experienced a risk with marketing strategies of some companies. For example, during 1999 and 2000 in order to favor their technology and penetrate the market, certain chemical companies were not selling their better yielding conventional soybean varieties in order to sell their HTC (Knezevic, personal communication). This is not surprising because the seed industry is now controlled by the chemical industry. However, such behavior is a serious breach of trust and ethics.

Conclusion

To maintain a positive attitude, excellent weed control tools are available regardless whether cropping systems are based on HTC or conventional crops. HTC is a valuable technology, but it will not solve weed control problems. The key is the management of this technology. HTC should be used as just another tool for weed control and only when it is needed. Their use should be only within the principles of integrated weed management in order to remain a valuable tool to producers. Despite the concerns and risks with this technology, many producers use HTC as the main weed control tactic. Understanding philosophies and attitudes of producers towards weed control can be challenging at times. Many times weed control decisions are based on the perceptions of weed populations rather than the actual economic losses from weeds. For example, despite the fact that many studies indicated that control of late emerging weeds may not be necessary they are perceived by producers as important because: (1) they are commonly used as indicators of their agronomic skills, (2) controlling all weed escapes is essential in order to renew the land leasing contracts and (3) marketing strategies of the herbicide industry have made season-long weed control as the industry standard. Currently, many herbicide companies market their weed control programs as guaranteed to provide weed-free fields regardless of environmental or agronomic conditions, and many fields are regularly resprayed free of charge. As a result, producers in the United States are less likely to use alternative control measures, which has become major obstacle for reducing herbicide use in agriculture.

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