Herbicide Resistance in the Americas – Status and Best Management Practices

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Introduction

Since the beginnings of crop production thousands of years ago, weeds have adapted to practices adopted by humans to remove these undesirable plants from fields. One of the first examples was the phenological adaptation in China of weedy rice species to appear more like cultivated rice plants in order to avoid being hand weeded (Burgos and Lawton-Rauh 2011). Since that time, farmers have employed a wide range of weed control methods and all have been challenged by natural selection and adaptation of weeds. Today this problem has received greater attention than ever as technologies are rapidly adopted across wide areas of the globe in order to increase food production in concert with a rapidly growing population. Glyphosate-tolerant cropping systems are a primary example of this phenomenon. Since their introduction in the mid 1990's, glyphosate-tolerant crops have reached a level of use that is unprecedented in its rapidity of adoption and scope. The advantages of the glyphosate system are clear. These include reduced soil erosion, improved water quality, reduced fuel consumption, reduced carbon emissions, improved efficiency, and improved grower profitability (Cerdeira, et al 2011, NRC/NAS 2010). However, these clear advantages have led to a widespread adoption and dependence on glyphosate-tolerant crops and in turn resulted in a rapidly growing problem with glyphosate-resistant weeds (Table 1).

Table 1. Glyphosate-resistant weed species by region as reported in the International Survey of Herbicide Resistant Weeds (www.weedscience.org), 2012.

Brazil	***Argentina Chile Paraguay***	***Columbia***	***USA Canada***
Conyza boneriensis	*Cydon hirsutus*	*Conyaza boneriensis*	*Amaranthus palmeri*
Conyza canadensis	*Echinochloa colona*	*Eleusine indica*	*Amaranthus tuberculatus*
Conyza sumatrensis	*Lolium multiflorum*		*Ambrosia artemisiifolia*
Digitaria insularis	*Lolium perenne*		*Ambrosia trifida*
Lolium multiflorum	*Sorghum halepense*		*Conyza boneriensis*
	Digitaria insularis		*Conyza canadensis*
			Kochia scoparia
			Eleusihe indica
			Lolium rigidum
			Poa annua
			Sorghum halepense

Extent of the problem

While there is general agreement that the problem of herbicide resistant weeds is widespread and growing, the true extent of the problem is difficult to assess (Heap, 2012). Growers often attribute the failure of a given herbicide application to resistance even though poor performance can be the result of many other factors. Even at sites where resistance is confirmed by professionals, accurate information on the actual area infested is lacking. The only reliable method of estimation is systematic sampling and greenhouse comparison to known susceptible populations or molecular analysis (when practical). This method is difficult and costly, and rarely done for that reason.

Nonetheless, analysis of the problem, discussion of solutions, and projections for the future require some way to estimate the scope of the problem. Surveys of a large number of US growers have been conducted to estimate the infestations of key herbicide-resistant weed species (Prince et al 2012, proprietary market research). While imperfect, this provides some basis to work from. Estimates from these surveys place glyphosate-resistant weed infestation levels at anywhere from 10 to 40% of U.S. corn (*Zea mays*), soybean (*Glycine max*), and cotton (*Gossypium hirsutum*) hectares. This infestation has been increasing at an estimated rate of 20 to 30 percent per year. The most common glyphosate-resistant species in North America come from the genus *Amaranthus* followed by *Conyza*, and *Ambrosia*. If this rate of increase continues unchecked, in theory 100% of U.S. crop hectares would be infested with glyphosate resistant weeds in less than 7 years.

Further, an increasing number of weed populations are exhibiting resistance to more than one mode of action. The International Survey of Resistant Weeds (www.weedscience.org) indicates that 6 weed species in Brazil and 14 in the United States have developed resistance to multiple herbicides. Many of these multiple-resistant species have resistance to glyphosate. In 2010, the University of Illinois analyzed samples of *Amaranthus tuberculatus* from 24 fields with suspected glyphosate resistance (Tranel, et al. 2012). Approximately 29% of those fields had populations of *Amaranthus* that were resistant to both glyphosate and ALS herbicides. An additional 29% of those fields contained populations resistant to glyphosate, ALS, and PPO herbicides.

Grower Response to Herbicide Resistant Weeds

In many ways, grower response to herbicide resistance problems resembles a typical human response to any unpleasant situation with the first stage usually being "denial". The grower feels that the problem will affect others but not him or that if he experiences the problem that new technologies will be readily available to solve the issue. In this fashion, growers can justify continued use of practices that are unsustainable. In the case of glyphosate, many growers simply increase the application rate when confronted with decreasing effectiveness. In Brazil, the average amount of glyphosate applied per hectare has approximately doubled over the past 5 years (Adegas 2011). A similar trend has occurred in the US and other areas where glyphosate-tolerant crops are utilized. While not all of this increase can be attributed to resistant or tolerant weeds, it is an indication that growers are needing to apply more glyphosate to achieve desired results. In the absence of other changes in weed control practice, increasing rates do nothing to address the long-term problem. As a next step, growers will usually try to employ other herbicides either in sequence, in mixture, or in substitution for their glyphosate program.

One of the last options employed by U.S. growers in response to resistance is tillage. The advent of the glyphosate tolerant cropping system has allowed growers to reduce tillage substantially. This has decreased labor and fuel requirements and reduced soil erosion. Widespread infestations of glyphosate-resistant weeds now pose a threat to conservation tillage (Price, et al 2011). Many producers have expanded the size of their farming operations and many do not have the ability to perform multiple tillage operations for weed control due to limited access to labor and equipment needed to cover large areas in a timely fashion.

Proactive Management of Resistance

Recommendations for proactively managing resistance have long been in place. The recent increase in resistance issues have resulted in renewed efforts to education growers on best management practices.

Recent publications (Norsworthy et al 2012) and educational modules produced by the Weed Science Society of America (www.wssa.net) emphasize the following best management practices:

01- Understand the biology of the weeds present.
02 - Use a diversified approach to weed management focused on reducing the number of weed seed in the soil seedbank.
03 - Plant into weed-free fields and then keep fields as weed free as possible.
04 - Plant weed-free crop seed.
05 - Scout fields routinely.
06 - Use multiple herbicide mechanisms of action that are effective against the most troublesome or herbicide-resistance-prone weeds.
07 - Apply the labeled herbicide dose at recommended weed sizes.
08 - Emphasize cultural practices that suppress weeds by utilizing crop productivity and competitiveness.
09 - Use cover crops or synthetic mulches for physical suppression of weeds where appropriate.
10 - Use mechanical and biological management practices where appropriate.
11 - Prevent weed seed production.
12 - Prevent field-to-field and within-field movement of weed seed or vegetative propagules.
13 - Manage weed seed at harvest and post-harvest to prevent a buildup of the weed seedbank.
14 - Prevent an influx of weeds into the field by managing field borders.

Barriers to Adoption of Best Management Practices

While a large majority of U.S. growers express concerns about glyphosate resistance weeds, many are still reluctant to change their weed management and production practices to address the problem before it occurs. The commonly employed resistance management practices are those that growers find easiest to implement. While 70-80% of growers who plant glyphosate-tolerant crops in the U.S. apply residual burndown herbicides or use preplant tillage, only about 25% use any kind of in-crop tillage between the rows. A very high proportion, approximately 90%, plant seed that is certified to be free of weed seed and use the recommended rate of herbicide. Unfortunately, most do not clean tillage or harvesting equipment when moving from field to field, thus spreading weed problems over their entire operation.

Application of residual herbicides at or shortly before planting provides additional modes of action that complement postemergence glyphosate treatments. While a growing percentage of US growers utilize soil residual herbicides, there is still a significant proportion that do not. According to private market research, in 2010 over 50% of the glyphosate-tolerant crops in the US received a soil residual herbicide around planting, mostly in corn and cotton and less so in soybeans. Fewer growers apply combinations of other herbicides with postemergence glyphosate. Slightly over 50% of the glyphosate-tolerant crop area received just glyphosate postemergence. When combined, the use of alternative MOA herbicides on glyphosate-tolerant crops, either preemergence or postemergence, is approximately 90% for corn, 70% for cotton, and 56% for soybeans.

Projections for the Future

New herbicide modes of action are unlikely to be available in the near future (Gerwick 2010). Therefore, preservation of existing herbicides is critical. Predictions about the future development of herbicide resistance on a macro basis are difficult to make and are somewhat a matter of opinion. However, if one assumes no change in grower behavior or the rate of increase in glyphosate resistance, it is possible that a large portion of the crop area in the Americas will be infested with glyphosate-resistant weeds before the end of the present decade. Alternatively, if new technologies become available soon and growers adopt best management practices, it may be possible to preserve some of the value of the glyphosate-tolerant cropping system and the utility of herbicides in general.

In any case, the successful management of herbicide resistance will require a cooperative approach between scientists, industry, and growers. Recommendations to address the problem must be based on sound science, supported by company policies, and be practical for growers to implement.

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