ISB NEWS REPORT
AGRICULTURAL AND ENVIRONMENTAL BIOTECHNOLOGY

August 2010

RISK MANAGEMENT

Sustainability of Glyphosate-based Weed Management: The Benchmark Study

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Introduction

One key to improved global crop production efficiency is the effective management of weeds, which are ranked as the number one crop pest by a majority of farmers[1]. This is no great surprise, as weeds are constantly evolving within the man-caused agroecosystems by adapting to high selection pressures imposed by crop production practices and, importantly, developing resistance to herbicides. Genetically engineered (GE) herbicide resistant (HR) crops facilitate better weed management and thus improved yields and more efficient use of resources, while minimizing risks to the environment (e.g., soil erosion). Since the commercial introduction of glyphosate resistant (GR) crops in 1996, this technology has likely been the most rapidly-accepted agronomic production practice in the history of agriculture. Farmers in the United States plant an estimated 50% of the GE GR crops grown globally, and in 2009 the National Agricultural Statistics Service (NASS) reported that 85% of corn, 88% of upland cotton, and 91% of soybean hectares were planted to GE GR varieties. The rapid adoption of GE GR crops occurred because glyphosate controls most economically important weeds and simplifies weed management. The consistent and high level of weed control provided by glyphosate facilitated the widespread adoption of no-tillage systems that conserve soil and energy resources as well as improve time management efficiencies for farmers. However, the wide-spread adoption of GE GR crops, resulting in the grower decision to simplify weed management to the applications of glyphosate, imposed considerable selection pressure on weed communities. This pressure predictably resulted in weed population shifts, including the inevitable evolution of weeds with resistance to glyphosate[2].

Benefits and risks associated with GE GR crops

The benefits and risks of the widespread adoption of GE GR crops on agroecosystems and for society has been a contentious topic of debate in scientific journals and the popular media. The complexity of assessing benefits and risks of GE GR crops is great, and often there is considerable variability, depending on the specific GE under assessment. Also adding to the complexity of assessing benefits and risks are the production practices utilized to cultivate the GE GR crop and the specific agroecosystem in which the crops are grown. Adopters of GE GR crops suggest that a major benefit has been the greatly reduced effort needed to implement a weed management system that significantly increases crop production. Simplicity of weed management strategies, improved time management, better success in conservation tillage systems, and crop safety are also

VirginiaTech
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PUBLISHED BY

Information Systems for Biotechnology

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1900 Kraft Drive, Suite 103
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noted as significant benefits of GE GR crops. Societal benefits reflect improved water quality and reduced soil erosion as a result of increased adoption of conservation tillage and the increased use of an herbicide (glyphosate) that is classified by the Environmental Protection Agency as being one of the safest herbicides available.

Risks attributed to the adoption of GE GR crops include the alleged displacement of small-farmers, food safety apprehensiveness, GE pollen movement to wild species, volunteer GE GR crops, and other issues. Several of these risks (i.e., GE pollen movement to wild species) are not a problem with the current suite of GE GR crops. Similarly, other issues are less clear. Often the published literature on the ecological, toxicological, and environmental risks of GE GR crop systems is contradictory. It is critically important to assess risks attributable to GE GR crops on solid, objective science.

However, one risk that is significant is the evolved resistance to glyphosate in weeds. Currently 19 weed species have evolved glyphosate-resistant populations globally and ten glyphosate-resistant weed species have been identified in the US, most of which evolved resistance to glyphosate in GE GR crop systems (**Fig. 1**)[3]. It is important to recognize that the impact of GE GR technology on weed communities and evolved resistance to glyphosate is not directly attributable to the use of a GE GR crop, but rather an indirect effect of the management of the GE GR crop system. A recently announced report by the National Research Council (*The Impact of Genetically Engineered Crops on Farm Sustainability in the United States*) (www.nationalacademies.org) addressed the complexity of the benefits and risks surrounding the adoption of GE GR crops. This report, based on an extensive review of the body of science available, concluded that evolved weed resistance to glyphosate, while not unique to GE GR crop systems, represents a significant problem for the sustainability of the technology and suggested that weed management programs must be diversified in order to

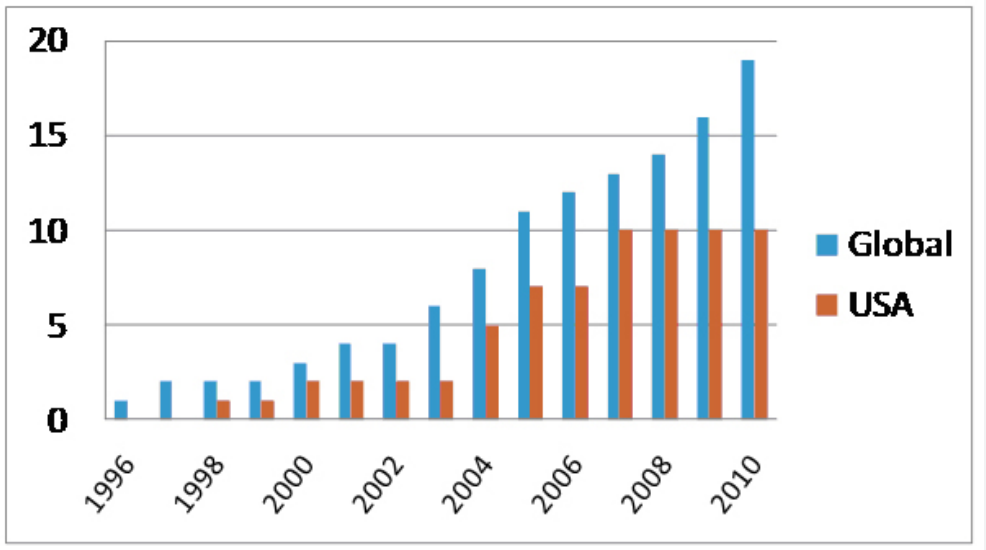

Figure 1. Number of weed species that have evolved resistance to glyphosate. Adapted from www.weedscience.org.

maintain the benefits of the GE GR crop systems.

A multi-state, multi-year, field-scale study: THE BENCHMARK STUDY

A multi-state field-scale project is underway in the six states where the Benchmark Study Survey was conducted (**Fig. 2**)[4]. The Benchmark Study Survey represented an extensive telephone survey of more than 1000 growers from Illinois, Indiana, Iowa, Mississippi, Nebraska, and North Carolina to assess grower perceptions of GE GR technologies in corn, cotton, and soybean. While other studies, either with regard to scale or time, have been reported, the Benchmark Study is unique with regard to temporal, scale, geography, and crop systems.

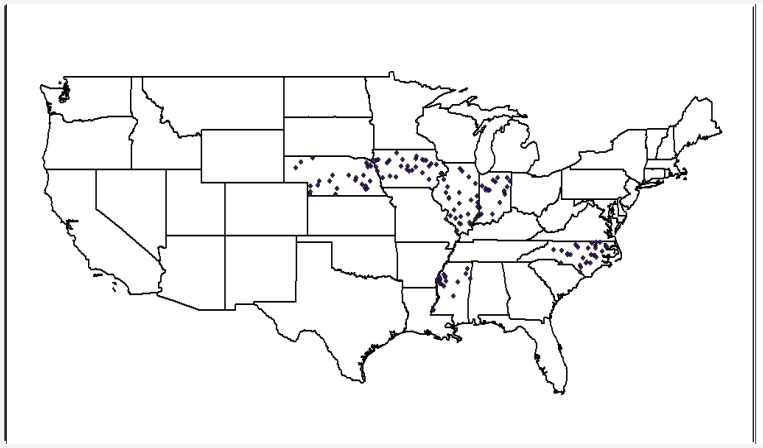

Figure 2. Location of farms included in the Benchmark Study.

The agricultural, temporal, and geographical factors encompassed by the Benchmark Study will result in robust assessments of the sustainability of GE GR-based crop systems with a focus on weed management. The objective of the Benchmark Study is to compare growers' weed management practices with stratagies recommended by university weed scientists and determine the relative sustainability GE GR crop systems with regard to economics and weed community shifts, including the evolution of GR weed populations.

Approximately 150 growers in Illinois, Indiana, Iowa, Mississippi, Nebraska, and North Carolina were selected from respondents to a survey to participate in the Benchmark Study (**Fig. 2**)[4]. Growers provided a representative field of at least 10 ha, which was divided into near-equal halves. On one-half of the field, the grower continued using the current weed management program, typically multiple applications of glyphosate. On the other half, the grower used university-recommended herbicide resistance best management practices (HRBMP). HRBMP typically includes soil-applied herbicides that provide residual activity on important weeds in the field, and specifically those weeds that have demonstrated the ability to evolve resistance to glyphosate. Data and soil samples are being collected and include assessments of weed populations, weed species diversity, weed seedbank, crop yields, and economic returns.

Conclusions to date

When the Benchmark Study is completed, the resultant agronomic, economic, and ecological data will provide an excellent base upon which GE GR crop sustainability can be assessed. Preliminary results are favorable with regard to managing the potential evolution of GR weeds with diversifying tactics, while maintaining profitability of the GE GR system. The first publications describing the results from the Benchmark Study have been submitted for publication and will likely become available late in 2010. Importantly, the initial barriers that were encountered in the Benchmark Study—an inconsistent level of grower awareness of the potential risks to the sustainability of the GE GR crop systems attributable to evolved glyphosate resistance in weed populations, and a concern that the alternative weed management tactics (HRBMP) represented needless additional costs to weed management—have been addressed successfully.

However, changes have occurred since the initiation of the Benchmark Study, including an escalation the number of weeds with evolved resistance to glyphosate and the frequency of GR weed populations (**Fig. 1**)[3]. These changes reinforce the critical importance, addressed by the Benchmark Study, of performing comparisons of weed management tactics in GE GR crops. It is clear that grower awareness of GR weeds has increased dramatically since the initiation of the Benchmark Study[5]. Noteworthy is the observation from preliminary results that university-recommended HRBMP, while initially thought to be more costly by

the growers participating in the Benchmark Study, has proven to provide more economic return on investment or is no more costly than grower weed management practices. Importantly, it is apparent from early Benchmark Study data that the adoption of HRBMP will delay and help manage evolved GR weed populations when compared with grower practices that emphasize simple and convenient tactics. Where growers persist in using simple tactics (i.e., glyphosate alone), it is inevitable that weed populations will ultimately evolve resistance to the tactic, often with consequences that are economically and environmentally difficult to overcome[6].

When concluded, the Benchmark Study will provide invaluable data to describe sustainable and profitable weed management programs for GE GR crop systems designed to lower the potential risk of evolving weed resistance to glyphosate. This unique comprehensive study conducted in six states over five years in multiple cropping systems will provide a robust assessment of how growers utilized the GE GR technologies and will detail the implications that these decisions have on weed populations and the economics of crop production. Importantly, the results will detail how to sustainably and economically manage weeds at a scale that is applicable at the grower-level.

While most fields where GE GR crops are grown do not yet have GR weed populations, there is irrefutable evidence that the number of GR weed populations is increasing at an increasing rate[3]. Regardless, growers are still reticent to proactively adopt HRBMP. A greater educational emphasis on HRBMP in GE GR crops will help farmers effectively manage the evolution of GR weeds and optimize profitability of GE GR crops. The Benchmark Study will provide the basis for this educational process, thus preserving the sustainability of the globally-important GE GR crops. Regardless, the Benchmark Study must be supplemented with additional research into the specific resistance mechanisms to insure the continued development of scientifically-based management practices to support grower educational programs.

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