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Benchmark Study: II. A 2010 Survey to Assess Grower Awareness of and Attitudes toward Glyphosate Resistance

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A 2010 survey of 1,299 corn, cotton, and soybean growers was conducted to determine their attitudes and awareness regarding glyphosate-resistant (GR) weeds and resultant implications on weed management practices. An additional 350 growers included in the current study participated in a 2005 survey, and these answers were compared across time so that cross-sectional and longitudinal comparisons of responses could be made. Most growers surveyed in 2010 were aware of the potential for weeds to evolve resistance to glyphosate; however, many growers were not aware of glyphosate resistance in specific weeds in their county or state. Growers in the South were different from growers in other geographic regions and were significantly more aware of local cases of GR weeds. Awareness of GR weeds did not increase appreciably from 2005 to 2010, but the percentage who reported GR weeds as problematic was significantly higher. Grower reports of GR weeds on-farm in 2010 were up considerably from 2005, with growers in the South reporting significantly more instances than growers in other regions. Growers in the South were also more likely to consider glyphosate resistance a serious problem. Overall, 30% of growers did not consider GR weeds to be a problem. It appears that most growers received information about glyphosate resistance from farm publications, although in the South this percentage was less than for other geographic regions. Growers in the South received more information from universities and extension sources.

Nomenclature: Glyphosate, corn, *Zea mays* L.; cotton, *Gossypium hirsutum* L.; soybean, *Glycine max* (L.) Merr.

Key words: Evolved resistance, glyphosate-resistant crops, resistance management, grower survey, grower attitudes.

En 2010 se realizó una encuesta a 1299 productores de maíz, algodón y soya para determinar sus actitudes y conocimientos en relación a las malezas resistentes a glyphosate (GR), y las consecuentes implicaciones en las prácticas de manejo de malezas. Un grupo adicional de 350 productores incluidos en el estudio actual participaron en una encuesta en 2005, y sus respuestas fueron comparadas a través del tiempo de tal manera que se pudieran hacer comparaciones transversales y longitudinales de las mismas. La mayoría de los productores encuestados en 2010 estaban conscientes del potencial de las malezas para desarrollar resistencia a glyphosate; sin embargo, muchos de ellos no sabían de malezas específicas resistentes a glyphosate en su condado o estado. Las respuestas de los productores del sur fueron diferentes a las de los productores de otras regiones geográficas ya que los primeros estaban significativamente más al tanto de casos locales de malezas GR. El conocimiento sobre malezas GR no se incrementó apreciablemente de 2005 a 2010, pero el porcentaje de quienes reportaron malezas GR como problemáticas fue significativamente mayor. En 2010 los reportes de productores con problemas de malezas GR en su finca fueron considerablemente más frecuentes que en 2005, con productores en el sur reportando significativamente mayor incidencia que los de otras regiones. Además, los productores en el sur consideraron con mayor frecuencia la resistencia a glyphosate como un problema serio. En general, 30% de los productores no consideraron que las malezas GR sean un problema. Parece que la mayoría de los productores recibió información sobre la resistencia a glyphosate en publicaciones agrícolas, aunque en el sur este porcentaje fue menor que en las otras regiones geográficas. Los productores del sur recibieron más información de universidades y de fuentes de extensión agrícola.

Initially, glyphosate-resistant (GR) crops were attractive for the cost savings, improved weed management, and simplicity of weed control (Duke and Powles 2009), leading to widespread adoption of glyphosate-based management programs. Producers continued to favor genetically modified cultivars of corn, cotton, and soybean, as has been the situation since these technologies became commercially available in the late 1990s,

with 64 million hectares planted with genetically modified crops in 2009 (James 2009).

This shift dramatically changed the manner by which glyphosate was utilized. Continued reliance on one cropping system over a long period created an opportunity for weed shifts within the weed community due to selection pressures, resulting in weeds that were best adapted to the system. The reliance and overuse of glyphosate in these cropping systems has contributed heavily to the development of GR weeds; to date glyphosate resistance has evolved in 21 weed species worldwide, and 13 weed species in the United States (Heap 2011). Glyphosate resistance is a major consideration for cropping systems based on GR crops. The use of glyphosate in a more sustainable manner must be addressed proactively and collaboratively by researchers, practitioners, and growers.

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Previous surveys have targeted producers to gauge their awareness and attitudes with regard to glyphosate resistance in weeds. Foresman and Glasgow (2008) conducted a survey to determine how growers use GR cropping systems and their awareness, perceptions, attitudes, and experiences with GR weeds. Less than 40% of growers surveyed believed that they had GR weeds on their farm, and only 40% believed glyphosate resistance was getting worse. Only 9% of respondents in their southern subset ($n = 200$) said they would limit GR technology. Only one in five of the northern subset reported a willingness to rotate to a non-GR crop.

Scott and VanGessel (2007) surveyed Delaware soybean growers to gauge their level of concern with GR horseweed (*Conyza canadensis* L.), and how these concerns would affect GR soybean and glyphosate usage. Not surprisingly, growers without GR horseweed on their farms were less aware of the evolution of GR horseweed, and tended to overestimate, by 2 yr or more, the amount of time required for glyphosate resistance to evolve in a continuous GR soybean cropping system. However, there was little difference in responses between those with and without GR horseweed on their farms when they were asked about the likelihood of a second GR weed species evolving.

An economics-based study by Hurley et al. (2009) surveyed growers to determine the benefits of a GR weed management program, focusing on how those benefits were affected by grower practices and attitudes. In this survey of 1,200 growers, growers who were concerned about glyphosate resistance consistently reported lower benefits for GR crops. Cotton growers, in particular, reported a decrease in benefit of almost \$25/ha when they were concerned about glyphosate resistance. However, when compared with the almost \$124/ha increase in benefit cotton growers attributed to GR cotton over conventional cotton, the overall finding was that although many growers are concerned about glyphosate resistance, this concern reduces but does not eliminate the value of GR crops for the grower. Scott and VanGessel (2007) also found that although growers with GR horseweed on their farms incurred higher costs for glyphosate resistance management, there was no impact on the preference for GR soybean.

A survey as a part of the Benchmark Study was conducted in 2005, and included nearly 1,200 growers from six states to assess their perceptions on the benefits and challenges of using GR crops (Shaw et al. 2009). As the survey instrument was developed by weed scientists, a majority of the questions were targeted at determining grower practices that affected the weed spectrum and selection pressures on their farms, but questions were also included to gauge grower awareness about the evolution of glyphosate resistance, how it had affected weed management, and the origin of information describing glyphosate resistance. The survey examined in this paper is a follow-up to the initial 2005 Benchmark Study survey.

Johnson et al. (2009) assessed grower concerns about GR weeds and perceptions of the tactics used to manage or delay the evolution of this problem. Awareness of glyphosate resistance was dependent on farm size, with 75% of the larger-scale producers reporting awareness. Thirty percent or fewer of those surveyed felt GR weeds were a serious agronomic problem. In a previous study of corn and soybean growers in

Indiana, 36% of growers expressed concern about GR weeds (Johnson and Gibson 2006). One of the major factors that influenced where growers got their information was the perception of the relative seriousness of GR weeds. The majority of growers reported that farm press publications were the primary source of information on GR weeds. Growers who deemed GR weeds to be moderate to highly serious tended to get their information from universities' researchers and cooperative extension services. Few farmers felt that tillage or rotating to a non-GR crop would be effective strategies to address glyphosate resistance.

Papers developed from the 2005 Benchmark Study survey, presented as a series in *Weed Technology*, included a discussion of changes in herbicide use patterns in GR cropping systems (Givens et al. 2009a); a review of tillage trends after adoption of GR crops (Givens et al. 2009b); an analysis of grower views of problematic weeds and changes in weed pressure for GR cropping systems (Kruger et al. 2009); and a complete overview of the first survey (Shaw et al. 2009). Additional reports were presented as a series in *Pest Management Science* (Givens et al. 2011; Owen et al. 2011), which covered a much larger scope of field research relating to GR weeds beyond the survey. However, a paper in the *Pest Management Science* series from Givens et al. (2011) included a more in-depth analysis of results from the 2005 Benchmark Study survey regarding many of the issues covered in this paper. Givens et al. (2011) frequently serves as a comparison for results from the 2010 Benchmark Study survey reported herein, as the survey described in this paper is a follow-up to the initial 2005 Benchmark Study survey.

The first objective of this paper was to examine current levels of grower awareness regarding GR weeds. The second objective was to determine the extent to which growers believe they are experiencing GR weeds on their farms. The third objective was to quantify the perceived seriousness of GR weeds. And finally, the fourth objective was to determine where growers obtain information about GR weeds. For each objective, results from the current 2010 survey were compared against the results from the 2005 Benchmark Study survey.

Methods and Materials

A survey was developed by a team of weed scientists representing a diverse geography of universities from Illinois, Indiana, Iowa, Mississippi, Nebraska, and North Carolina. The survey was used for a 2005 telephone poll of growers in these states. These states were selected to ensure a mix of cropping practices and environments and represent major areas of GR cropping acreage. Complete details of this initial survey are reported in Shaw et al. (2009). Additionally, topical papers developed from the survey included herbicide use patterns (Givens et al. 2009a), tillage trends (Givens et al. 2009b), problematic weeds (Kruger et al. 2009), and grower attitudes (Johnson et al. 2009). Two papers in a related series in *Pest Management Science* (Givens et al. 2011, Owen et al. 2011) also discuss issues of grower awareness to evolved resistance.

The new, follow-on survey was readministered by Market Probe (formerly Marketing Horizons) from December 10,

2009 to January 21, 2010 with only slight differences (Prince et al. 2012). A random selection of 1,299 growers was made from a list of all growers who signed an agreement with Monsanto Agricultural Products Company to use GR (Roundup Ready™) crops. An additional 350 growers who participated in the 2005 Benchmark Study survey were invited to participate in the 2010 survey also, resulting in a total of almost 1,650 growers for the 2010 survey. Selection criteria for growers required them to: (1) be actively involved in farming, (2) be responsible for the decisions concerning the seeds, traits, and herbicides purchased for their operation, (3) plant a minimum of 101 ha of corn, cotton, or soybean in 2009, and (4) have planted GR crops for a minimum of 3 yr. The minimum farm size ensured that survey respondents were full-time growers who derived a significant portion of their livelihood from farming. Producers were disqualified if anyone in their household worked for a farm chemical manufacturer, distributor, or retailer, or if they worked for a seed company other than as a farmer/dealer.

The 2010 survey was broadened to represent a national cross-section of growers, and to better delineate differences that might exist in grower attitudes and perceptions on the basis of crop region. Growers in the 2010 study represented 22 corn/soybean states and the cotton region. For some analyses, states were grouped into three geographical regions: South, East, and West (Figure 1). The first section of the survey was designed to elicit information about crops currently grown and crop history, including experience with GR crops and was used to divide growers into groups on the basis of cropping systems for subsequent survey sections. The second section of the survey targeted answers about weed population density and tillage practices on a case study field, and contained questions about perceptions of weed pressure and weed shifts after adoption of GR cropping systems. This section also asked growers to identify specific weeds with which they had experienced management problems. The third section addressed herbicide use and growers answered questions about current and previous herbicide use practices, including application timing and herbicide rates. Growers were asked to highlight any changes in herbicide use they had made in the previous 3 yr. The final section focused on grower attitudes and awareness related to GR weeds and management practices specific to GR weeds, including their experiences (if any) with GR weeds and what practices they personally were using to manage or prevent GR weeds in their specific cropping systems.

On the basis of answers from Section one of the survey, growers were assigned to one or two designated cropping systems. These cropping systems included: continuous GR soybean, continuous GR cotton, continuous GR corn, GR corn/GR soybean rotation, GR cotton/GR soybean, GR cotton/GR corn, GR soybean/non-GR crop rotation, GR corn/non-GR crop rotation, and GR cotton/non-GR crop.

Respondents were asked a series of yes/no questions, and several scaled questions in which they were asked to evaluate an issue on a scale of 1 to 10, with 1 being the worst possible rating. Growers were also asked several open-ended questions and questions for which they were provided a list of answers from which to choose.

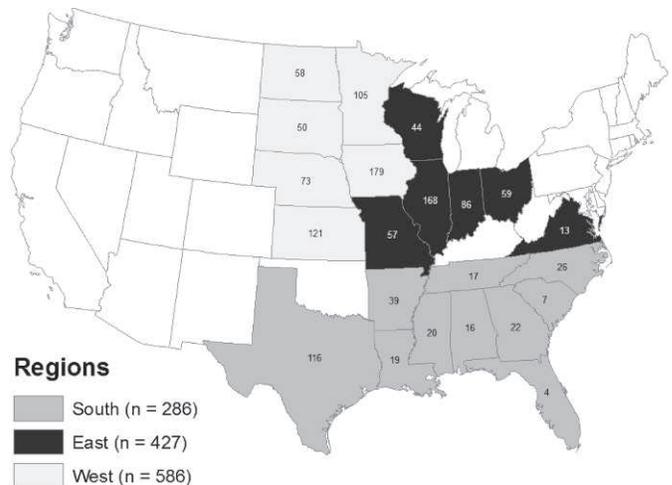


Figure 1. Geographic distribution of regions defined by survey with totals for survey respondents in each state and region.

Data for the overall survey were analyzed using McNemar's test (Conover 1999) for the yes/no questions, and *t* tests and frequency counts for questions with scaled answers. For the growers who were surveyed in the original 2005 Benchmark Study survey as well as the current survey, paired *t* tests were used to compare questions with scaled answers to track changes in the answers of individual growers over the 5-yr period. To compare differences between regions, Kruskal-Wallis testing (Conover 1999) was done. All analyses were performed at the 0.05 significance level.

Results and Discussion

Growers were asked if they were aware of the potential for weeds to develop resistance to glyphosate herbicides. Ninety-seven percent of growers answered "yes," which was significantly higher than the percentage answering "yes" (88%) in the 2005 Benchmark Study survey ($P < 0.05$; Givens et al. 2011). If growers answered "yes," they were asked if they were aware of specific weeds in their state and county that have been documented as resistant to glyphosate. Only 64% (vs. 44% in 2005, Givens et al. 2011; $P < 0.05$) were aware of specific GR weed species in their state and even less (38% in 2010; question was not asked in 2005) were aware of GR weed species in their county. Differences between regions were not significant for awareness of GR weed evolution ($P = 0.35$, Table 1), but differences were present between regions with regard to awareness of specific GR weeds in the county and state ($\chi^2 = 19.9, 43.3$, respectively; $P < 0.05$ for both). Growers in the West region reported awareness to GR weeds in their state less frequently (57%) than growers in the East and South (69% for both). Growers in the South, however, were more likely (54%) to report awareness to GR weeds in their county than growers in the East (38%) and West (30%) (Table 1). Givens et al. (2011) found no differences between states with respect to a grower's awareness for the potential of a weed to evolve glyphosate resistance, and no differences between states with

Table 1. Growers in the 2010 Benchmark Survey grouped by region reporting an awareness of the potential for weeds to evolve glyphosate resistance regionally, in their state and county.

Region	Awareness of potential to evolve resistance	Aware of specific weeds at state and county levels	
		State	County
		% of growers	
East (<i>n</i> = 423)	98	69	38
South (<i>n</i> = 295)	96	69	54
West (<i>n</i> = 547)	97	57	38

respect to grower awareness of documented cases of resistance in their state in the 2005 Benchmark Study survey. When these questions were examined on the basis of cropping systems (Table 2), the only finding of interest was that growers in a continuous GR corn system answered yes and no in almost equal proportions about awareness to state instances of GR weeds. This was not observed in any of the other eight cropping systems. Some of the cropping systems had a limited number of growers, so this information should be interpreted with caution.

Growers were asked if they had personally experienced any weeds on their farms that were resistant to glyphosate. This information is self-reported by growers and is not validated by scientific assessment; thus the information should be considered personal opinion and interpreted with caution. Twice the percentage reported in the 2005 Benchmark Study survey (15%, Givens et al. 2011), roughly one-third (32%) of growers from the 2010 survey reported experiencing GR weeds on their farms, with a disparately large percentage coming from the South region (53%) ($\chi^2 = 80.6$, $P < 0.05$). Foresman and Glasgow (2008) observed that both awareness and on-farm presence of GR weeds were higher with their Southern subset of growers. They attributed the difference in regions to the prevalence of GR horseweed in cotton. It should be noted that this survey was administered before the rapid increase in GR Palmer amaranth (*Amaranthus palmeri* S. Wats) (Culpepper et al. 2006). Givens et al. (2011) acknowledged also that at the time their survey was conducted (2005 to 2006), instances of publicized glyphosate resistance were rare, and this may have affected their results. An

Table 2. Growers in the 2010 Benchmark Survey grouped by cropping system reporting an awareness of the potential for weeds to evolve glyphosate resistance regionally, in their state and county.

Cropping system	Awareness of potential to evolve resistance	Aware of specific weeds at state and county levels	
		State	County
		% of growers in systems	
Continuous glyphosate-resistant (GR) soybean (<i>n</i> = 145)	95	72	52
Continuous GR corn (<i>n</i> = 215)	97	51	26
Continuous GR cotton (<i>n</i> = 94)	97	62	48
GR corn/GR soybeans (<i>n</i> = 607)	98	62	32
GR cotton/GR soybeans (<i>n</i> = 33)	100	91	85
GR cotton/GR corn (<i>n</i> = 20)	91	70	50
GR soybeans/non-GR crop (<i>n</i> = 370)	97	71	42
GR corn/non-GR crop (<i>n</i> = 164)	97	59	38
GR cotton/non-GR crop (<i>n</i> = 68)	97	71	59

Table 3. Growers who reported glyphosate-resistant (GR) weeds on their farms in the 2010 Benchmark Survey grouped by cropping system.

Cropping system	On-farm glyphosate resistance
	% of growers in system
Continuous GR soybean (<i>n</i> = 145)	54
Continuous GR corn (<i>n</i> = 215)	20
Continuous GR cotton (<i>n</i> = 94)	52
GR corn/GR soybeans (<i>n</i> = 607)	23
GR cotton/GR soybeans (<i>n</i> = 33)	76
GR cotton/GR corn (<i>n</i> = 20)	60
GR soybeans/non-GR crop (<i>n</i> = 370)	34
GR corn/non-GR crop (<i>n</i> = 164)	29
GR cotton/non-GR crop (<i>n</i> = 68)	51

assessment by cropping system showed that higher percentages of growers in rotations with GR cotton reported GR weeds on their farm; however, it should be noted that cropping systems including cotton had a relatively low number of growers (Table 3). Other cropping systems had mixed results. Continuous GR soybean and continuous GR cotton had relatively even percentages of growers with respect to those reporting GR weeds on their farms and those who did not. GR corn rotated with GR soybean and continuous GR corn yielded low percentages of growers reporting GR weeds on their farms. Low instance of growers reporting GR weeds on their farms did not just result from having GR corn, however, since GR soybean rotated with a non-GR crop also showed considerably lower percentages for growers reporting GR weeds on their farms.

Growers were asked to rate the seriousness of weed resistance to glyphosate on a scale of 1 to 10, with 10 being very serious. Half of all growers surveyed considered glyphosate weed resistance to be a serious problem (rating of 7 or higher); however, 30% did not (rating of 4 or lower; Table 4). Compared with ratings from East and West regions (Table 4), higher percentages of growers in the South reported this as a very serious problem (ratings of 9 or 10; $\chi^2 = 77.66$, $P < 0.05$). For the repeat respondents, although overall awareness of glyphosate resistance increased only marginally from 93 to 98%, the percentage reporting GR weeds as a serious problem increased substantially from 38% in 2005 to 56% in the 2010 survey. Similar to the overall results for the 2010 survey, however, 27% still reported that the problem was not serious.

Growers were also asked where they were obtaining information related to GR weed issues. Overall, the most frequent response was farm publications, with 41% of respondents indicating that this was their main source for information about GR weeds (Table 5). These results agreed with the overall results of the 2005 Benchmark Study survey

Table 4. Ordinal rankings for grower ratings of the seriousness of glyphosate-resistant weeds from the 2010 Benchmark Survey.

Region	Not serious (1–4)	Neutral (5–6)	Serious (7–8)	Very serious (9–10)
East	30	24	27	19
South	19	13	23	45
West	37	20	26	17
Overall	30	20	26	24

Table 5. Sources from which growers cited receiving their information regarding glyphosate resistance in the 2010 and 2005 Benchmark Surveys.

Region	Dealers/retailers	Farm publications	Monsanto	Other farmers	Syngenta/touchdown	University/extension
% of responses						
East	24	45	3	9	2	18
South	17	34	7	13	3	27
West	25	42	3	9	2	18
Overall 2010 ^a	22	41	4	10	2	20
Overall 2005 ^b	17	41	*	6	*	14

^a Rounding may result in some totals being ± 1 from 100%.

^b Data from Givens et al. (2011).

*Data are reported for “chemical companies” and not individual companies in 2005. Together chemical companies as a category were 2%.

(Givens et al. 2011; Johnson et al. 2009), where farm press publications were also the most popular source for information. Dealers/retailers and university/extension sources of information were the next most frequent responses (22% and 20%, respectively). These results may be potentially misleading as there is no way to identify articles written by or using university research and extension personnel as sources for farm press publications.

Although awareness about GR weeds is increasing nationwide, the problem may not generally be viewed as a “local” problem by growers. With the exception of growers in the South, many growers were not aware of GR weeds in their immediate vicinity. This is somewhat surprising given the rise in reports from growers of GR weeds on their farms. However, once again, growers in the South region more frequently reported having GR weeds on their farms, which could explain why the region consistently reported more growers who were aware of the potential for resistance and had an awareness of GR weeds at the state and county levels. Not surprisingly, growers in the South were much more likely to respond that GR weeds are a serious problem. This in all likelihood is due to a higher percentage of acres infested, coupled with the severe ramifications of Palmer amaranth on production systems in the South. This response could also be a product of where growers are getting their information since growers in the South favored university researchers and extension more than other regions. With awareness of GR weeds increasing and the incidence of GR weeds on farms rising, it is more important than ever for all information sources to coordinate educational efforts to provide growers with the most objective and accurate information about glyphosate resistance so they can make the best management decisions for their specific situation. With occurrence of GR weeds on farms increasing, it is necessary to address the widening information gap between information providers such as researchers, extension personnel, and retailers with growers.

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