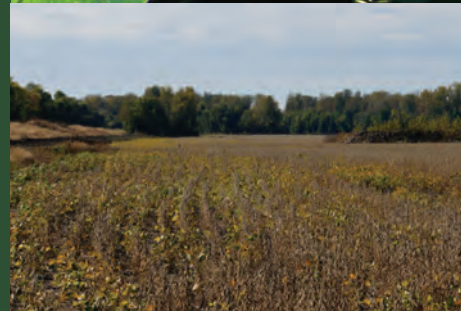




## *Midwestern Soybean Farmers' Perceptions and Management of Glyphosate Resistant Weeds*



**IOWA STATE UNIVERSITY**  
Extension and Outreach



United States  
Department of  
Agriculture      National Institute  
of Food and  
Agriculture

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# Midwestern Soybean Farmers' Perceptions and Management of Glyphosate Resistant Weeds

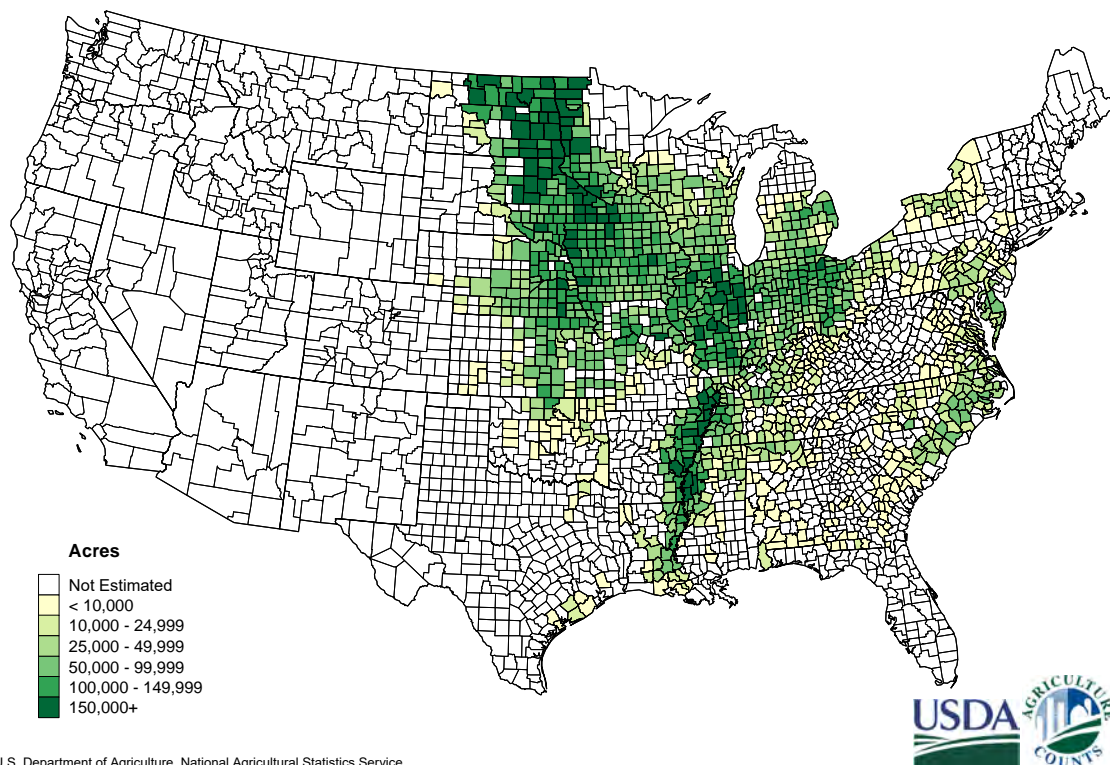
## Introduction

Glyphosate resistant weeds have emerged as a serious threat to U.S. agricultural production. In 1996, Monsanto's Roundup Ready genetically engineered herbicide-resistant seed varieties first became commercially available. As a result, post-application of the herbicide glyphosate increased dramatically. Over-application and misuse of glyphosate also followed, which fostered the evolution of new glyphosate resistant weeds [1]. By 2016, 16 glyphosate resistant species had been identified in the U.S. alone, with another 37 species identified worldwide [1]. The impact of weed resistance continues to grow, disproportionately affecting soybeans as compared to other glyphosate resistant crop varieties. By 2014, more than 96 percent of U.S. soybeans were herbicide resistant varieties [2], indicating that resistant weeds are likely to impact U.S. soybean farmers into the future.

A weed's likelihood for evolving glyphosate resistance is predominantly linked to three aspects: weed biology, intensity of glyphosate use, and glyphosate rate [3]. Current best practices to avoid

and delay the evolution of new glyphosate resistant varieties of weeds promotes an integrated weed management approach consisting of both chemical and non-chemical actions [4]. As weed resistance has increased, the use of glyphosate as the sole herbicide has decreased but remains significant [2]. The USDA estimates that resistant weeds will infest almost all U.S. row-crop fields by 2020 [5], and thus it is crucial for effective management strategies to be developed and employed by farmers.

This report summarizes the results of a survey of Midwestern soybean farmers' beliefs, attitudes, and practices surrounding the issue of glyphosate resistant weeds. It assesses how glyphosate resistance is impacting farmers; perceptions of the severity of the problem; whom or what farmers feel is responsible for the issue; how it currently is managed; and how this issue should be managed in the future. The findings provide valuable information which can be used to support public and private endeavors to address the glyphosate resistance issue and ensure the future success of the U.S. soybean industry.



U.S. Department of Agriculture, National Agricultural Statistics Service

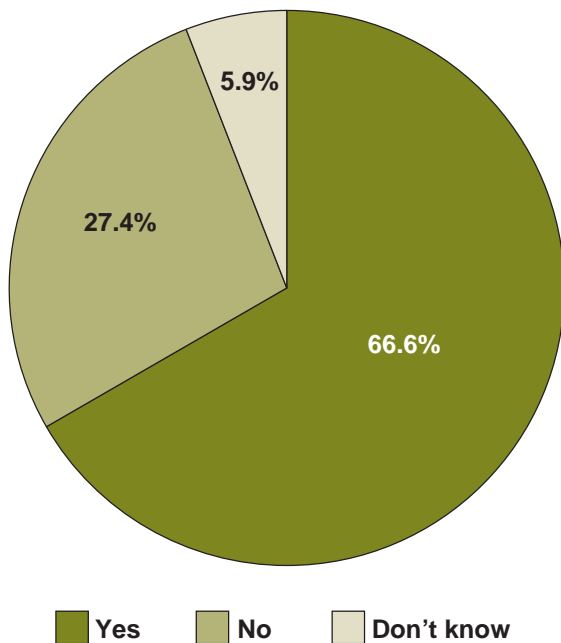
Figure 1. Soybeans 2016: Planted Acres by County for Selected States [14]

## Methodology

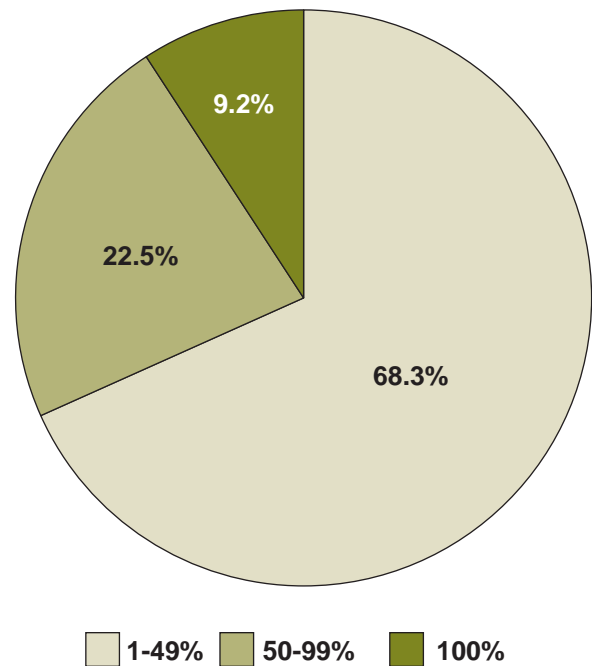
In March 2016, a mail and internet survey was administered to 2,400 soybean growers in Iowa, Indiana, and Illinois. These states were selected because in 2015 they were among the top five soybean producing states in the U.S. [6] (figure 1). The survey examined soybean farmers' beliefs, attitudes, and practices concerning glyphosate weed resistance and its impact on their soybean operations. Usable surveys were received from 725 farmers, a 31 percent response rate, and approximately one-third of the surveyed farmers were from each of the three respective states.

## Farmers' Experiences with Weed Resistance

The survey asked a series of questions about soybean farmers' experiences with glyphosate resistant weeds. Exactly two-thirds (67 percent) reported that their fields had been infested with weeds resistant to the herbicide glyphosate. Over a fourth (27 percent) had not experienced an infestation, and 6 percent were unsure one way or another (figure 2). Farmers who had experienced resistant weeds then indicated the amount of land that had been affected: 68 percent of farmers saw resistance in 1-49 percent of acres, 22.5 percent in 50-99 percent of acres, and 9 percent in 100 percent of their crops (figure 3). Those who had not



**Figure 2. Fields infested with weeds resistant to the herbicide glyphosate**



**Figure 3. Percent of acres with glyphosate resistant weeds**

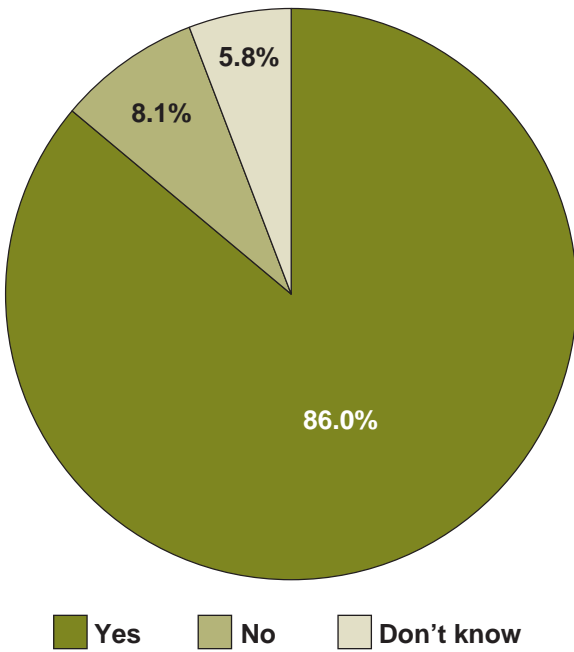
experienced an infestation of glyphosate resistant weeds were asked whether they believed that resistance could occur on their farm. Eighty-five percent indicated that they believed it could occur on their farm while only 5 percent believed that it could not occur on their farm. The remaining 10 percent were unsure.

## Impact of Weed Resistance

Farmers who had experienced infestation by glyphosate resistant weeds were asked how production costs and yields were affected. The majority (86 percent) reported that their costs had increased (figure 4). Only 8 percent stated that glyphosate resistance had not increased their costs, while 6 percent were unsure. Almost half of respondents who had experienced weed resistance (48 percent) indicated that their yields had decreased, while 31 percent reported that their yields had not been negatively affected. The remaining 20 percent of farmers were unsure.

## Farmers' Concerns about Glyphosate Resistance

Farmers were next presented with eight statements related to glyphosate resistance and asked to identify whether they *strongly agreed*, *agreed*, *disagreed*, *strongly disagreed*, or *did not know*.



**Figure 4. Glyphosate resistance increased production costs (\$/planted acre)**

The results showed that the majority of farmers were concerned about the problem of glyphosate resistance for both agriculture and their farms. The majority believed they were successfully managing resistance, though they lacked faith in technology’s ability to solve the issue. Almost all farmers (97 percent) *agreed* or *strongly agreed* that they were concerned about glyphosate resistance (table 1). Nearly three-fourths (72.5 percent) *agreed* or *strongly agreed* that glyphosate resistance presents a serious problem to their farming operation. At the same time, a majority (83 percent) believed that they were successfully managing the problem. Nevertheless, most farmers (92 percent) believed that glyphosate resistance is a serious problem in agriculture. Over three-fourths (77 percent) *agreed* or *strongly agreed* that resistance management on their own farms would be more effective in reducing the rate of glyphosate resistance in weeds if operators of nearby farms also used the same resistance management strategies.

Three additional statements looked at whether farmers had faith in various solutions to resistance. Almost two-thirds of farmers (64 percent) *disagreed* or *strongly disagreed* that resistant weeds were not a problem because new technologies would be developed to manage them (table 1). Likewise, 69 percent *disagreed* or *strongly disagreed* that human ingenuity will address the problem. The majority of respondents (85 percent)

also believed the problem of resistance would occur again with new biotech crops introduced for managing weeds.

### Farmers’ Concerns about the Non-Target Effects of Herbicides

Farmers were next asked to rate their level of agreement to six statements about the non-target (unintended) effects of herbicides. These statements fell within three categories: the environment or sensitive crop health, human health, and the “herbicide/transgenic treadmill.” Farmers ranked to what extent they *strongly agreed*, *agreed*, *disagreed*, *strongly disagreed* or *did not know* about each topic. The “herbicide/transgenic treadmill” refers to the cycle of the development of resistance to herbicides. It is created by an increased use of herbicides or the introduction of new genetically engineered crop and herbicide pairings, which then lead to increased resistance or new occurrences of resistance [7].

### Effects on the Environment/or Sensitive Crops

Two statements related to concerns about the unintended effects of herbicides on the environment. The first statement read: “I am concerned about the effect of herbicides on beneficial insects, microorganisms, habitat for pollinators, etc.” Over three-fourths (79 percent) *agreed* or *strongly agreed* with this statement. The other statement asked about herbicide drift causing injury to sensitive crops. A slightly higher percentage expressed concern about this issue, with 84 percent *agreeing* or *strongly agreeing*.

### Effects on Human Health

Two statements addressed concerns about the unintended effects of herbicides on human health. More than three-fourths of farmers *agreed* or *strongly agreed* that they were concerned about the effects of herbicides on the health and safety of their family (79 percent) and about the effects of herbicides on the health and safety of the public (76 percent) (table 2).

### The Treadmill Effect

Two statements related to concerns about the “treadmill” effect of weed control. The majority



**Table 1. Concern about glyphosate resistance**

	Strongly disagree	Disagree	Agree	Strongly agree	Don't know
	—Percentage—				
I am concerned about glyphosate resistance.....(n=723)	1.2	1.7	37.1	59.6	0.4
Glyphosate resistance is a serious problem within agriculture.....(n=716)	1.4	5.0	44.8	47.2	1.5
Resistance-management practices on my farm would be more effective in reducing the rate that glyphosate resistance develops in weeds if operators of nearby farms also used them.....(n=723)	2.2	10.9	47.0	30.2	9.7
I am successfully managing glyphosate resistant weeds on my farm.....(n=715)	1.5	9.9	54.3	29.0	5.3
Glyphosate resistance presents a serious problem to my farming operation.....(n=722)	3.5	21.9	44.7	27.8	2.1
It's only a matter of time before weeds will evolve resistance to new biotech crops introduced for managing weeds.....(n=718)	1.0	6.5	63.4	22.3	6.8
Glyphosate-resistant weeds are not a major concern because new technologies will be developed to manage them.....(n=718)	15.5	48.7	24.4	4.0	7.4
Weed resistance is not a big issue because human ingenuity will address the problem.....(n=719)	16.8	52.4	20.4	2.5	7.8

of farmers (86 percent) *agreed* or *strongly agreed* that they felt like farmers were on a never-ending herbicide treadmill to deal with weeds (table 2).

Almost three-fourths (76 percent) *agreed* or *strongly agreed* that farmers were on a never-ending transgenic-herbicide treadmill.

**Table 2. Concerns about the non-target effects of herbicides**

	Strongly disagree	Disagree	Agree	Strongly agree	Don't know
	—Percentage—				
I am concerned about the effects of herbicides on my family's health and safety..... (n=724)	2.9	15.6	44.2	35.2	2.1
I feel like farmers are on a never-ending herbicide treadmill to deal with weeds..... (n=722)	1.4	10.2	52.5	33.5	2.4
I am concerned about the effects of herbicides on the public's health and safety..... (n=722)	4.3	17.5	43.8	32.3	2.2
I am concerned about herbicide drift causing injury to sensitive crops (eg specialty crops, nursery plantings)..... (n=724)	1.7	13.0	54.3	29.7	1.4
I feel like farmers are on a never-ending transgenic-herbicide treadmill to deal with weeds..... (n=716)	1.4	13.1	50.6	25.0	9.9
I am concerned about the effect of herbicides on beneficial insects, microorganisms, habitat for pollinators etc. .... (n=724)	2.3	14.1	57.6	21.5	4.4



## Sources of Information on Managing Weed Resistance

One survey item asked farmers to identify the primary source of information that they seek for guidance on managing weed resistance. Six choices were given, including an “Other” category where farmers could write-in a source other than those provided. Farmers who responded with more than one source were also included in the “Other” category.

Of the farmers who answered, over two-thirds (69 percent) of farmers indicated that their primary source of information was their chemical/fertilizer dealer, followed by crop scout/consultant (8 percent), extension/university professional (5.5 percent), other farmers (2 percent), and custom applicator (1 percent) (figure 5). Finally, sixteen percent of farmers indicated “Other” or were placed in that category for indicating multiple sources (figure 5).

## Factors Responsible for Glyphosate Resistance

Nine survey items asked farmers to indicate to what extent various factors contributed to the development of glyphosate resistant weeds. Farmers rated whether they thought each factor was *not important*, *somewhat important*, *important*, *very important*, or if they *don't know*. The results

showed that farmers believed the following were either *important* or *very important* factors in the development of weed resistance: repeated use of glyphosate (92 percent); glyphosate’s high level of effectiveness discouraged the use of alternative herbicides (87.5 percent); glyphosate’s low cost discouraged the use of alternative herbicides (86 percent); use of below label glyphosate rates (84 percent); improper glyphosate application timing or techniques (83 percent); current agronomic weeds were well adapted to herbicides (66 percent); reductions in tillage made possible with Roundup Ready based cropping systems (61 percent); inconsistent information on the risk of glyphosate resistant weeds (60 percent); crop advisors not taking a long-term approach to weed management (57 percent) (table 3).

It is important to mention that farmers expressed notable levels of uncertainty regarding two factors. Twelve percent of farmers expressed that they *didn't know* whether agronomic weeds were well adapted to herbicides, and another 12 percent noted that they *didn't know* if crop advisors do not take a long-term approach to weed management (table 3).

## Stakeholder Responsibility

Stakeholders in agriculture have identified a variety of actors in the development of the glyphosate

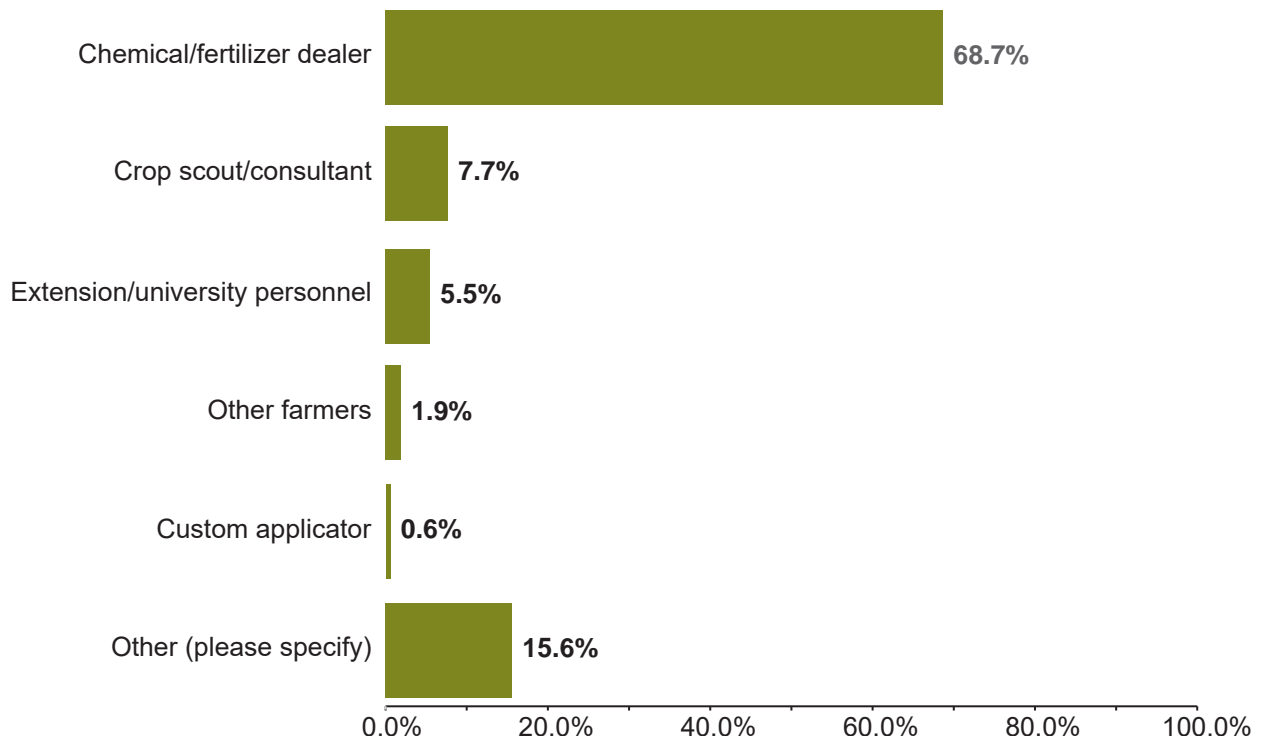


Figure 5. Primary source of information for managing weed resistance

**Table 3. Perspectives on important factors in the development of glyphosate resistant weeds**

	Not important	Somewhat important	Important	Very important	Don't know
	—Percentage—				
Repeated use of glyphosate..... (n=723)	0.8	6.4	29.2	62.9	0.7
Glyphosate's low cost discouraged the use of alternative herbicides..... (n=723)	1.7	10.5	31.3	54.8	1.8
Use of below label glyphosate rates..... (n=722)	2.4	10.1	29.4	54.3	3.9
Glyphosate's high level of effectiveness discouraged the use of alternative herbicides..... (n=724)	1.0	10.1	36.0	51.5	1.4
Improper glyphosate application timing or techniques ..... (n=721)	1.5	13.0	36.2	46.7	2.5
Reductions in tillage made possible with Roundup Ready based cropping systems ..... (n=723)	9.5	26.4	36.1	24.6	3.3
Crop advisors do not take a long-term approach to weed management..... (n=720)	7.1	24.0	36.3	20.7	11.9
Current agronomic weeds are well adapted to herbicides ..... (n=724)	2.8	19.9	49.3	16.4	11.6
Inconsistent information on the risk of glyphosate resistant weeds..... (n=722)	5.1	28.9	44.3	15.7	6.0

resistance issue, ranging from the government, to agrochemical and seed companies, to farmers. The survey asked farmers to rate six particular stakeholders' level of responsibility for the development of glyphosate resistance on a scale by indicating *none, little, some or much responsibility*.

The stakeholder viewed as having the most responsibility for glyphosate resistance were farmers themselves. Most farmers reported that they had at least *some* responsibility (95 percent) in the development of resistance (table 4).

Pesticide manufacturers were also seen as greatly responsible: 89 percent of farmers chose the *some or much* category. Seed companies were viewed by 74 percent as having at least *some* responsibility. University scientists and pesticide applicators were viewed as similarly accountable, with 62 and 61 percent of farmers selecting *some or much* responsibility for each respective stakeholder.

The government was the only stakeholder whom the farmers did not overwhelmingly see as a responsible actor in the development of glyphosate

**Table 4. Perspectives on stakeholder group responsibility for the development of glyphosate resistant weeds**

	No responsibility	Little responsibility	Some responsibility	Much responsibility
	—Percentage—			
Farmers ..... (n=721)	1.4	3.2	35.9	59.5
Pesticide manufacturers..... (n=718)	2.6	7.7	43.6	46.1
Seed companies..... (n=717)	4.5	21.8	46.4	27.3
Pesticide applicators..... (n=715)	10.5	28.8	39.4	21.3
University scientists.....(n=711)	8.3	30.1	40.8	20.8
Government (e.g., EPA, USDA) ..... (n=714)	17.4	32.6	31.2	18.8

resistance. Responses were split, with 50 percent believing the government possessed *little-to-no* responsibility, and 50 percent viewing the government as having *some* responsibility (table 4). Overall, these results suggest that farmers believe a number of stakeholders' share responsibility for the development of glyphosate resistance, with the government as the least responsible.

## Strategies to Address Glyphosate Resistance

How farmers are combating glyphosate resistant weeds is important to know as their strategies may affect, among other things, environmental and human health as well as weed resistance. One of the main benefits attributed to the use of genetically engineered seeds tolerant to glyphosate is that farmers could cut their use of pesticides, sometimes by as much as half, using the Roundup Ready system [8]. However, if farmers have been applying more herbicides in order to combat glyphosate resistant weeds, the benefit may be canceled out.

Farmers were provided with 11 weed management methods and an open-ended "Other" category. They were asked to indicate strategies they had implemented in the last five years to address herbicide resistant weeds. The strategies were then classified as either *chemical* or *non-chemical*.

### Chemical Strategies

The most common strategy was application of pre-emergence herbicides, with 90 percent of farmers indicating use of this method (figure 6). Seventy-one percent reported increasing their sites of action with post-emergence glyphosate applications, and 59 percent indicated rotating herbicide chemistries from one year to the next. About one-third (36 percent) reported increased use of glyphosate to address resistant weeds as part of their weed management plan.

### Non-Chemical Strategies

The most popular non-chemical strategy for combating resistant weeds was scouting for weeds, which was indicated by the vast majority of farmers (87 percent) (figure 6). Eighty percent also reported utilizing crop rotation, and 62 percent attempted to control weeds in adjacent non-crop land. Hand-weeding had been done by 41 percent,

while 37 percent utilized tillage specifically for weed control. The least popular non-chemical strategies employed by farmers were using a cover crop (25.5 percent) and reducing the use of glyphosate resistant seed varieties (21.5 percent). Eighteen percent of farmers also indicated "Other."

## Effectiveness of Strategies

Farmers were next asked to report on the effectiveness of the strategies they had utilized to control weeds. If a farmer responded *yes* to utilizing a strategy, the farmer was asked to report whether the method was *not effective at all*, *somewhat effective*, *effective*, or *very effective*. Farmers could also mark *not clear how effective* or *don't know*.

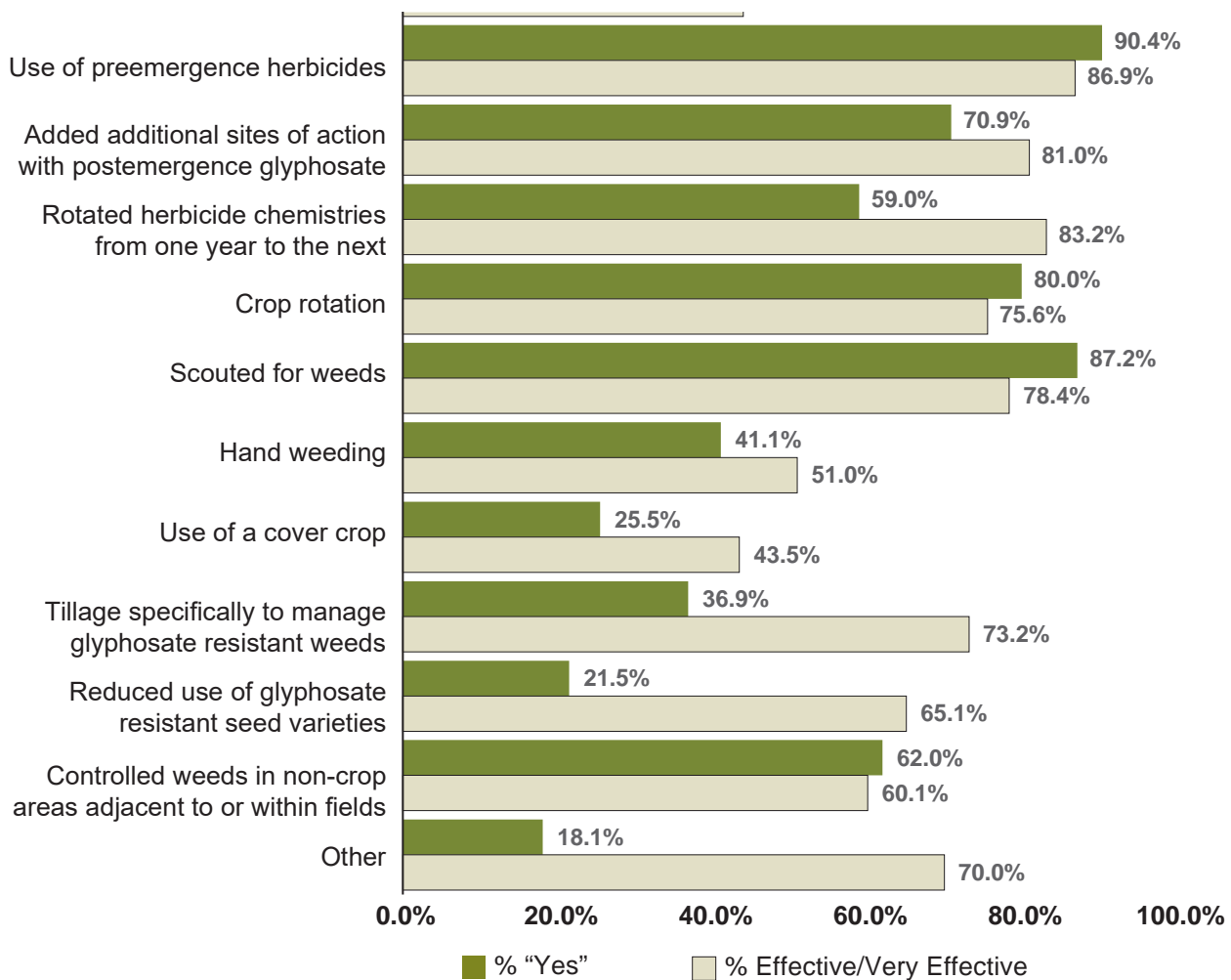
Results indicate that farmers believed most of the strategies were either *effective* or *very effective* components of their resistant weed management program. Most farmers reported use of preemergence herbicides (86 percent); rotating herbicide chemistries from one year to the next (83 percent); adding additional sites of action with post-emergence glyphosate applications (81 percent); scouting for weeds (78 percent); crop rotation (75.6 percent); tillage specifically to manage glyphosate resistant weeds (74 percent); reduced use of glyphosate resistant seed varieties (65 percent); "other" self-reported strategies (70 percent); and controlling weeds in non-crop areas adjacent to or within fields (60 percent) (figure 6). The strategies farmers reported as having the least effective impact toward managing resistant weeds were hand weeding (51 percent), increased use of glyphosate (44 percent), and use of a cover crop (44 percent).

Overall, the most common strategies utilized as part of farmers' weed management plans were also typically believed to be effective as indicated by them checking *effective* or *very effective* on the survey. This suggests that the most popular management techniques are possibly the most effective, and other farmers who are not employing these strategies could potentially benefit from this shared knowledge.

## Long Term Strategies

Various approaches have been suggested for long-term strategies to manage herbicide resistance, from the development of new sites of action for herbicides to employing agricultural approaches less reliant





**Figure 6. Strategy utilized to manage glyphosate resistant weeds (% Yes)  
Belief that management strategy was effective (% Effective/Very Effective)**

on chemicals [9]. Considering farmers’ opinions on how to deal with herbicide resistance in the long term is essential, as farmers are less likely to adopt strategies that they perceive as high risk, or that they do not think are effective [10].

The survey presented farmers with eight statements regarding possible long term strategies to address herbicide resistance. Five response categories were provided to measure levels of farmers’ support: *strongly disagree*, *disagree*, *agree*, *strongly agree* or *don’t know*. Over three-fourths of farmers reported either *agreeing* or *strongly agreeing* with four particular approaches: 1) farmers need to adopt a diversified approach to weed management (99 percent); 2) chemical companies need to develop new herbicide sites of action (91 percent); 3) biotech companies need to develop new herbicide-resistant biotech crops (85.5 percent); and 4) the USDA and EPA should approve

new herbicide-resistant biotech crops and their associated herbicides more quickly, such as Enlist or RR Extend (75 percent) (table 5).

Considerably fewer farmers agreed that the remaining four strategies were necessary for addressing herbicide resistance in the long term. Only fifty-eight percent reported that they *agreed* or *strongly agreed* that herbicide registrants should provide economic incentives to encourage farmers to implement resistance management practices (figure 5). Fewer farmers (42 percent) *agreed* or *strongly agreed* that agriculture needs to shift towards integrated crop production systems that are less reliant on herbicides. Finally, less than one-third of farmers *agreed* or *strongly agreed* that there needs to be more stringent label restrictions on herbicides (33.5 percent), and the government should provide economic incentives to encourage

**Table 5. Perspectives on necessary long term strategies to address herbicide (including glyphosate) resistance**

	Strongly disagree	Disagree	Agree	Strongly agree	Don't know
—Percentage—					
Farmers need to adopt a diversified approach to weed management.....(n=722)	0.4	0.7	42.5	56.1	0.3
Chemical companies need to develop new herbicide sites of action.....(n=719)	0.8	3.6	57.9	32.7	5.0
The USDA and EPA should approve new herbicide-resistant biotech crops (such as Enlist or RR Xtend) and their associated herbicides more quickly... (n=723)	2.4	13.0	45.0	30.0	9.7
Biotech companies need to develop new herbicide-resistant biotech crops.....(n=721)	1.4	8.3	58.5	27.0	4.7
Herbicide registrants should provide economic incentives to encourage farmers to implement resistance management practices.....(n=721)	7.4	24.1	45.8	11.9	10.8
The government should provide economic incentives to encourage farmers to implement resistance management practices.....(n=723)	18.0	43.6	21.4	8.0	9.0
Agriculture needs to shift towards integrated crop production systems that are less reliant on herbicides.....(n=720)	5.7	41.3	34.9	7.1	11.1
There needs to be more stringent label restrictions on herbicides.....(n=723)	8.4	47.2	28.1	5.4	10.9

farmers to implement resistance management practices (29 percent).

## Conclusions

The results of this survey can be used to inform and influence approaches to managing glyphosate resistant weeds in Midwestern soybean acres. Two-thirds of soybean farmers reported already being affected, and the majority of the remaining farmers believed it could occur in the fields in the future. Continued efforts to effectively manage glyphosate resistant weeds is necessary to protect a critical U.S. commodity worth more than U.S. \$21 billion in exports alone during the 2015 fiscal year [11].

**Glyphosate weed resistance is a complex topic for soybean farmers.** Large proportions of farmers expressed general and specific concerns about the effects and implications of the presence of glyphosate resistant weeds. Results indicated that farmers believe this is a cyclical problem that will not be readily solved by human ingenuity or technology. Examining the concerns related to non-target effects of herbicides also revealed that approximately three-fourths of farmers were worried

about the impact of herbicides on the health of crops, ecosystems, and humans. Nevertheless, the continued use of glyphosate as a major method for managing weeds in soybean fields suggests that farmers are more concerned about the impact of a potential weed infestation on their soybean yields. Farmers’ willingness to continue applying glyphosate regardless of the possible unintended consequences suggests a feeling of dependency upon it.

**Multiple stakeholders contributed to the development of resistant weeds and they should also be part of the solution.** Farmers indicated that they themselves were the most responsible for the development of glyphosate resistance through improper use. Agribusiness actors, including pesticide manufacturers and seed companies, were also viewed as greatly responsible. Importantly, these three stakeholders were also seen as playing the most critical role in developing strategies for the effective long-term management of glyphosate resistance.

Regarding the role of government regulations and oversight, farmers expressed that they neither felt the government played a significant role in the development of glyphosate resistant weeds, nor did

they believe regulations should play a large role in solving the problem. Farmers mostly felt that the government should make it easier for agribusiness to develop solutions by quickly approving the use of biotech crops and herbicides. These findings suggest that farmers would like to see a multi-stakeholder approach to addressing herbicide resistance, but with minimal government oversight.

**Chemical and fertilizer dealers are critical sources of information for weed management techniques.** Agricultural chemical and seed companies' current solutions to glyphosate resistance, including the development of new genetically engineered seeds with stacked traits of tolerance to herbicides, will reinforce the "transgenic treadmill." The soybean industry seems aware of this and is encouraging farmers to use more integrated weed management strategies other than herbicides to avoid the recurrence of resistance [12].

Over two-thirds of farmers indicated chemical and fertilizer dealers were their primary source of information for managing weed resistance. This suggests that weed management outreach efforts should be directed toward dealers with the goal that up-to-date weed management information and technical assistance will be shared with farmers.

**Farmers feel conflicted about the best approaches to managing glyphosate resistance.** Many soybean farmers both recognized a need

for diversified herbicide resistance management strategies, while also strongly desiring the development of new herbicide-resistance crops and chemicals. There were also notable opinion gaps. A considerable percent of farmers, ranging from 0-11%, indicated that they "don't know" if particular strategies should be included in a long-term plan selected *don't know* in response to whether the survey's suggested strategies should be included in a long-term plan to address herbicide resistance. This is concerning because the current best management practices for weed control and prevention of new glyphosate resistant weeds promote an approach using a combination of mechanical, chemical, and cultural options [13]. The survey results indicated that most farmers still heavily rely on chemical strategies over non-chemical strategies for weed management.

Regarding why glyphosate has been overused and misused, farmers pointed to glyphosate's ease of use and affordability as key contributing factors to the development of resistance. This suggests that a low-cost and labor saving solution is most desirable. Although farmers want to diversify their weed management strategies, the labor savings that come from chemical strategies is a critical factor in their lack of adoption of integrated weed management. By considering farmers' needs and wants, the most effective approaches are more likely to be adopted for managing resistant weeds and combating the development of new resistant weed varieties in the future.



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