GLYPHOSATE RESISTANT WEED UPDATE

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Introduction

Weeds evolve in response to the management practices that we impose on them. The evolution of herbicide-resistant weed biotypes is just one example of their adaptation. In regards to herbicide resistance, we have experienced two major periods in the evolution of herbicide resistance starting with triazine resistance and followed by ALS-inhibitor resistance. Currently, we are in the midst of a time period where the evolution and spread of glyphosate-resistant weeds is occurring. In reflecting on this current time, I wonder if we also evolve in how we respond to herbicide resistant weeds. Do we progress through five phases similar to the Kubler-Ross model, which are 1) denial, 2) anger, 3) bargaining, 4) depression, and 5) acceptance? Let me explain using a little literary license on the original model.

1) Denial

When glyphosate-resistant crops were first introduced, many individuals were highly skeptical that glyphosate resistance would ever occur. Well reasoned arguments, which were based on biochemistry, were used to support this denial phase. Common mechanisms leading to resistance with other herbicide modes of action appeared to be unlikely to occur with glyphosate. However, glyphosate-resistant horseweed evolved within years after the introduction of glyphosate-resistant soybean. Even with this example of resistance, many individuals remained in a state of denial, stating that resistance would only occur in a couple weed species. However, at this time, eight glyphosate-resistant weeds are documented in the U.S. and a total of 13 glyphosate-resistant species exist world wide. Clearly, the agricultural industry no longer denies the potential or existence of glyphosate-resistant weeds. However, I wonder how many growers are still in this phase in terms of their farm operation where "Glyphosate-resistance won't ever happen to me."

2) Anger

Did we experience an anger phase with regard to glyphosate resistance? I think there might have been some variants on this theme a few years ago when university weed scientists were actively trying to increase grower awareness and stewardship practices. At times our message was being challenged, discouraged, or discredited, but there was no direct anger. Some may have thought "This is a great technology, why are you attacking it?" As university scientists, we may have also been seriously disappointed, although not angry that growers and industry were not willing to address the issue or act more proactively.

3) Bargaining

One example of bargaining that I have heard in relation to glyphosate resistance is when growers ask questions like "If I tank mix a low rate of herbicide "X" with glyphosate, that will be good enough, right?" It sounds like bargaining to me. However, I don't know if any quick and easy solutions exist for the glyphosate-resistant weed problem. Adding a second herbicide will not be effective on weeds when the spectrum does not overlap. Another angle some growers are bargaining on is that new herbicides or new traits will provide a solution if or when glyphosate-resistance evolves.

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4) Depression

The depression phase could be summed up as "Why bother doing anything. It's going to happen anyway." With glyphosate resistance, this is a hard attitude to argue against because herbicide resistance is hard to predict when or where it might develop next. It's also hard because we can't guarantee that proactive stewardship practices will prevent glyphosate resistance from evolving in a field or that resistant seed won't be introduced from another farm.

5) Acceptance

The final phase in the Kubler-Ross model is acceptance, which I hope is acknowledging the glyphosate-resistance issue, promoting good stewardship, and actually enacting appropriate resistance management practices. In several aspects, I believe we are getting much closer to this phase. National commodity leaders, herbicide and seed industry representatives and others at a national meeting in the spring of 2007 recognized the existence and potential impact of glyphosate-resistance, which is a major shift from the fall of 2004. Industry is progressing in being more proactive in recommending stewardship practices. The sooner we accept the risk and consequences of resistance, the sooner we can enact good stewardship.

Glyphosate-Resistant Weed Updates

The current status of glyphosate-resistant weeds is summarized in Table 1. The first glyphosate-resistant species in the U.S. was reported in 2000 and eight species have occurred in at least 18 different states since that time. Additional weed species are currently under investigation.

Table 1. Summary of glyphosate-resistant weeds in the U.S. and in other countries.

Species confirmed in the US	Number of states	Species under investigation	Other species in other countries
Common ragweed	4	Common cocklebur	Junglerice
Giant ragweed	3	Common lambsquarters	Goosegrass
Horseweed	16	Kochia	Wild poinsettia
Palmer amaranth	4	Johnsongrass	Buckhorn plantain
Waterhemp	3		Johnsongrass
Hairy fleabane	1		
Italian ryegrass	2		
Rigid ryegrass	1		

It is interesting to review which weed species have evolved resistance to herbicides in general as a method to forecast other weed species that might have the potential to evolve resistance to glyphosate. Table 2 summarizes the most common weed species with herbicide resistance in the Midwest. The number of different herbicide modes of action that a weed species is resistant to within a state is listed within the table. For example, biotypes of kochia in North Dakota are resistant to three modes of action, the ALS inhibitors (chlorsulfuron), triazines (atrazine), and growth regulators (dicamba). Weed species and states that are shaded have glyphosate resistance as one of the resistant biotypes. These species appear to have a higher tendency to evolve herbicide resistance based on the number of states with resistance and resistance to more than one mode of action. Four of the top seven weed species have already evolved glyphosate resistance; two of the other top seven are currently under investigation; and the seventh weed (pigweed spp.) is in the same family as waterhemp, which has glyphosate-resistant biotypes. The species that are not currently resistant to glyphosate may have a higher potential to be one of the next species to

develop glyphosate resistance. In this list, the foxtail species and shattercane are the next two species on the list in terms of frequency of states (i.e. five) with biotypes that are resistant to other modes of action.

Table 2. Summary of the most common weed species with herbicide resistance in the Midwest with states arranged from west to east.

	Number of biotypes with resistance to different modes of action											
Weed species	ND	SD	NE	KS	MN	IA	MO	WI	IL	MI	IN	OH
Pigweed spp.	1			1	1			1	1	2	1	1
Kochia	3	1		2	1	1		2	2		2	
Waterhemp			1	4		2	4	1	4	1		1
Common ragweed				1	1		1	1	1	2	1	2
Lambsquarters					1	1		1	1	2	1	2
Giant ragweed				1		1		1	1		2	2
Horseweed			1	1			1		1	4	1	2
Foxtail spp.	1				2	2		1		1		
Shattercane			1	1		1					1	1
Cocklebur				1	1	1	1					1
Sunflower		1		1		1	1					
E. black nightshade	1							1	1			
Wild oat	2				1							
Velvetleaf					1			1				
Wild carrot										1		1
Smartweed spp.						1					1	

Observations from Other States

- Missouri estimates 4% of the state has glyphosate-resistant waterhemp and one biotype has multiple resistance to glyphosate, ALS inhibitors, and PPO inhibitors. Multiple herbicide resistance creates significant challenges in controlling problem weed species like waterhemp.

- Ohio has glyphosate-resistant giant ragweed confirmed in 11 counties and one biotype has multiple resistance to glyphosate and ALS inhibitors (FirstRate). ALS inhibitor-resistant giant ragweed is suspected in most non-GMO soybean fields in Ohio. A common ragweed biotype with both glyphosate and ALS inhibitor resistance has also been reported in Ohio.

- Indiana has glyphosate-resistant or tolerant giant ragweed in 14 counties. One 300 acre field has glyphosate-resistant horseweed, glyphosate-resistant giant ragweed, and glyphosate-tolerant common lambsquarters in the same field. The proposed herbicide program to control these three resistant species increased from approximately $18/a to $37/a. The additional herbicide application is not included in the cost.

Glyphosate Management Recommendations

1. Start with a clean field and control weeds early by using a burndown treatment or tillage in combination with a preemergence residual herbicide as appropriate.
2. Apply integrated weed management practices.
   a) Use multiple herbicide modes-of-action with overlapping weed spectrums in sequences or mixtures.
   b) Use cultural practices such as cultivation and crop rotation, where appropriate.
3. Use the full recommended herbicide rate and proper application timing for the hardest to control weed species present in the field.
4. Scout fields after herbicide application to ensure control has been achieved. Avoid allowing weeds to reproduce by seed or to proliferate vegetatively.
5. Use good agronomic principles that enhance crop competitiveness as well as scouting, monitoring and cleaning equipment between fields.

In terms of a simple management practice like using a preemergence herbicide, I asked the following questions in the fall of 2007: "What percent of glyphosate-resistant corn gets a preemergence herbicide treatment?" and "What percent should get a preemergence herbicide?" The same questions were asked for soybeans. The responses that I received from about 325 ag professionals are summarized in Figures 1 and 2. Most ag professional see value in treating more corn acres with preemergence herbicides than is current practice. Many ag professionals also believe more soybean acres should be treated preemergence, but the percentage is not as high as for corn. While preemergence herbicide use could improve overall weed management, it would also add a second mode of action within the same season as when glyphosate is used, which is one of the glyphosate management recommendations.

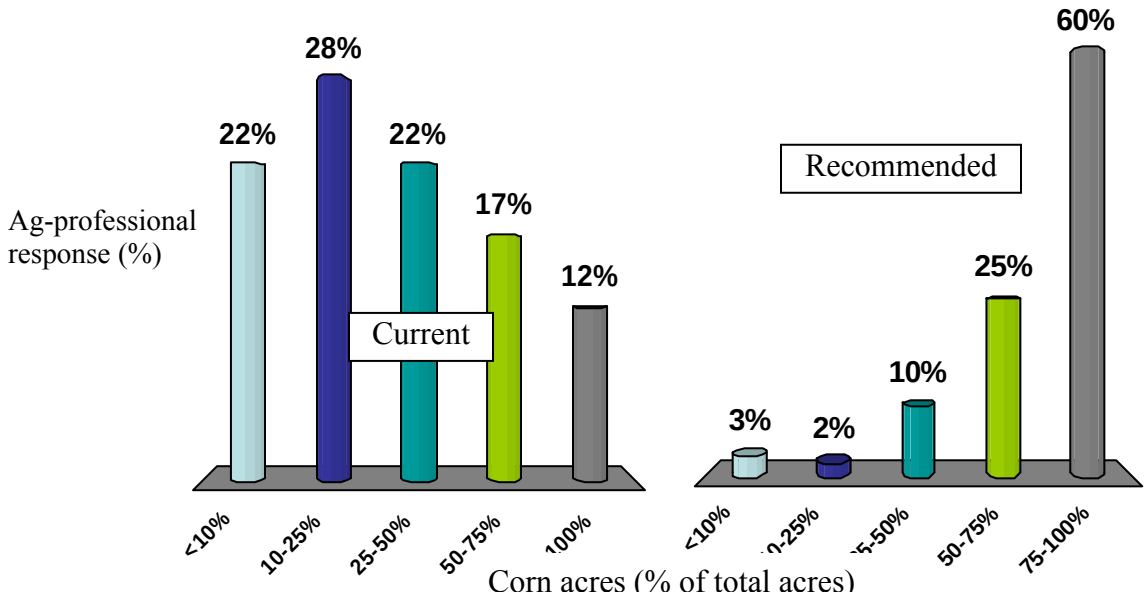

Figure 1. Percent of corn acres that currently receive a preemergence herbicide treatment in Wisconsin as estimated by ag professionals and percent of corn acres that these ag professionals believe should get a preemergence herbicide to improve weed management.

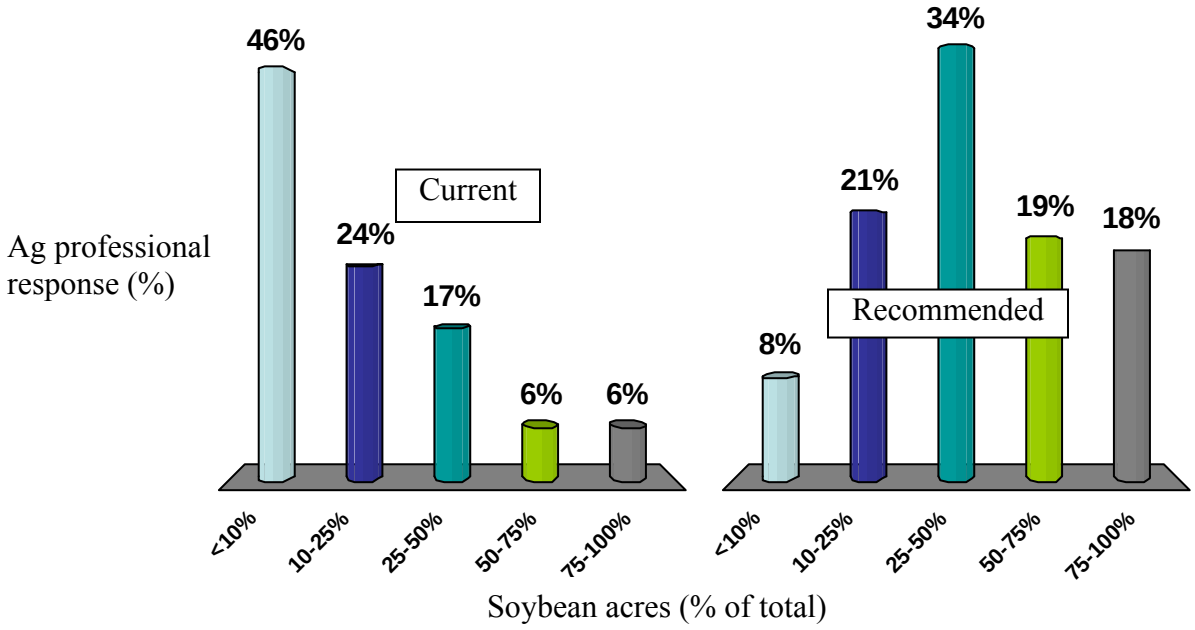

Figure 2. Percent of soybean acres that currently receive a preemergence herbicide treatment in Wisconsin as estimated by ag professionals and percent of soybean acres that these ag professionals believe should get a preemergence herbicide to improve weed management.

I certainly hope that the Wisconsin agricultural industry and growers have reached the acceptance phase with glyphosate resistance and adopt more robust weed management programs. Adopting a practice such as adding a preemergence herbicide treatment should increase the sustainability of glyphosate-based cropping systems and extend the value of glyphosate-based technologies. This practice will have the greatest impact if the weed spectrum of the preemergence herbicide overlaps with the weed spectrum of the glyphosate.