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Farmers' Perspectives on Management Options for Herbicide-Resistant Weeds

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The acceptance and adoption of Integrated Pest Management (IPM) strategies, whose basic scientific underpinnings date back to the 19th century (Kogan, 1998), has varied in the United States and around the world. For example, a recent survey of published work reported a good record of IPM adoption in Western United States fruit and nut systems (Farrar et al., 2016), while Integrated Weed Management (IWM) adoption amongst mid-western organic producers has been uneven (Decker et al., 2014). The challenges farmers face in adopting IPM practices vary greatly by pest, region, production system, and other factors, which may account for some of the variation in adoption rates. At the same time, pressures on farmers to incorporate integrated management approaches are increasing along with a growing societal awareness of agro-ecological problems and calls for farmers to become more sustainable. However, farmers also continue to face market forces that push them to intensify agricultural production (Ashwood et al., 2014; Lawrence et al., 2012), placing farmers at the center of a difficult management situation.

These pressures are likely a factor in understanding why farmers in the United States so rapidly adopted genetically modified crops (GMOs) (Ervin et al., 2010). The most widely used GMOs in the United States over the past two decades have been glyphosate-resistant corn, soybean and cotton varieties, with 94% of U.S. soybean acres, 85% of corn acres, and 89% of cotton acres planted to these varieties as of 2015 (Livingston et al., 2015; Wechsler, 2016). Despite concerns over the possible carcinogenic properties of glyphosate (Guyton et al. 2015), as well as the detection of low levels of glyphosate in the environment (Battaglin et al., 2014), the adoption of glyphosate tolerant crops has been pronounced in the United States, Argentina and Brazil (Bonny 2016). Glyphosate can kill almost any plant quickly, cheaply, and relatively safely (Ervin, Glenna, and Jussaume, 2010; Frisvold and Reeves, 2011), and has had numerous benefits when used with glyphosate tolerant crops. This technological package has enabled farmers to meet pressures to lower some of the ecological impacts of their farming while maintaining economic viability. The glyphosate-based weed management system has eliminated much of the need for time and labor intensive weed control practices such as tillage and hand weeding (Shaw et al., 2012). Additionally, glyphosate is comparatively one of the least toxic pesticides to animals, is less volatile than many other herbicides, and tightly binds to the soil, which reduces some of the potential for water contamination. Thus, the rapid adoption of the glyphosate technological package helped reduced management uncertainty for adopters (Rogers, 1995). Also, by eliminating the need for tillage, the glyphosate-resistant crop system has helped reduce carbon dioxide emissions equivalent to the impact of removing 4 million family cars from the road (Duke and Powles, 2008).

However, the persistent use of glyphosate, along with other factors, has endangered these benefits by quickly leading to a decrease in the effectiveness of glyphosate for weed control (Livingston et al., 2015), as weeds have evolved resistant to glyphosate (Bonny, 2016). Subsequently, the call to adopt integrated weed management approaches has been renewed (Hammond et al., 2006; Livingston et al., 2015). In addition, it appears that farmers will need to implement these approaches on a "community" basis (Ervin and Jussaume, 2014) when weed seeds or pollen are mobile across farms and effectively managing resistant weed populations becomes a regional challenge.

It will be extremely difficult for U.S. farmers to cooperatively adopt integrated weed management practices. We may now have arrived at an historical point in time where farmers face structural challenges that simply make it

too difficult for them to adopt integrated management practices. Farmers who are now being asked to adopt integrated weed management practices as part of a larger set of holistic management activities that are designed to remediate against resistant weeds, the overuse of fertilizers, and a host of other agro-ecologically related management issues while also facing pressures to increase the productivity of their farm operations. Given this, the structural challenges facing farmers are reflected—that is neither causing or caused by—and expressed in a set of farming-related ideologies. In other words, we believe that there is a dominant ontology in U.S. farming that places a strong emphasis on simplicity, ease, independence and year-to-year decision making, and that the related ideological components reflect the structural difficulties farmers face in adopting a variety of sustainable agriculture practices.

The reluctance of U.S. farmers to adopt techniques to mitigate the spread of weed resistance is not due to a lack of knowledge about the existence of the problem or the possible tools that could be used. Rather, it is difficult for farmers to adopt recommended weed management practices because they must consider their weed management options within broader farm management and farm structure contexts. This framework builds on the findings of Zwickle, et al. (forthcoming) that Midwest farmers have significant knowledge of ecological weed management practices, yet are constrained in their use by various tradeoffs in economic risks and environmental benefits. We suggest that this conundrum is reflected in the ideologies farmers use when assessing the problem of weed resistance—and other agricultural production issues. To illustrate this, we highlight two ideologies that we have found farmers hold: technological optimism and individualism (Dentzman, Gunderson, and Jussaume 2016). The empirical evidence that we use was collected as part of an interdisciplinary project on weed resistance. As part of that project, we conducted focus group interviews in the spring of 2015, and a self-reported survey of farmers in major production regions during the winter of 2015-16 (See boxed item about data sources).

Data Sources from an Interdisciplinary Study on Weed Resistance

The first phase of our research project was focus group interviews. Ten focus groups were conducted between February and May of 2015, with four in Iowa, two in Minnesota, two in North Carolina, and two in Arkansas. The second phase of our mixed-methods procedure was a self-reported survey instrument on weed management practices. This survey was implemented early in 2016, and yielded 839 usable questionnaires from farmers in 28 different U.S. states, with 41% of the completed questionnaires coming from Arkansas, Iowa, Illinois, Minnesota, Nebraska and Texas. The data presented in the two tables in this article are derived from that survey.

Farmer Recognition of the Weed Resistance Dilemma

Farmer awareness of the existence of weeds that are resistant to herbicides is not lacking in the farming community. Most respondents to our survey stated that they were aware of the presence of weeds on their farms and a vast majority of farmers—over 90%—stated that they were concerned about the potential presence of weeds resistant to a herbicides. These results are similar to findings in the 2014 Iowa Farm and Rural Life Poll (Arbuckle and Lasley, 2014). This suggests that there has been a marked change in recent years in awareness of this issue. In a benchmark study of farmers' herbicide-resistant weed awareness, Johnson et al. (2009) found that only 30% of growers surveyed thought that glyphosate resistance was a serious issue. The substantial increase in farmers' awareness and concern may be in part due to the presence of an increasing number of glyphosate-resistant weeds, as well as more frequent presentations and information transfer to growers about the implications of herbicide resistance (Bonny, 2016; Owen et al., 2011).

Most farmers understand the processes by which weeds— and other pests—evolve resistance. More than three-quarters of those in our survey either somewhat or strongly agreed that it was only a matter of time before pests develop resistance to new weed technologies (Table 1). This reflects an appreciation for how modern agricultural practices contribute to the evolution of pest resistance. Perhaps most interesting of all is that most farmers stated that they somewhat or strongly agreed that any new herbicides developed would be similarly overused (and thus

Table 1: Respondents' Agreement on Herbicide Resistance Statements

	<i>Strongly/Some- what Disagree</i>	<i>Neither Agree nor Disagree</i>	<i>Somewhat Agree</i>	<i>Strongly Agree</i>
It's only a matter time before pests develop resistance	5%	13%	56%	24%
Modern ag. practices contribute to the evolution of weed resistance	12%	20%	47%	22%
Any new chemical mode of action will be overused	13%	26%	46%	15%
Companies need to do a better job of keeping up with resistance	10%	31%	42%	17%

Source: Survey conducted by the authors

lead to new weed resistances). A high percentage of farmers in the 2013 Iowa Farm and Rural Life Poll also stated that new pest technologies lead to the evolution of resistance, that the way farmers use those technologies contributes to the evolution of resistance, and that seed and chemical companies should do more to respond to that evolution (Arbuckle and Lasley, 2014).

Table 2: Respondents' Agreement on Effective Approaches for HR Weed Management

	<i>Very/Some- what Unlikely</i>	<i>Neither Unlikely nor Likely</i>	<i>Somewhat Likely</i>	<i>Very Likely</i>
Private Company Investment in new herbicide MOAs	5%	9%	45%	42%
LGU discovery of new weed management strategies	10%	17%	45%	29%
Community based action to adopt best management practices	29%	30%	31%	10%

Source: Survey conducted by the authors

Farmers are not only aware of the problem of weed resistance and how it occurs, but they are also aware of different recommendations for controlling weed resistance. Farmers believe that it is more likely that the private sector (new herbicide modes of action) and land grant universities (weed management strategies) can develop the solutions to weed resistance problems (Table 2). At the same time, the farmer respondents are split over whether privately led community action would be an effective approach.

Farmer Optimism and Individualism

Farmers' desire to rely on chemical-based weed management approaches is a reflection of farmers' recognition that they are in a quandary in which they are pressured to address this emerging agro-ecological problem in a way that does not lead to either increases in management time and costs or to negative environmental impacts. This dilemma was highlighted in the farmer focus groups where two major themes that emerged across our focus groups in response to questions about weed management were technological optimism and individualism. "Technological optimism" refers to farmers' hope that new technology will provide continuous solutions to herbicide resistance. "Individualism" refers to farmers' belief that each individual farmer knows what is best for their farm and should be allowed to make these decisions without interference from others. At the same time, farmers' technological optimism and belief in individualism are always expressed in a manner that demonstrates an awareness that hope in new technology and belief in individual decision-making are not absolute. Farmers do recognize the limitations of relying too much on new technology or individual decision making. This ideological dissonance reflects the structural pressures facing farmers.

The hope for never-ending technological solutions that would help farmers maintain a simple weed management approach was expressed in a number of our interviews. One grower from Iowa said:

"I think we're all hoping somewhere in that chemistry, there's something that comes around that's a new version. Yeah, stall long enough, maybe they'll figure something out, give us another product."

This was a common sentiment among growers— that any practices they were currently trying were to bide time until a new chemistry could be developed, at which point they would go back to a simpler and easier chemical weed management plan. A grower from Minnesota emphasized this desire to rely on new chemistries as opposed to alternative management practices:

"In other words, trying to keep a company keeping new ideas coming, keeping new products moving in the pipeline...this is never going to go away. You're always going to have an issue with whatever herbicide comes out. So keeping new options coming is more important than really the agricultural practices and all that."

At the same time, while growers consistently expressed technological optimism, they were by no means naïve about the need for better management practices. As stated by another Iowa grower:

"We don't want to go back to no chemicals. We're not going to do that. We can't all go organic. So, you can't stand in the way of progress. But, we also know that there's going to be a problem later. We've got to be smart enough to realize we've got to manage it. We've got to use the tool properly. Otherwise, we've got a disaster waiting on us down the road."

This recognition of the need for better management practices often was related to a need for improved management of chemical tools. In addition, a dissonance was also expressed about whether new chemical tools by themselves would really provide a long-term solution to the problem of weed resistance. Examples of this are expressed in the following quotes from a farmer in North Carolina:

"I see problems being solved, but at the same time, new ones coming up all along. As far as a cure-all, I don't see that happening"

Farmers also recognized that their hope for, and dependence upon, new chemical solutions is connected to a dilemma wherein farm size has increased to the point where alternative approaches have become problematic. A farmer in Iowa expressed the following:

"And chemicals has [sic] changed everything to the point where, you know, an extremely large operation with not much manpower can farm a lot of acres, because they are -- we have all become chemical reliant. And to move away from that culture is going to be difficult."

Farmers know that they are on a treadmill where dependence on new chemicals is necessary for them to continue farming large acreages, and also understand the challenges they face that are associated with the ideology they share about being their "own bosses" (Mooney, 1988). While they hold this ideological element strongly, as is the case with technological optimism, farmers understand the contradictory dimensions of this ideology of being independent actors. This may be particularly true in the context of managing herbicide-resistant weeds.

Statements about individualism were generally very strongly worded and came up when farmers were asked whether they would discuss weed management with a neighbor who had herbicide resistance problems. The following quote from growers in Iowa and Minnesota, respectively, relate to individualism and farm neighbors:

"Your original question was what do you do if the neighbor has weeds, though. My answer would be nothing. I don't see myself going up and knocking on the door, and saying, ' you need to get rid of your weeds.'

"But I know there's some neighbors that I got [sic] – you can try talking to them about it and you – you just couldn't get a whole lot of . . . they wouldn't be receptive at all."

Once again, however, growers recognized the challenges and dissonance present with respect to individual versus coordinated weed management approaches. Farmers know that having neighbors who don't work on managing weed resistance in an area can create problems for others, and yet find it difficult to approach certain neighbors whom they perceive as unwilling to be responsive. This sentiment is perhaps best reflected in the following exchanges that took place in Minnesota and Iowa, respectively about neighbor growers who were not managing resistance:

Participant 1: *"Bite your tongue."*

Moderator: *"Hmm?"*

Participant 1: *"Bite your tongue and wait."*

Participant 2: *"Harder."*

Participant 3: *"Yeah, till it bleeds."*

Participant 1: *"Just think, shoot the neighbor"* (laughter)

Participant 2: *"Hoping he'll die. Hoping he'll die soon"*

Participant 3: *"Oh yeah"*

While these statements were made in jest, the jokes resonated with participants on a deeper level—everyone empathized with the point and found them funny because of the underlying shared meaning that was clearly about how difficult it can be to communicate with farmer neighbors. While part of this attitude can be attributed to the notion that every farmer is doing their best and doesn't need to be told how to manage their farm, there also appears to be a fear that discussing herbicide-resistant weeds with neighbors may become a problem for the original complainant. Growers fear that they may be criticized for their own management practices if they point out a neighbor's herbicide-resistant weeds. Yet, farmers also recognize the need for improved cooperation, as evidenced by this statement by a participant from Iowa:

"I'd like a means of knowing what other people are doing. I know what runs through my mind a lot is, 'I wonder what they did? I wonder what that person did? I wonder what that guy did on his field, it looks good'... And it would be nice to have a bigger bank of that knowledge."

Future Solutions

Farmers share a strong hope for a new magic bullet herbicide and are reluctant to engage in community-level action to address herbicide-resistant weeds, despite the fact that they recognize that overuse of herbicides contributes to the evolution of weed resistance and that coordinated action to address this problem would be beneficial. Clearly, farmers are unlikely to abandon their hope for simple weed management solutions. Thus, IWM educational and informational programs may want to stress how IWM can preserve and support the potential continued use of some chemical herbicides. It is also vital that farmers understand the reality of the herbicide discovery process—it takes a very long time and there is no guarantee of developing a new effective herbicide. This may aid in supporting some farmers' own emerging skepticism regarding chemical solutions, with IWM providing a solution to the dissonance created by doubting the longevity of chemical herbicides while still believing they are a necessary part of weed management.

Farmers are well aware of the issues related to weed resistance and of the challenges these new weeds pose to them. There is no need for an educational campaign that seeks to educate farmers about how weeds are rapidly evolving resistance to the widespread use of herbicides. Farmers are cognizant of the problem, although they may not have reached the point where they perceive this problem to be at a "crisis" stage. Farmers also hope that the solution to their problem will come from the innovation and diffusion of the next glyphosate-like herbicide that will simplify their weed management. The reasons for this hope are complex and contradictory, but the hope exists. Thus, if coordinated approaches are necessary to address the evolution of weed resistance, then educators should employ a learning approach that engages with farmers in a way that helps them understand the limitation of their hope and the potential efficacy of community-based and/or integrated approaches to weed management.

Furthermore, understanding how ideologies function, and under what conditions farmers might transcend them, is necessary for understanding issues connected to the promotion of sustainable agriculture. This helps provide at least a partial explanation as to why farmers do not practice IWM in spite of understanding how IWM works

(Wilson et al., 2009). Programs attempting to build upon a community approach must consider ideological barriers that may inhibit adoption of such an approach. For instance, farmers from our focus groups were strongly against 'telling their neighbors how to farm' but were nonetheless interested in accessing a wider range of farmer knowledge regarding herbicide resistance. Creating moderated forums wherein farmers discuss these and other issues could be a useful way for improving information exchange without violating the taboo of 'telling your neighbor how to farm.'

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