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Theme Overview: Herbicide Resistance Management

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Articles in this Theme:

Farmers are experiencing increasing numbers of herbicide resistant weeds across most areas of the country. Left unchecked, this pattern threatens crop yields, farm profit, community cohesion, and environmental quality. Current public and private efforts to stem the tide of weed resistance for the most part have failed. Papers in this issue examine factors leading to weed resistance, socio-economic barriers to resistance management, and new policy options moving forward. But first, it's important to understand how we arrived in this predicament.

The adoption of genetically modified crop (GMO) varieties that are herbicide resistant (HR) has been rapid and widespread. HR crops first became commercially available in 1996. Today 89% or more of U.S. corn, cotton, soybean, and sugar beet acreage are planted to HR varieties. There are similarly high adoption rates for HR canola in Canada and the United States. In the United States, HR alfalfa—more recently introduced—accounts for roughly a third of newly seeded acreage. HR cotton and soybean varieties now account for the majority of global acreage of these crops. Most HR crop acreage is planted to glyphosate resistant (GR) varieties. Because the herbicide glyphosate controls more than 300 weed species, growers can control many broadleaf and grass weeds effectively using one herbicide instead of many different ones.

Adoption of HR crops has been rapid despite mixed evidence that they increase farm profits. Researchers have suggested HR crops provide benefits difficult to capture using standard farm profit estimates. These benefits include simplification of weed-management decisions, convenience, increased flexibility in timing, reduced crop damage, lower environmental risk, lower management time requirements, and compatibility with conservation tillage. Growing weed resistance to other herbicides may also account for the popularity of GR varieties.

Weed scientists stress that, to delay the evolution of weed resistance, it is critical to use a diversified mix of weed control strategies. Growers can use non-chemical control (such as tillage, row spacing, and crop rotations) along with different chemical controls. If herbicides *are* used, avoiding reliance on herbicides with the same mechanism of action (MOA) is crucial. The widespread adoption of GR crops in the United States, though, led to a dramatic reduction in the diversity of weed control tactics. Growers have relied less on non-chemical control methods and among chemical methods, have relied heavily on glyphosate, often relying on multiple applications of only glyphosate.

By 2001, glyphosate resistant weeds were identified in fields growing continuous GR crops and applying only glyphosate.Since then there has been a steady increase in the number of states and cropping systems with GR weeds.The number of GR weed species has grown as has the number of species resistant to multiple herbicides with different MOAs.There have also been growing reports of resistant weed problems leading in wholesale field abandonment or requiring expensive hand weeding.

The growing weed resistance problem has not gone unnoticed by the scientific community, government agencies, or industry and commodity groups. The National Research Council (NRC) report on the sustainability of genetically modified crops devoted considerable attention to resistance issues and recommended a national public-private collaboration to develop cost-effective management programs (Ervin et al., 2010). Many of the report's findings were summarized in the *Choices* 2010 special issue on "Genetically Engineered Crops and U.S. Agricultural Sustainability." The 2016 NRC report on the future prospects for genetically engineered crops affirmed the importance of addressing resistance issues. The Weed Science Society of America (WSSA) and the U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) collaborated to publish a special issue of *Weed Science* on HR weeds (WSSA, 2012). The Council for Agricultural Science and Technology (2012) similarly issued a report outlining the economic and environmental consequences of resistance as well as options to combat it. WSSA and the NRC collaborated to organize two herbicide resistant weed summits in Washington, D.C. to bring together stakeholders to develop concrete action items to address resistance (NRC, 2012). In 2013, the USDA Economic Research Service and the Farm Foundation collaborated to organize a workshop on "Public Policies, Research and the Economics of Herbicide Resistance Management." Agricultural input industries and commodity groups have also been active participants in these endeavors in addition to supporting research on grower adoption of resistance management practices. On October 15, 2014, the U.S. Secretary of Agriculture, Tom Vilsack, announced plans for USDA to commit additional resources to address the growing herbicide resistance problem. More recently, the WSSA again organized a special issue in *Weed Science*, this time on socio-economic aspects of herbicide resistance management (Ward, 2016).

How successful have these efforts been in improving resistance management? First, the good news—there has been a tremendous increase in knowledge sharing among stakeholders concerned with resistance management with a great increase in multi-disciplinary research involving biological, physical, and social scientists. Grower awareness of the level of resistance problems, how they come about, and what steps can be taken to delay resistance appears much improved compared to 15 years ago. Some grower and extension-led initiatives, such as Arkansas's Zero Tolerance Program, have shown some promise.

Now the bad news—grower adoption of resistance management practices has been spotty and largely insufficient to date. Changes in awareness are not translating into changes in grower behavior. Industry has responded to glyphosate resistance by developing crop varieties resistant to multiple herbicides. This addresses some immediate grower weed management problems. Glyphosate remains a cheap and effect way to control many weed species still. Yet, many of the chemicals that will complement the new multiple resistant (MR) crop varieties—such as dicamba and 2, 4-D—have been used for many years. Some weeds have already evolved resistance to these herbicides and a growing number of weeds are evolving resistance to multiple herbicide MOAs. There have been no new commercially developed MOAs in the past 30 years. Reliance on MR crop varieties will be attractive to many growers who see them as "silver bullets" to solve their immediate problems. But this strategy is only a stopgap measure—resistance will evolve to more and more herbicides. Will the effectiveness of currently available MOAs be depleted one by one? Or, will growers have and adopt other weed control options to delay resistance?

The articles in this special issue summarize some of the latest social science research on managing herbicide resistant weeds. What is the economic nature of the problem? What are socio-economic barriers to adopting effective resistance management programs? What are policy options to address herbicide resistance?

The article by Osteen and Fernandez Cornejo provide historical background on the use of herbicides in U.S. agriculture.In the 1950s, herbicides were applied to relatively few acres of major field crops.But by the 1980s, herbicides were applied to nearly all of field crop acreage. Today, herbicides account for two-thirds of U.S. pesticide use. Herbicide use—measured by pounds of active ingredient applied—reached a peak in the 1980s, but began to decline in response to pesticide regulations and the use of new compounds with lower application rates. The introduction of GR crop varieties encouraged increased use of glyphosate, which initially displaced both older and newer chemistries. Total herbicide use, though, has increased once again since 2002 as the decline in older compounds has ceased, while glyphosate use continues to increase. The time that Osteen and Fernandez Cornejo note marks the beginning of increased herbicide use coincides with the takeoff in the number of herbicide resistant weeds as well as the states and cropping systems where they are found (Heap, 2014).

The article by Hurley discusses the rise of what he calls "shock and awe" pest management (SAPM). SAPM disrupted earlier trends toward integrated pest management (IPM) and precision agriculture.IPM strives to address insect pest and weed pests through selective use of chemical control and use of diverse control tactics that include non-chemical control.Precision agriculture stresses higher degrees of control over the amounts, timing and location of chemical applications. SAPM in contrast combines seed traits and broad spectrum chemical control to treat multiple problems throughout the crop year, even when treatment is not needed.The pre-packaging and bundling of multiple traits—often with chemical complements—facilitates mass production and has time-saving advantages for both very large and for part-time farmers.In some ways, though, SAPM represents a step backwards to the era of "one-size-fits-all, prophylactic crop management."Hurley calls for resilient pest management (RPM) that considers trade-offs between bolstering defenses against crop damage and minimizing that damage when defenses periodically, but inevitably, fail.To this end, he recommends integrating aspects of SAPM with IPM where they are compatible and revisiting non-chemical weed control programs, abandoned since the rise of HR crops.

Jussaume and Dentzman provide insights from rural sociology, relying on new survey and focus group information. They find that growers' failure to adopt resistance management practices does not stem from a lack of awareness of either the consequences and causes of resistance or methods to combat it. Rather, growers face economic constraints and hold onto ideologies that discourage adoption. Two ideologies they identify are technological optimism and individualism. Growers remain hopeful that industry will continue to provide new products that allow them to continue the simplified management features of HR crops. Similar to Hurley, they emphasize that increased farm size makes time-intensive weed management less attractive. Focus group results from a diverse set of states show that farmers are reluctant to discuss a neighbor's poor weed management practices with that neighbor. One lesson for extension efforts is that lack of awareness is not an adoption barrier, while time constraints, faith in new technologies, and reticence to tell others "how to farm" are more important constraints.

When resistant weeds are mobile, managing resistance can suffer from the classic "tragedy of the commons"—no one controls the resource—in this case, the effectiveness of herbicides—so no one manages it sustainably. For guidance on how to proceed, Ervin and Frisvold look to the research of Nobel laureate Elinor Ostrom and her colleagues on the management of common property resources (CPRs). Drawing from examples worldwide, this research identifies those features of local organizations that successfully manage their CPRs. Ervin and Frisvold identify management principles from this research that might be applied to HR weed management. Next, they consider historical examples from U.S. agriculture of successful community based approaches such as area-wide insect control, pest eradication programs, invasive weed management, and weed control districts. Some common features of successful U.S. programs reinforce lessons of Ostrom and colleagues. To develop community-based organizations to manage herbicide resistance, we do not have to start from scratch. One can build on legal precedents for and institutional memory of programs growers have already found to be successful. The work of Jussaume and Dentzman suggests that solving the collective action problem among growers will be a major impediment to resistance management. Building on successful examples of collective action in other areas may be one way to overcome grower reluctance.

For More Information

Bonny, S. 2016. "Genetically Modified Herbicide-Tolerant Crops, Weeds, and Herbicides: Overview and Impact." *Environmental Management* 57:31-48.

Ervin, D. E., Y. Carriere, W. J. Cox, J. Fernandez-Cornejo, R. A. Jussaume Jr, M. C. Marra, M. D. K. Owen, P. H. Raven, L. L. Wolfenbarger, and D. Zilberman. 2010. *The Impact of Genetically Engineered Crops on Farm Sustainability in the United States*. Washington, D.C.: National Research Council.

Fernandez-Cornejo, J., R. Nehring, C. Osteen, S. Wechsler, A. Martin, and A. Vialou. 2014. *Pesticide Use in U.S. Agriculture: 21 Selected Crops, 1960-2008*. U.S. Department of Agriculture, Economic Research Service Economic Information Bulletin EIB-124.

Frisvold, G.B., T.M. Hurley, and P.D. Mitchell. 2009. "Overview: Herbicide Resistant Crops–Diffusion, Benefits, Pricing, and Resistance Management." *AgBioForum* 12:244-248.

Gould, F., R. Amasino, D. Broussard, C. Buell, R. Dixon, J. Falck-Zepeda, M. Gallo, K. Giller, L. Glenna, T. Griffin, B. Hamaker, P. Karieva, D. Magraw, C. Mallory-Smith, K. Pixley, E. Ransom, M. Rodemeyer, D. Stelly, C. Stewart and R. Whitaker. 2016. Genetically Engineered Crops: Experiences and Prospects. Washington, D.C.: National Research Council. doi: 10.17226/23395.

Heap, I. 2014. "Global Perspective of Herbicide-Resistant Weeds." *Pest Management Science* 70:1306-1315.

National Research Council (NRC). 2012. *National Summit on Strategies to Manage Herbicide-Resistant Weeds: Proceedings of a Symposium.* Washington, D.C.: National Academies Press.

Norsworthy, J.K., S.M. Ward, D.R. Shaw, R.S. Llewellyn, R.L. Nichols, T.M. Webster, K.W. Bradley, G. Frisvold, S.B. Powles, N.R. Burgos, and W.W. Witt. 2012. "Reducing the Risks of Herbicide Resistance: Best Management Practices and Recommendations." *Weed Science* 60(sp1):31-62.

Shaw, D., S. Culpepper, M. Owen, A. Price, and R. Wilson. 2012. "Herbicide-Resistant Weeds Threaten Soil Conservation Gains: Finding a Balance for Soil and Farm Sustainability." *Council for Agricultural Science and Technology Issue Paper* 49:1-16.

Shaw, D.R., M.D.K. Owen, P.M. Dixon, S.C. Weller, B.G. Young, R.G. Wilson, and D.L. Jordan. 2011."Benchmark Study on Glyphosate-Resistant Copping Systems in the United States. Part 1: Introduction to 2006–2008." *Pest Management Science* 67:741-746.

Ward, S. 2016. "Human Dimensions of Herbicide Resistance." *Weed Science* 64(sp1):551-551.

Weed Science Society of America (WSSA). 2012. "Introduction to the Special Issue of Weed Science on Herbicide Resistance Management." *Weed Science* 60(sp1):1-1.

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