

Understanding the Decision-Making Process in Weed Management to Better Effect Change

David Ervin and Raymond Jussaume

Herbicide resistance management (HRM) is a “wicked problem” that involves multiple, complex and uncertain causes and effects over time in the way humans and nature interact. The potential influences include biophysical, climatological, technological, economic, social and community factors. As such, HRM defies simple technological fixes, such as stacked traits, but requires adaptive management on the part of a community that experiments and learns to discover effective long-term control. These efforts likely will vary over cropping systems, local communities and regions. The search for effective solutions is complicated even further when herbicide resistance moves across fields and farm boundaries due to pollen flow and other processes. Under these circumstances, individual farmers cannot be expected to take action on their own to stem the spread of herbicide resistance because they are unsure whether their neighbors will reciprocate. This situation raises the issue of how neighbors and the larger community may affect HRM, an area that has been understudied in weed management. When herbicide resistant weeds are mobile across the landscape, all farmers and other stakeholders must be engaged in creating effective control programs. A holistic interdisciplinary decision framework is needed to sort out the roles of interacting natural and human influences on weed management. Further, natural and social scientists should collaborate with farmers and their advisers to integrate their real-time knowledge. Given this inherent complexity, we expect that the choice before farm managers is not *between* new technologies, integrative on-farm tactics, educational programs, incentives and governmental policies, but rather to develop a portfolio approach in which combinations of the approaches can be tailored adaptively through experimentation to fit the specific situation.

The Economics of Herbicide Resistance Management

Terrance Hurley and George Frisvold

The repeated use of a herbicide diminishes its effectiveness as weeds that are not controlled by it (i.e., resistant) become more common through natural selection, while weeds that are controlled (i.e., susceptible) by it become less common. While using a herbicide today benefits farmers through better weed control, it also imposes a future cost by accelerating resistance, which can lead to more weed damage later. Effective herbicide resistance (HR) management carefully balances this tradeoff between today's net benefits (benefits minus costs) of herbicide use with future net benefits. Achieving this balance can be difficult because managing resistance often involves incurring immediate, certain costs, while the benefits accrue in the future and are less certain.

A number of motivations guide farmers' herbicide management decisions. Some are monetary, such as herbicide costs and revenues from higher crop yields. Others are non-monetary, such as the desire for simplicity and flexibility in farming, concerns for human and environmental safety, a grower's time horizon or aversion to risk, uncertainty, quality of life, and aspirations to steward the land for future generations. An individual farmer's decisions are also guided by decisions of other farmers, companies that supply seed, chemicals and other inputs, consultants and advisors, extension agents, landlords, lenders, media sources, regulations, and farm programs. These different players and institutions can all, to varying degrees, influence the economic returns to managing resistance. This influence can be positive or negative. For example, the effectiveness of an individual farmer's attempts to manage resistance can be diminished if neighboring farmers do not also manage resistance. This is because resistance can spread from neighboring farmers' fields through the movement of weed seed and pollen. Thus, an individual farmer's economic incentive to manage resistance can hinge crucially on what other growers do. Sales programs offered by herbicide manufacturers to increase market share can encourage the repeated use of the same herbicides, contrary to the fundamental principles of HR management. Alternatively, sales programs that provide economic incentives for diverse weed control can encourage HR management. Soil conservation programs can discourage some farmers from using tillage practices that help manage resistance. While there is general agreement that economic incentives play a central role in farmer resistance management decisions, these incentives are affected through many diverse channels. Therefore, promoting resistance management will require multiple tools and approaches.

Toward a Community-Based Approach for Weed Management

David Ervin and George Frisvold

Early research on managing pest resistance concluded that mobility applied only to insects, but a growing body of evidence indicates that it also applies to weeds. If herbicide resistance traits are mobile across farms, the susceptibility of those weeds to herbicides is a resource shared by all operators in the farm community. In such circumstances, it is in the collective, long-term interest of farmers to delay resistance and to conserve the usefulness of a herbicide as a weed management tool. Yet, steps taken by individual farmers in the short-run to conserve the usefulness of a herbicide (such as using alternative weed control tactics) can be costly. Thus, delaying resistance becomes a “common pool” problem – each farmer has an individual incentive to use the herbicide in the short run without considering effects on resistance. As such, individual farmers may not manage resistance because they are not assured their neighbors will match their actions.

There have been three stereotypical approaches to managing common pool resources. A first approach is to impose government regulation requiring all growers to comply with specified weed management practices enforced with noncompliance penalties. Historically, such *command-and-control* approaches to resource management have proved costly. This can occur because uniform standards do not provide adequate flexibility or incentives for innovation, while monitoring and enforcement can be costly. A second approach, using *incentive schemes* (public or private), offers growers payments or rebates to alter behavior. Incentive schemes are more popular with those being regulated, but in agriculture, require private or public funds to implement and also can suffer from high monitoring costs and lack of flexibility. The third, *community-based approach* would encourage programs led by growers themselves. This approach has the advantage that growers actively design the management program and oversee its implementation, perhaps in collaboration with industry, government and universities. The role of government here is distinctly different from that of the top-down, command-and-control or incentive approaches. It is often as a facilitator and provider of scientific knowledge and complementary investments. Implementation and compliance still require significant design and monitoring effort and cost as well as a clear delineation of the relevant community of stakeholders. Yet, there are past examples in agriculture, such as groundwater management, pest eradication programs, and area-wide invasive weed control programs where community based approaches have succeeded.

Diverse Approaches to Herbicide-Resistant Weed Management

Micheal Owen

The need to expand the adoption of tactics, in addition to herbicides, to more effectively and sustainably manage herbicide-resistant weeds and mitigate the selection for herbicide resistance where it has not yet become a problem is critical. Herbicide resistance in key weeds reflects agricultural systems where herbicides have been the principle and often sole tactic for controlling weeds—the most important pest complex in production agriculture. Historically, a more diverse suite of mechanical and cultural tactics supplemented the herbicide components of a weed management program. However, for the last 15 years, glyphosate has been the primary tactic used on a majority of the row crop acres in the United States. There are many reasons and justifications for this pest control approach including, but not limited to: time management efficiency, cost, effectiveness, and the simplicity and convenience of glyphosate-based weed control. Not unexpectedly, the predominantly short-term and ecologically narrow focus of the approach has resulted in adaptation within weed populations to the extent that it is clear that weed management in crops is not sustainable when based primarily on a single herbicide, in the absence of other herbicides and more diverse management practices. While herbicides will continue to play a significant role in weed management, including those populations that have evolved herbicide resistance(s), innovative new biological, cultural and mechanical approaches that supplement herbicide-based weed management are important parts of successful herbicide-resistant weed management. The key to extending the useful life of herbicides is for weed management advisors to recommend, and decision makers to adopt a diverse suite of tactics, in addition to herbicides, as part of locally customized, holistic and diverse weed management programs to establish sustainable control of weeds including the burgeoning population of herbicide-resistant weeds.

Rethinking Education and Outreach for Successful Herbicide Resistance Management

Amy Asmus and Jill Schroeder

Education is a key component of the outreach effort on Herbicide Resistance Management (HRM). However, traditional approaches for delivery of information must be reevaluated in light of other topics presented at this summit. Grower willingness to accept and use available information and technology to execute best management practices for HRM is complicated by the social, economic, and regulatory barriers to adoption. Therefore, we must consider that the traditional approach of “delivering” education must be accompanied by a clear understanding of the target audiences, a willingness to adopt new, diverse technologies, and engage the affected community in developing solutions. The keys to successful outreach include the recognition that growers have intimate knowledge of what practices work on their farms and they have access to many, sometimes competing and conflicting, information sources. The creators of these information sources and the key influencers have a responsibility to provide complete, non-biased, scientifically-sound and consistent information to decision makers and to be willing to partner with others to provide the best HRM options and advice. The agricultural community must recognize that the resources used by growers, the most effective management practices, and the barriers to adoption of HRM will vary greatly across management systems and regions. Our perception of educators must expand to include not only Extension specialists but also consultants, retailers/dealers, industry representatives, pesticide applicators, commodity organizations, farm press, growers, land managers, federal, state and tribal agencies and others. Education and outreach with regards to HRM must be integrated into all the information provided for crop production and land management. Educators must understand their audience; their learning styles, access to technology and information, risk tolerance, economic flexibility and more. In addition, educators must be flexible in how they structure their outreach, which can include traditional education, but must consider new, non-traditional approaches as well as participating in community-based solutions. Partnerships among stakeholders, including agricultural groups, regulatory agencies, financial providers, retailers, farm managers, industry research, marketing and sales, educators, sociologists and economists are needed to provide current information, to adapt information delivery, and engage communities to solve the herbicide resistance problem.

Carrots and Sticks: Incentives and Regulations for Herbicide Resistance Management

John Soteres, Michael Barrett and David Shaw

A cooperative and coordinated effort of the public and private sectors is required to change the future of herbicide resistance. Financial incentives, whether public or private, can help overcome market-driven (driven by cost and profit) barriers to trial and eventually long term adoption of herbicide resistance best management practices (BMPs). Adoption of insect pest management and soil conservation practices supported by government incentives has been successful when sufficient resources existed to fund and effectively administer the programs. Industry incentives can and have been used to encourage herbicide resistance BMP use. Participation in voluntary, not legally required, herbicide resistance management (HRM) programs can be successful with strong enough incentives, well-defined participation standards, and measured results. Threat of credible government regulation can also serve as a strong incentive for behavior change and participation in voluntary HRM programs. The Environmental Protection Agency - Office of Pesticide Programs (EPA-OPP) regulates herbicide use under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). Discovery of new herbicide resistance is currently reported to EPA under FIFRA section 6(a)(2). It may be within the authority of EPA-OPP to regulate herbicide use for HRM. EPA-OPP can also encourage or require registrants to include proactive herbicide resistance management information on the herbicide label or as part of other activities, such as educational programs. Recently, EPA-OPP proposed requiring a registrant to manage herbicide resistance through a monitoring, reporting and mitigation program. While proactive HRM is preferred, prescriptive herbicides use directions (e.g., application frequency or mandated rotation of mechanisms of action) for HRM is not considered an effective approach as individual farm conditions vary so greatly. Instead, to foster individual and industry innovation, it is more important to allow local flexibility in designing appropriate HRM strategies rather than to attempt to define a "one size fits all" approach. On the other hand, an active monitoring, reporting and mitigation program for new resistance cases has potential, if carefully designed and implemented, to help curb further resistance development and spread.

Key action items to be discussed at the Summit include:

- Increase awareness that everyone engaged with agriculture has a role in managing herbicide resistance and accountability for that role.
- Develop a herbicide resistance management certification program for weed management decision makers and advisors.
- Reduce regulatory barriers to herbicide resistance management; e.g. conservation compliance.
- Establish prototypical, community-based area-wide herbicide resistance management programs for specific threats; e.g. Palmer amaranth in Iowa.
- Communicate the effect of herbicide resistance management on short and long-term farm profitability.
- Implement programs for scouting and controlling weed escapes.
- Provide short-term financial incentives to reduce the cost of developing and implementing field-by-field herbicide resistance management plans.
- Market/promote consistent and scientifically sound herbicide resistance management programs.
- Incentivize innovation in non-chemical weed management practices.