Weed Science

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A progressive approach for integrated pest management

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My view

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Weed scientists have been trying to situate weed management within the framework of integrated pest management (IPM) for decades (McWhorter and Shaw 1982). Cover crops have recently been discussed in this space for their potential to unify efforts toward integrated weed management (IWM) research (Young 2020). In actuality, this apparent resurgence of cover crop research reminds us how IWM has merely coexisted with IPM. Cover crops can indeed support continued development of sustainable weed management, but true integration requires more than coexistence. Weed scientists must think beyond single management practices, whether they be herbicides, cover crops, or any new invention, to work toward IPM. By unifying behind the original goals of IPM, namely pesticide reduction and incorporation of ecological knowledge into agriculture, weed scientists can create progress for our discipline.

Entomologists first started writing explicitly about "integrated control" in the middle of the 20th century, calling for consideration of the detrimental effects of broad-spectrum insecticides on biological controls (i.e., naturally enemies or beneficial predatory insects) (DeBach 1951). Synthetic pesticides like DDT and 2,4-D were becoming more popular in agriculture following their postwar commercialization and through the advent of the Green Revolution. IPM was necessarily a reaction to a sudden reliance on chemical insect control, and IPM practitioners recognized the complementarity of using biological and chemical controls together (Stern et al. 1959). Concerned entomologists recognized that pesticides could be a useful tool for regulating highly disturbed agroecosystems, but also that pesticides are inherently disruptive to the ecological systems on which agriculture is built (Smith and Hagen 1959). For intensified cropping systems increasingly dependent on synthetic inputs, IPM was constructed to reduce dependence on pesticides, though not eliminate them entirely.

Other pest management disciplines became included in IPM while it grew in importance. Interest in IPM expanded alongside the environmental movement, as ecology and sustainability became increasingly popular in the middle of the 20th century (Gay 2012). By the early 1970s, a U.S. government report embraced the potential for IPM, including cultural, mechanical, and biological control, to reduce pesticide risk when used against a wide variety of pests, including weeds (Council on Environmental Quality 1972). Around the same time, the National Science Foundation funded the Huffaker Project, which represented a major step toward broadening the scope of IPM, including making it even more integrative of systems-level ecology and interdisciplinary decision making (Perkins 1982). Furthermore, the namesake of the Huffaker Project, Carl Burton Huffaker, spent parts of his career working on biological control of weeds, such as his research on St. Johnswort (*Hypericum perforatum* L.) in northern California (Perkins 1982). Today, scientific regulators in the United States and Europe continue to include weeds within the definition of IPM (Barzman et al. 2015; *A National Road Map* . . . 2018).

This historical context illustrates two foundational aspects of IPM that remain important: weed science is definitely included as a part of IPM, and weed scientists have the responsibility to develop weed management programs that are not focused on herbicides. A false distinction between weeds and pests inhibits progress toward the goal of reducing pesticide dependency. For example, entomologists have realized the challenge of the "other IPM," that is, integrated pesticide management, resistance management, and pesticide substitution masquerading together as IPM (Ehler 2006). Weed scientists have been facing the same issues for decades, but the lack of a common IPM framework and language has caused us to continue to adhere to the other IPM while entomologists have found relative success. While many weed scientists do understand the underlying inclusion of weeds in IPM, a preponderance of weed science literature refers to IWM. Weed scientists' self-imposed separation of IWM and IPM is harmful to the interdisciplinary cooperation that is critical for the ecological, agronomic, and practical development of IPM.

Weed scientists have further entrenched IWM by refining IPM to apply only to weeds. Frameworks detailing levels of integrated management based on space, time, and practice have been created for IWM (Cardina et al. 1999; Swanton and Weise 1991). Useful though these frameworks may be, they are basically translations, rather than extensions, of existing IPM frameworks. Herbicides continue to represent the logical basis of IWM, even though contemporary IPM models focus more on biologically intensive management of all kinds of pests

(Kogan 1998). The diversified management practices called for in IWM are typically in addition to conventional herbicide programs, making IWM fall behind IPM in terms of pesticide reduction.

There are, of course, strong reasons for using different practices to manage weeds compared with other types of pests, but these reasons do not preclude weed scientists from using the same ecological approaches and systems thinking required by IPM. In fact, the differences between weeds and pests at higher trophic levels can cause the interactions that necessitate concurrent management of all pests (Norris 2005). Certain specific practices do not apply to weeds and other pests in the same way, but IPM gives us the ecological knowledge to understand why one pest management practice can lead to divergent results. Weed scientists do not need to throw out all of IPM just because weed populations sometimes become unmanageable when applying economic action thresholds, for example; we can use IPM to choose a relevant practice based on ecological awareness, such as awareness of weeds' higher fecundity and longer generation time compared with other pests.

I agree with a recent paper arguing that cover crops are aligning current trends in weed science with IPM (Young 2020). No fewer than a dozen studies focusing on cover crops have been published in *Weed Science* since 2018, as indexed by Web of Science. This line of research has a long history, however, with studies of weed-suppressing cover crops in the literature for decades (Barnes and Putnam 1983; Teasdale et al. 1991). Cover crops give weed scientists the opportunity to do whole-ecosystem research on a cultural practice that shifts weed management from an exercise in control to a more delicate balancing act. When weed-suppressing cover crops can potentially provide rodent habitat, vector fungal diseases, and host insect pests, the necessity of a broader IPM approach becomes clear. Agroecosystem-level thinking is further underscored by the many relationships cover crops have with soil health, water and irrigation, agronomic or horticultural logistics, and other factors across the agroecosystem.

Despite the merits of cover crops, it is important to recognize that cover crops in themselves cannot unlock IPM. Replacing herbicides with cover crops as the main tool for weed management would not bring about a new era of IPM; it would serve to reinforce the existing dichotomous frameworks (i.e., deciding whether management programs are more or less integrated) that underpin IWM. Weed scientists can realize new progress toward IPM by recommitting not to individual management practices, but to the biology and ecology that has always been central to our discipline. This basic understanding is essential for using IPM to understand how a variety of weed management practices will affect a particular cropping system. Yes, new management practices like cover crops use ecological design that contributes to IPM, but IPM must be more than the arbitrary stacking of new pest management practices (Ehler and Bottrell 2000). IPM requires us to judiciously integrate multiple management practices using biological and ecological principles.

Scientific reductionism and the nature of applied research can slow progress toward integrative discovery, but weed scientists have many opportunities for new and specific lines of study that build IPM. A dearth of information about genetics, population biology, soil seedbanks, and ecological interactions for many weed species represents a virtually limitless opportunity for basic research that can serve IPM. Likewise, new and renewed management practices, such as harvest weed seed control, robotic cultivators, or thermal weeders, can be researched as input substitutions to meet pesticide reduction goals. Various IPM frameworks also call for research dealing with weed prevention, biopesticides, precision agriculture, and weed monitoring.

Biological weed management is an original tenet of IPM that also demands renewed interest from weed scientists. As demonstrated by cover crops, consideration of cultural practices and the whole cropping system is an important feature of weed science research that can only flourish under IPM. Cover crops and other forms of biologically intensive management certainly add more complexity to agricultural management compared with the practices listed in the previous paragraph. This type of complexity, however, is exactly the kind of challenge IPM allows us to embrace. By understanding site-specific ecological factors that make biological pest management possible, weed scientists can move toward the biological integration that is fundamental to IPM.

Beyond new management research, IPM is most exciting in how it supports a reimagining of what weed science represents as a discipline. Despite its organization alongside the development of synthetic herbicides, weed science has never only been about killing plants. Weed science is meant to protect agriculture and other managed ecosystems, but much of the discipline eschews environmental protection in favor of exerting power over plants. IPM offers a framework for us to focus less on controlling weeds and more on understanding them. Pesticide reduction is now more important than ever, considering herbicide-resistant weeds, climate change, agricultural extensification, and other factors. But weed management with fewer herbicides requires more insights into how weeds move, change, and interact within their environment. IPM allows weed scientists to make progress toward a future with both fewer weed problems and stronger agroecosystems.

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