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Editorial: Weed Biology and Ecology in Agroecosystems

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Editorial on the Research Topic

Weed Biology and Ecology in Agroecosystems

SUMMARY

Novel tactics are needed to manage herbicide resistant weeds. The most successful strategies will likely incorporate multiple tactics, such as chemical, cultural, and mechanical methods, in an integrated weed management (IWM) approach. All of these methods should target weak points in the species life cycle, which are best identified through detailed knowledge of weed biology and ecological interactions. The knowledge needed to create successful IWM systems spans a wide breadth of scientific disciplines. This special topic in Weed Biology and Ecology covers aspects of weed evolution and community shifts, seedbank biology, and the combination of multiple tactics in an IWM approach, including decision support tools and the use of lasers. An examination of the role of herbicides in IWM is also included. These contributions represent various perspectives on IWM and represent a framework for considering weed management in an agroecosystem through a multidisciplinary lens focused on weed biology and ecology.

An understanding of weed biology and ecology is critical to the ability to create an effective weed management program. As the global occurrence of novel herbicide resistant biotypes continues to increase, an enhanced focus is being placed upon Integrated Weed Management (IWM), which combines multiple practices with biological and ecological considerations, including chemical, cultural, and mechanical methods (Bagavathiannan and Davis, 2018; Gage and Schwartz-Lazaro, 2019). Examples of plant traits which promote success of weedy species in agroecosystems are tolerance to disturbance and stress, genetic variation, phenotypic plasticity, variable seed dormancy, rapid seed germination and growth, prolific seed production, effective dispersal, rapid nutrient sequestration, and production of allelopathic exudates. Through an understanding of weed biology and ecology, it is possible to identify integrated methods and application timings which provide the greatest impact on the reduction of weed seeds which are returned to the system. New technological adaptations, such as harvest weed seed control, precision agriculture, robotics, herbicide tolerance traits, competitive cultivars, biocontrols, and others, are advancing the possibilities for successful weed control programs when combined with knowledge of weed biology and ecology.

We consider our special topics issue as a call to action to present new insights or perspectives in the use of weed biology and ecology to form the basis of management in agroecosystems. Therefore, in preparing this issue, we have brought together authors and reviewers from a wide array of disciplines from around the world to provide several avenues of research. From the

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resulting set of manuscripts, several overarching themes emerged: (1) weed species evolution and community shifts in response to management, (2) integrating knowledge of seedbank biology in management, (3) role of weed biology and ecology in IWM, including decision support tools and advanced technologies to enhance weed management, and (4) transitioning away from reliance upon chemical control.

The characteristic traits of weedy species which promote success in managed habitats may allow rapid evolution of weeds (e.g. changes in genotype, phenotype, geographic range, or competitive ability) in response to disturbance, stress, and management. Understanding the rate and mechanisms of weed evolution can help facilitate the design of programs that minimize undesirable adaptations through management of weed survivorship and fecundity. While management associated with crop production has been an ancient form of selection pressure contributing to weed evolution, natural selection has also continued to act upon domesticated crop species, leading to the de-domestication of crops as they evolve weedy traits (Ellstrand et al., 2010). This selection pressure has led to independent de-domestication events in weedy/red rice (*Oryza* spp.), with the confirmation by Vigueira et al. that weedy rice populations in South Korea and the United states are genetically distinct. Two traits most often cited as the basis for the evolution of weedy rice are seed shattering and dormancy, but less is known about vegetative traits (plant stature, nitrogen assimilation, photosynthetic capacity, etc.). In a study of 14 accessions of weedy rice from the United States and South Asia, Huang et al. found that there is no consistent vegetative trait or physiological mechanism that has led to de-domestication in weedy rice, which supports the idea of multiple pathways to the evolution of weediness. Hybridization events between crop species and their wild relatives has been associated with rapid adaptation and evolution of crop-wild hybrids (Campbell and Snow, 2007; Hovick et al., 2012; Hartman et al., 2013). However, in a study of 40 weedy *Raphanus* populations, Shukla et al. found that evolution rates of crop-wild hybrids were lower than those of weedy populations, but crop-wild hybrids exhibited traits associated with increased fitness that were consistently expressed across a moisture gradient. The response of individual species to management may also lead to community shifts, according to species functional traits, as was documented by Cordeau et al. in response to long-term soil nutrient management. Knowledge of the response of the weed community to management may allow future manipulation to selectively favor less economically damaging species.

Successful weed management can be observed in weed seedbank reduction. While most traditional management programs target weeds in the vegetative stage of growth, new technologies in harvest weed seed control are expanding opportunities to manage the seedbank (Walsh et al., 2013, 2018; Schwartz-Lazaro et al., 2017; Shergill et al., 2020). Once seed rain occurs, seeds may persist for long periods of time in the soil seedbank (Burnside et al., 1996; Conn et al., 2006). An example of the role of seed dormancy and fecundity in weediness can be seen in the *Echinochloa* species, in which Tahir and Burgos rated 94 accessions and determined that both factors varied greatly among and within each species. This impacts the longevity of each species in the soil seedbank. Further effects on the soil seedbank can be impacted not only by a weed's biology and ecology, but by IWM practices, such as cover crops. Nichols et al. examined fields beginning in either a corn or soybean rotation and the effects of winter cover cropping on the weed communities and changes in the soil seedbank composition over time. They found that increases in cover crop biomass did not correlate to weed suppression or reductions in the soil seedbank, which is the opposite of previous studies (Moonen and Bàrberi, 2004; Mirsky et al., 2010; MacLaren et al., 2019; Smith et al., 2020). However, it can be concluded that the combined impacts of crop rotation and cover crops, with additional weed management tactics, can reduce the weed seedbank.

Another emergent theme is understanding the importance of weed biology and ecology in improving IWM programs. Herbicides are an essential IWM tool and understanding the evolution and distribution of herbicide resistant weeds is vital. Jones et al. screened 239 samples of *Lolium perenne* across four different herbicide sites of action and confirmed some level of herbicide resistance to three of the four sites of action. This level of resistance resulted in elimination of a critical herbicide application timing. Thus, considering the increasing concern of availability and efficacy of herbicides, non-chemical weed management tactics, such as the use of cover crops, decision support tools, and advanced technologies, need to be examined. Cover crops provide several ecological services in addition to weed suppression, such as reduced soil erosion, enhanced nutrient cycling, reduction of nitrate leaching, and improved water quality of agricultural field runoff (Ruffo et al., 2004; Strock et al., 2004; Snapp et al., 2005; Hodgdon et al., 2016; Osipitan et al., 2018, 2019). Determining the proper level of cover crop biomass for weed suppression, coupled with proper cover crop termination timing, is critical to protect crop yields. Vollmer et al. found that for cereal rye, summer annual weed control was improved with delayed termination timing to allow for biomass to accumulate. Lacroix et al. developed IPSIM-Cirsium to evaluate varying infestation levels of *Cirsium arvense* as a function of farming practices, environmental conditions, and soil types. This is similar to another decision support tool, Palmer amaranth Management Model (PAM), that allows farmers to input their management practices to determine how to best drive down the soil seedbank (Lindsay et al., 2017). Additional novel non-chemical weed management tactics include the use of low energy lasers to control weed species such as *Lolium rigidum* (Coleman et al.) and the use of harvest weed seed control tactics in combination with other cultural (e.g., planting date and cover crops) weed management tactics (Beam et al.). The use of each additional IWM tactic consistently drove down weed populations over time (Thill et al., 1991; Norsworthy et al., 2012). These research findings assist in developing novel weed control options in conservation cropping systems, and the success of implementation hinges on an understanding of weed biology and ecology.

In addition to presenting novel research and technological advancements in weed biology and ecology, compelling perspectives on the future of IWM were made. For example, Colbach et al. found that although it has been well-documented that weed species contribute to crop yield loss (Cousens, 1985; Weaver et al., 1987; Blackshaw, 1993; Knezevic et al., 1994; Chikoye et al., 1995), there is a need to transition away from extended herbicide use, which rarely result in increased weed infestations if additional IWM tactics are utilized. Further specific parameters can affect this relationship between weed infestations and reduction in crop yields, such as weather and soil conditions, species combinations, and other variables (Bauer et al., 1991; Lindquist et al., 1996), and studies which isolate individual parameters and elucidate the individual role of herbicides are needed.

To understand the complexity of agroecosystems, a multidisciplinary and collaborative approach is needed. Like IWM systems, a diverse approach to weed ecology and biology can be combined to provide a larger picture of the problem at hand. It is important that this collaborative effort includes people from academia, industry, farmers, and public citizens. There have been similar calls to action (Davis et al., 2009; Ward et al., 2014; Müller-Schärer et al., 2018). One common theme is a focus on innovation in teaching and training students to solve complex problems in agroecosystem management, as well as increased networking and cooperation, technology transfer, and knowledge sharing between scientists in diverse yet complimentary fields of research (Chauhan et al., 2017). Long-term funding to support multidisciplinary approaches may be difficult to maintain, but some model outreach initiatives which incorporate weed biology education have emerged, such as the Australian Herbicide Resistance Initiative (AHRI), Getting Rid of Weeds through Integrated Weed Management (GROW) and the United Soybean Board's TakeAction campaign in the US, and the Southeast Asian Regional Centre for Tropical Biology (SEAMEO BIOTROP). As current and future agronomists, ecologists, biologists, weed scientists, social scientists, etc., it is our responsibility to engage those who will work toward creating significant and meaningful changes within agroecosystems.

AUTHOR CONTRIBUTIONS

LS-L, KG, and BC wrote and edited the article. All authors contributed to the article and approved the submitted version.

REFERENCES

Bagavathiannan, M. V., and Davis, A. S. (2018). An ecological perspective on managing weeds during the great selection for herbicide resistance. *Pest Manag. Sci.* 74, 2277–2286. doi: 10.1002/ps.4920

Bauer, T. A., Mortensen, D. A., Wicks, G. A., Hayden, T. A., and Martin, A. R. (1991). Environmental variability associated with economic thresholds for soybeans. *Weed Sci.* 39, 564–569.

Blackshaw, R. E. (1993). Downy brome (*Bromus tectorum*) density and relative time of emergence affect interference in winter wheat (*Triticum aestivum*). *Weed Sci.* 41, 551–556.

Burnside, O. C., Wilson, R. G., Weisberg, S., and Hubbard, K. G. (1996). Seed longevity of 41 weed species buried 17 years in eastern and western Nebraska. *Weed Sci.* 44, 74–86.

Campbell, L. G., and Snow, A. A. (2007). Competition alters life history and increases the relative fecundity of crop-wild radish hybrids (*Raphanus* spp.). *New Phytol.* 173, 648–660. doi: 10.1111/j.1469-8137.2006.01941.x

Chauhan, B. S., Matloob, A., Mahajan, G., Aslam, F., Florentine, S. K., and Jha, P. (2017). Emerging challenges and opportunities for education and research in weed science. *Front. Plant Sci.* 8:1537. doi: 10.3389/fpls.2017.01537

Chikoye, D., Weise, S. F., and Swanton, C. J. (1995). Influence of common ragweed (*Ambrosia artemisiifolia*) time of emergence and density in white bean (*Phaseolus vulgaris*). *Weed Sci.* 43, 375–380.

Conn, J. S., Beattie, K. L., and Blanchard, A. (2006). Seed viability and dormancy of 17 weed species after 19.7 years of burial in Alaska. *Weed Sci.* 54, 464–470. doi: 10.1614/WS-05-161R.1

Cousens, R. (1985). A simple model relating crop yield loss to weed density. *Ann. App. Biol.* 107, 239–252.

Davis, A. S., Hall, J. C., Jasieniuk, M., Locke, M. A., Luschei, E. C., Mortensen, D. A., et al. (2009). Weed science research and funding: a call to action. *Weed Sci.* 57, 442–448. doi: 10.1614/WS-09-020.1

Ellstrand, N. C., Heredia, S. M., Leak-Garcia, J. A., Heraty, J. M., Burger, J. C., Yao, L., et al. (2010). Crops gone wild: evolution of weeds and invasives from domesticated ancestors. *Evol. Appl.* 3, 494–504. doi: 10.1111/j.1752-4571.2010.00140.x

Gage, K. L., and Schwartz-Lazaro, L. M. (2019). Shifting the paradigm: an ecological systems approach to weed management. *Agriculture* 9:179. doi: 10.3390/agriculture9080179

Hartman, Y., Uwimana, B., Hooftman, D. A. P., Schranz, M. E., van de Wiel, C. C. M., Smulders, M. J. M., et al. (2013). Genomic and environmental selection patterns in two distinct lettuce crop-wild hybrid crosses. *Evol. Appl.* 6, 569–584. doi: 10.1111/eva.12043

Hodgdon, E. A., Warren, N. D., Smith, R. G., and Sideman, R. G. (2016). In-season and carry-over effects of cover crops on productivity and weed suppression. *Agron. J.* 108, 1–12. doi: 10.2134/agronj2015.0419

Hovick, S. M., Campbell, L. G., Snow, A. A., and Whitney, K. D. (2012). Hybridization alters early life-history traits and increases plant colonization success in a novel region. *Am. Nat.* 179, 192–203. doi: 10.1086/663684

Knezevic, S. Z., Weise, S. F., and Swanton, C. J. (1994). Interference of redroot pigweed (*Amaranthus retroflexus*) in corn (*Zea mays*). *Weed Sci.* 42, 568–573.

Lindquist, J. L., Mortensen, D. A., Clay, S. A., Schemnk, R., Kells, J. J., Howatt, K., et al. (1996). Stability of coefficients in the corn yield loss-velvetleaf density relationship across the north central US. *Weed Sci.* 44, 309–313.

Lindsay, K., Popp, M., Norsworthy, J. K., Bagavathiannan, M., Powles, S., and Lacoste, M. (2017). PAM: decision-support for long-term palmer amaranth (*Amaranthus palmeri*) control. *Weed Technol.* 31, 915–927. doi: 10.1017/wet.2017.69

MacLaren, C., Swanepoel, P., Bennett, J., Wright, J., and Dehnen-Schmutz, K. (2019). Cover crop biomass production is more important than diversity for weed suppression. *Crop Sci.* 59, 733–748. doi: 10.2135/cropsci2018.05.0329

Mirsky, S. B., Gallandt, E. R., Mortensen, D. A., Curran, W. S., and Shumway, D. L. (2010). Reducing the germinable weed seedbank with soil disturbance and cover crops. *Weed Res.* 50, 341–352. doi: 10.1111/j.1365-3180.2010.00792.x

Moonen, A. C., and Bàrberi, P. (2004). Size and composition of the weed seedbank after 7 years of different cover-crop-maize management systems. *Weed Res.* 44, 163–177. doi: 10.1111/j.1365-3180.2004.00388.x

Müller-Schärer, H., Sun, Y., Chauvel, B., Karrer, G., Kazinczi, G., Kudsk, P., et al. (2018). Cross-fertilizing weed science and plant invasion science to improve efficient management: a European challenge. *Basic Appl. Ecol.* 33, 1–3. doi: 10.1016/j.baae.2018.08.003

Norsworthy, J. K., Ward, S. M., Shaw, D. R., Llewellyn, R. S., Nichols, R. L., Webster, T. M., et al. (2012). Reducing the risks of herbicide resistance: best management practices and recommendations. *Weed Sci.* 60, 31–62. doi: 10.1614/WS-D-11-00155.1

Osipitan, O. A., Dille, J. A., Assefa, Y., and Knezevic, S. Z. (2018). Cover crop for early season weed suppression in crops: systematic review and meta-analysis. *Agron. J.* 110, 2211–2221. doi: 10.2134/agronj2017.12.0752

Osipitan, O. A., Dille, J. A., Assefa, Y., Radicetti, E., Ayeni, A., and Knezevic, S. Z. (2019). Impact of cover crop management on level of weed suppression: a meta-analysis. *Crop Sci.* 59, 833–842. doi: 10.2135/cropsci2018.09.0589

Ruffo, M. L., Bullock, D. G., and Bollero, G. A. (2004). Soybean yield as affected by biomass and nitrogen uptake of cereal rye in winter cover crop rotations. *Agron. J.* 96, 800–805. doi: 10.2134/agronj2004.0800

Schwartz-Lazaro, L. M., Norsworthy, J. K., Walsh, M. J., and Bagavathiannan, M. V. (2017). Efficacy of the integrated harrington seed destructor on weeds of soybean and rice production systems in the Southern United States. *Crop Sci.* 57, 2812–2818. doi: 10.2135/cropsci2017.03.0210

Shergill, L. S., Schwartz-Lazaro, L. M., Leon, R., Ackroyd, V. J., Flessner, M. L., Bagavathiannan, M., et al. (2020). Current outlook and future research needs for harvest weed seed control in North American cropping systems. *Pest Manag. Sci.* 76, 3887–3895. doi: 10.1002/ps.5986

Smith, R. G.,Warren, N. D., and Cordeau, S. (2020). Are cover crop mixtures better at suppressing weeds than cover crop monocultures? *Weed Sci.* 68, 186–194. doi: 10.1017/wsc.2020.12

Snapp, S., Swinton, S., Labarta, R., Mutch, D., Black, J., Leep, R., et al. (2005). Evaluating cover crops for benefits, costs and performance within cropping system niches. *Agron. J.* 97, 322–332. doi: 10.2134/agronj2005.0322a

Strock, J., Porter, P., and Russelle, M. (2004). Cover cropping to reduce nitrate loss through subsurface drainage in the northern US Corn Belt. *J. Environ. Qual.* 33, 1010–1016. doi: 10.2134/jeq2004.1010

Thill, D. C., Lish, J. M., Callihan, R. H., and Bechinski, E. J. (1991). Integrated weed management-a component of integrated pest management: a critical review. *Weed Technol.* 5, 648–656.

Walsh, M., Newman, P., and Powles, S. (2013). Targeting weed seeds in-crop: a new weed control paradigm for global agriculture. *Weed Technol.* 27, 431–436. doi: 10.1614/WT-D-12-00181.1

Walsh, M. J., Broster, J. C., Schwartz-Lazaro, L. M., Norsworthy, J. K., Davis, A. S., Tidemann, B. D., et al. (2018). Opportunities and challenges for harvest weed seed control in global cropping systems. *Pest Manag. Sci.* 74, 2235–2245. doi: 10.1002/ps.4802

Ward, S. M., Cousens, R. D., Bagavathiannan, M. V., Barney, J. N., Beckie, H. J., Busi, R., et al. (2014). Agricultural weed research: a critique and two proposals. *Weed Sci.* 62, 672–678. doi: 10.1614/WS-D-13-00161.1

Weaver, S. E., Smits, N., and Tan, C. S. (1987). Estimating yield losses of tomato (*Lycopersicon esculentum*) caused by nightshade (*Solanum* spp.) interference. *Weed Sci.* 35, 163–168.

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