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Editorial: Integrated weed management for reduced weed infestations in sustainable cropping systems

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Editorial on the Research Topic
Integrated weed management for reduced weed infestations in sustainable cropping systems

Summary

Weeds are a major biotic constraint of agricultural systems worldwide interfering with crop production and resource use efficiency (Oerke, 2006; Colbach et al., 2020). Chemical control is a cost- and time-effective weed management method and for that reason remains as the most widely and frequently used method to sustain agricultural productivity and food security in the current era. However, repeated use of a limited number of herbicide active ingredients in non-diversified crop rotations enhances the selection of herbicide-resistant weed biotypes. The over-reliance on chemical weed control has led to shifts in weed communities (Mahaut et al., 2019) which are now becoming dominated by highly competitive and herbicide-resistant prone species able to cause significant yield losses (Adeux et al., 2019b). Widespread herbicide resistance (Heap, 2023) accompanied by the increasing concern of herbicides entering the food chain and/or impacting the environment has created a tremendous demand for alternative weed management methods.

Alternative weed management practices that reduce weed populations indirectly lowers selection pressure thus helping delay the evolution of further herbicide resistance. Controlling weeds during the critical period of weed removal is paramount for achieving the full yield potential of any crop (Zimdahl, 1988; Colbach et al., 2020). In conservation tillage with cover cropping, research on the critical period of weed removal is warranted to further elucidate cover crop weed suppressive attributes and efficient utilization of herbicides (Kumari et al.). Preventive weed control measures include all the possible means that restrict the entry and establishment of weeds in an area. Cultural control is an ecological method of weed control in which good crop management methods are followed to stimulate rapid crop growth and canopy closure (Petit et al., 2018). Cultivar selection, planting time, seeding rate and method, fertilizer rates, and water management are some of the critical agronomic management decisions that can not only impact yield but also the time of crop and weed emergence thus crop-weed interactions (Kaur et al., 2018). The use of organic or plastic mulch is another alternative weed control strategy, mainly for specialty crops (Schonbeck, 1999). Physical weed control measures such as burning, flame weeding, and soil steaming can be used to effectively control weed emergence and growth through plant or seed exposure to high temperatures. An integrated approach incorporating soil steaming, cover crops, and mulching can result in reduced herbicide reliance and effective weed control (de Oliveira et al.).

Complete reliance on any one weed management practice, either chemical or non-chemical, may fail within a relative short time due to the rapid evolutionary ability of weeds (Neve et al., 2009). Integrated weed management (IWM) relies on a combination of multipronged measures deployed in a compatible manner aimed at reducing weed populations while sustaining the crop yield potential (Swanton and Weise, 1991; Kudsk, 2022). In IWM systems, cultural, mechanical, biological, and/or chemical strategies can be deployed to reduce weed seed germination, establishment, crop-weed competition, and the influx of weed seeds into the soil seedbank. While non-chemical weed management options are largely exploited in organic agricultural systems, the use of bioherbicides is an area that warrants further research (Cordeau et al., 2016; Triolet et al., 2020). The use of biocontrol agents can also be exploited for control of troublesome weeds such as *Puccinia punctiformis* for control of *Cirsium arvense* (Chichinsky et al.).

IWM decision-making process relies on environmental information, weed biology and ecology to control weeds in the most economical and sustainable possible way (Sanyal, 2008). Various methods, such as weed seed predation with granivorous fauna-ants, selective weeding of escaped weed plants, uprooting/hand pulling of weeds before seed setting, mechanical weed seed harvest, chaff lining, etc., can be used to prevent the spread and seedbank enrichment of weeds. The dispersal of weed seeds and vegetative propagules allow their territorial expansion (Benvenuti, 2007; DiTommaso et al., 2018). Dispersal of weed seeds is facilitated by many dispersal agents including wind, water, soil, crops, manure, and animals. However, ensiling conditions, livestock ingestion, and manure management can reduce weed seed viability thus be effective integrated non-chemical weed management options (Asaduzzaman et al.).

Weed distribution and management surveys can be important decision-support tools to identify common weed management challenges and the short- and long-term impact of IWM and other practices on weed populations. For instance, information gathered from the survey by Butts et al. provided direct insights into current rice weed management practices and a better understanding of current concerns. Crop-weed competition modelling can help defining the relationship between crop yield loss and weed density (or biomass) accounting for specificities of the weed species, crop and location. The shifts in weed spectrum and weed emergence time may affect the yield density equation, and improved knowledge of weed emergence periodicity may be used to enhance management tactics (Brown et al.). Models of crop-weed interference can contribute to improved weed management strategies and evaluation of weed control programs (Singh et al., 2020; Colbach et al., 2021).

Simplified cropping systems/rotations create and maintain a favorable environment for annual weeds whose emergence and growth phenology are similar to these crops, and its diversification may contribute to effective weed control. Practicing the same cropping sequence year after year leads to the simplification of management practices, including herbicide programs, which may eventually result in increased weed pressure threatening the sustainability of crop production. Crop diversification is an important component of IWM programs (Adeux et al., 2019a), and is one of the three principles in conservation agriculture systems (FAO, 2021; Cordeau, 2022). Differences in crop phenology and diverse management tactics can lead to a net loss in weed seed population density and composition in the soil seed bank, and reduced weed biomass (Liebman and Gallandt, 1997; MacLaren et al., 2020) (Nguyen and Liebman, Nguyen and Liebman). Cropping systems affected the germination patterns of most of the weed species due to differential selection pressures of IWM practices followed in these systems (Cordeau et al.). Rotating crops with dissimilar life cycles, or crops which require different agronomic practices, can help interrupt the weed life cycle. A change in the crop facilitates the change in planting time of the crop and use of different weed control practices along with herbicide rotation; thus, provide effective management of a particular weed species. Long-term cropping system experiment can be a powerful tool to compare the short and long-term outcomes of IWM strategies.

Besides providing effective weed suppression (Osipitan et al., 2018; Rouge et al., 2023), well-managed cover crops perform other ecological functions such as accumulating soil organic carbon, moderating soil temperature, improving water infiltration, improving water storage, reducing soil erosion, and reducing nitrate leaching. However, few studies showed that cover crops had no effect on weeds in the subsequent crops when cover crop did not accumulate enough biomass to impact weeds emergence through a mulch effect, or when cover crops were terminated by tillage and/or when in-crop weed management relied on herbicides, and concluded that intensive weed management could override the potential effect of cover crops on weeds in the subsequent crops (Adeux et al., 2021).

Conclusions

Weeds pose a major challenge to the sustainability of agricultural production systems, causing significant crop yield and economic losses. Chemical weed control tactics play a major role in weed management, maintaining the productivity of diverse cropping systems, reducing yield losses and facilitating conservation agriculture. However, limiting the reliance on a unique management lever, regardless its efficacy or cost, is critical for the sustainability of all cropping systems. IWM aims to diversify weed management strategies mainly by the means of non-chemical control methods, so that reliance on herbicides can be reduced (Shaner, 2014). IWM strategies involve a combination of physical, chemical and biological tools in an integrated way, without excessive reliance on any single measure. IWM can be a successful approach for managing the herbicide-resistant weeds and sustain crop production and global food security. Innovative and feasible IWM systems may be designed for diverse production situations that can reduce weed infestations and environmental impacts, and prolong the use of herbicides. Further improvement in the implementation of IWM approach requires support from governmental agencies, extension services, social scientists, marketing professionals, the crop protection manufacturing and distribution industry, along with weed scientists and farmers.

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