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OPINION ARTICLE

Weed biology: An important science to develop effective weed management strategies

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ABSTRACT

The world's population is increasing at an alarming rate and to feed this population, food production needs to be increased significantly. There are several abiotic and biotic factors affecting the productivity of crops. Among biotic factors, weeds are the most important constraint to crop production throughout the world. They cause a huge yield loss in different crops and cost growers a significant amount of money. Herbicides are widely used to control weeds; however, there are concerns over the evolution of resistance in weeds, limited availability of herbicides with new modes of action, and environmental pollution. These issues suggest the need to reduce reliance on herbicides and develop sustainable weed management programs. However, to develop such programs, there is a need to gain a better understanding of weed biology. This article briefly describes the importance of weed biology in managing weeds.

Keywords: Genetic diversity; Phenology; Seed ecology; Weed biology; Weed emergence; Weed management

INTRODUCTION

The global population is expected to be increased by 1 billion in the next 10 years and to feed this ever-increasing population, food production needs to be increased significantly. Several abiotic (*e.g.*, drought, flood, heat, *etc*.) and biotic (*e.g.*, insects, diseases, weeds, *etc*.) factors adversely affect the productivity of a crop. Among biotic factors, weeds are one of the most important constraints to crop production. In fact, weeds cause the highest potential crop yield loss among different pests (Oerke 2006). In India, for example, they cost more than US$ 11 billion each year to the Indian agricultural sector (Gharde *et al.* 2018). In Australia, weeds cost more than US$ 2 billion each year to grain growers (Llewellyn *et al.* 2016). These monetary values suggest that weeds cost agricultural production in low-income as well as high-income countries.

Herbicides are widely used to control weeds. Because of quick results and ease to use, herbicide use is replacing hand weeding in countries, where it was a common practice in the past. Sole reliance on herbicides, however, has resulted in the evolution of resistance in several weed species throughout the world. Globally, more than 500 unique cases of herbicide-resistant weeds have been reported and out of these, about 20% are from Australia (Heap 2022). Only three herbicide-resistant weed species (*Phalaris minor*, *Rumex dentatus*, and *Cyperus difformis*) have been reported from India; however, these limited numbers could be due to unawareness of the reporting procedure and limited research done on this aspect in India. In addition to the risk of developing resistance in weeds, there are concerns over the limited availability of chemicals with a new mode of action and environmental pollution. Recent reports on health concerns over the use of glyphosate have resulted in the ban of this most effective herbicide in some regions. These issues have challenged weed scientists around the world to develop ecologically-based weed management programs that rely less on herbicides. However, to develop such programs, detailed knowledge of weed biology and ecology is a prerequisite.

Previous review and perspective articles from my lab described in detail the importance of weed biology in improving the management of weeds (Chauhan 2012; Chauhan 2020; Chauhan and Johnson 2010; Chauhan *et al.* 2017; Mahajan and Chauhan 2020); therefore, this article will only briefly highlight the importance of weed biology. Weed biology is a broad topic and it is not possible to cover all the aspects of weed biology in this article. Seed ecology (including, seed bank dynamics), weed

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emergence patterns, weed phenology, phenotypic plasticity, fitness penalty (in relation to herbicide resistance), and genetic diversity are some of the components of weed biology. We, researchers and extension specialists, must understand that weed biology studies do not create new management products (*e.g.,* herbicides). These studies provide a concept for weed management, which weed scientists need to use in making informed decisions in the selection of weed control tactics for the industry.

Seed ecology

Seed germination and seedling emergence are affected by several environmental factors, such as temperature, light, water stress, seed burial depth, crop residue retention, flooding depth, *etc*. Information on the germination response of a weed species to these factors can help develop effective weed management programs through either suppressing germination or encouraging germination at times when weeds can easily be controlled (Chauhan and Johnson 2010). For example, information on the maximum depth, from which a weed species could emerge, helps in selecting tillage systems to bury seeds deep in the soil or promote their germination. Knowledge of vertical seed placement in the soil also indicates relative seed bank persistence life. For example, seeds on the soil surface under no-till farming systems would deplete faster than seeds buried in the soil under conventional-tilled farming systems (Chauhan *et al.* 2006). In a recent study, germination of *Phalaris paradoxa* was found to be very low on the soil surface (Kibasa *et al.* 2022). The authors suggested that adopting no-till systems could inhibit the germination of this species. Therefore, knowledge generated from seed ecology studies strengthens integrated weed management programs.

Emergence pattern

Weed emergence is a key process in determining the number of weed plants and their timing of appearance. Information on weed emergence patterns (i.e., these two variables) justifies or does not justify the application of herbicides to the crop. Predicting weed emergence timings can strengthen integrated weed management programs (Grundy 2003) by implementing models into technological platforms, such as software or Apps. This will be very important in dryland farming systems. Differential emergence patterns of different populations of a weed species indicate the occurrence of different emergence ecotypes and such knowledge highlights the need to adopt more location-specific and diversified weed control strategies to manage weed seed banks (Kumar *et al.* 2018).

Phenology

Phenology is the study of the timing of plant growth stages in response to environmental factors. Because of less interest in weed biology, crop phenology is heard and known more than weed phenology. Weed phenology is an important factor in understanding weed-crop competition. There are several factors affecting weed phenology but temperature and photoperiod are the most important factors, especially in irrigated conditions. Knowledge of phenology is critical to understand weed growth, weed seed production, weed biomass, and the level of potential competition with various crops. Phenology can also provide information if a particular weed species could be targeted using harvest weed seed control practices.

A recent study on *Echinochloa colona* phenology reported that this weed could emerge throughout the year in the eastern cropping systems of Australia (Chauhan 2022). This weed produced a considerable number of seeds at all planting times (**Figure 1**). Although *E. colona* is a summer weed species, these results suggest that it has the potential to expand its seasonality. Seasonal expansion is not new in weed species but in-time information could help tackle such weeds in a better way.

Genetic diversity

Genetic diversity is the heritable genetic variation within and among populations of a weed species (Li *et al.* 2007). It is one of the most important reasons for the success of a weed species. Information on genetic diversity helps in understanding the ability of a weed to adapt to different environments and the impact of herbicide selection on weed populations.

A species showing a high genetic variation would require a variety of control measures and constant changes in management practices to counter adaptation in weed populations (Bommarco *et al.* 2010). A recent study, for example, reported that high genetic diversity was present in *E. colona* populations from the Queensland and New South Wales states of Australia (Chauhan *et al.* 2022). The authors concluded that this response was indicative of free gene flow or herbicide resistance had evolved multiple times in this species. The study also indicated that the frequent use of herbicides for *E. colona* control may be the most important factor in the current extent of herbicide resistance observed in this species.

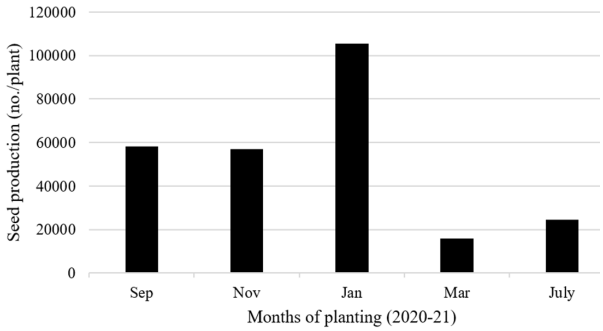

Figure 1. Seed production of *Echinochloa colona* when planted at Gatton, Queensland, Australia, in different months (Chauhan 2022).

Conclusions

Weeds will keep adapting to different management practices. Therefore, we need to be proactive and understand their biology before they become very problematic. Just relying on one tool (e.g., herbicides) for their management will not be enough. Based on weed biology knowledge, diversified weed management programs need to be developed. Such programs should not eliminate the use of herbicides but increase efficiency of herbicides.

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