



Editorial Integrated Weed Management: A Shift towards More Sustainable and Holistic Practices

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1. Introduction

Feeding more people sustainably is among humanity's biggest challenges in the next few decades [1]. It is estimated that agricultural production has to increase by 60% by 2050 in order to fulfill the food needs of the population [2]. There are many factors that limit crop production, including the presence of pests, diseases, and weeds.

Since the dawn of agriculture, farmers have come up against weeds. Weeds compete with crops for essential resources such as light, water, and nutrients [3]. Weeds outnumber pests and diseases in terms of their potential impact on crop production, with estimates indicating that they are responsible for the highest potential crop losses (34%) [4]. On a global scale, weeds cause economic losses exceeding US\$ 100 billion [5], to which we have to add the cost of herbicides of US\$ 25 billion [6]. These numbers underline the importance of keeping weeds under control and the need for a science that studies them. I consider this section to be a call to action to present news insights or perspectives that shape a new approach to sustainable weed management [7].

2. Integrated Weed Management

The discovery and commercialization of 2,4-D and other phenoxy herbicides in the 1940s provided the stimuli that started weed research on its way as a fully-fledged new science, and, since then, weed control has relied mainly on the use of chemical herbicides. Among the reasons for intensive herbicide use are: it is a cost-effective way to control weeds; the lack of threshold-based spraying decisions; and the absence of a sufficiently effective and cheap non-chemical method [8]. All the above has resulted in weed resistance, thus triggering environmental concerns [9]. To date, 269 weed species have evolved resistance to herbicides, and 21 out of 31 known modes of action for herbicides have been affected [10].

The speedy proliferation of herbicide-resistant weeds and the resulting environmental issues have forced farmers to adopt different approaches to weed management, i.e., reducing the employment of synthetic herbicides and their impact and spurring scientific research into seeking new control methods. In this regard, different approaches have been made that have recovered control methods used before the arrival of synthetic herbicides. For example, crop rotation, practiced by farmers since 6000 BC, is a tactic that allows the varying of selection pressure on weeds, preventing the dominance of any one weed species, and delaying the development of herbicide resistance. In southern Spain, the biennial sunflower-winter cereal rotation has been implemented for the last decade. It is aimed at controlling winter weeds and currently forms a consolidated and stable agricultural system [11].

The application of individual tactics may not be enough to achieve efficient weed control due to the high fecundity and dispersal capacity of some weed species [12]. In this context, Integrated Weed Management (IWM), rooted in the Integrated Pest Management concept, has emerged. IWM is an evolving approach that aims to effectively manage and reduce the impact of weeds in agricultural systems [13]. IWM combines different methods, such as chemical, biological, mechanical weeding, and/or specific crop



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Copyright: © 2023 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). management, to improve the efficiency of weed control. By using multiple strategies simultaneously, farmers can target weeds at different stages of their life cycle and disrupt their growth and reproduction. This approach reduces the reliance on herbicides alone, leading to more sustainable weed management. In recent years, new perspectives have emerged within IWM that reflect a shift towards more sustainable and holistic practices [14]. These tendencies emphasize the importance of integrated approaches, knowledge sharing, and the use of innovative technologies. In this regard, one important tendency is the recognition and integration of ecological principles in weed management [15]. Ecologicallybased weed management focuses on understanding the dynamics of weed populations, their interactions with the surrounding environment, and the contribution of weeds to ecosystem services [16–18].

Collaboration and knowledge sharing are also becoming increasingly significant in weed management. Farmers, researchers, extension services, and other stakeholders are engaging in collaborative networks to exchange information, experiences, and best practices. This collective approach facilitates the implementation and adaptation of IWM techniques based on local conditions and needs. By working together, stakeholders can develop innovative solutions and share the benefits of successful weed management strategies using Decision Support Systems [19].

Advancements in technology are also shaping new trends in IWM. Precision agriculture tools, such as satellite imagery, drones, and sensors, enable farmers to accurately map and monitor weed infestations in real time [20–22]. These technologies provide valuable data for decision-making, allowing farmers to target specific areas with precise interventions. Additionally, advancements in biological control methods (such as the use of beneficial insects, RNAi technology, allelopathy, and microbial bioherbicides [23–27]) offer promising alternatives to conventional chemical herbicide-resistant crops and weeds.

However, it would be essential to explore new extensions of the IWM in order to enhance its effectiveness. One such future development could involve considering the dispersal of weed propagules between fields. In this context, the concept of Landscape Weed Management (LWM) [28] could offer valuable insights in this respect. LWM suggests integrating weed control strategies at various spatial scales, ranging from the field to the landscape. Another step forward is the integration between specific-site management and IWM [29]. Although precision weed control has the potential to reduce herbicide usage by targeting weeds or patches more effectively and minimizing its application to surrounding areas, it does not contribute significantly to the progress of integrated weed management.

Weed management is experiencing a paradigm shift, emphasizing the need to strike a balance between ecosystem services and the disservices offered by weeds. By combining diverse control methods, embracing ecological principles, promoting collaboration, and leveraging innovative technologies, farmers can effectively manage weeds while minimizing the negative environmental, yield, and economic impacts. Future research should focus on understanding the agroecology of weeds and how they can be integrated with digital farming, the social environment, and biotechnology. Ultimately, this shift towards a more sustainable and comprehensive approach to weed management will play a crucial role in ensuring the long-term viability and resilience of agricultural systems.

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