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Editorial

The Future of Weed Science: Novel Approaches to Weed Management

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1. Introduction

The European Union takes the sustainability of pesticide use into serious account, and one of the main challenges of the EU Green Deal is the significant reduction in chemical control. Within this context, new and innovative approaches to weed management are highly necessary and widely studied [1,2].

This Special Issue is entitled 'The Future of Weed Science: Novel Approaches to Weed Management'. Some of the main topics covered by the 13 research, concept and review papers of this Special Issue include the following:

- Agronomic practices and the optimization of their performance;
- Precision agriculture and remote sensing to reduce herbicide use;
- Novel weed management techniques and approaches through the evaluation of robotics, UAV, deep learning, multispectral sensors, nanotechnology, etc.;
- The potential role of allelopathy in weed control;
- Nature-based products as novel herbicides

2. A Description of the Special Issue's Main Findings

2.1. Agroecological Weed Management and Cultural Practices

Agroecological weed management and several cultural (agronomic) practices such as cover crops, mulching, intercropping and crop rotation are at the core of non-chemical weed management methods [3,4]. Within this context, Yurchak et al. evaluated the efficacy of living and dead cover crop mixtures for weed suppression in sweet corn compared with the standard practice of using conventional tillage and pre-emergence residual herbicides. Their findings confirmed that adequate weed control was provided by the cover crop systems as well as the standard practice throughout the cropping cycle in all three years. In addition, there was no significant improvement in weed suppression with the application of herbicides within the cover crop treatments, while reduced yields were found in all cover crop treatments during the third year compared with those under conventional tillage.

Gazoulis et al. assessed the potential of delayed sowing and the false seedbed method against weeds in intercrops and monocultures of annual legumes and grass species. In particular, the false seedbed method (with shallow tillage at 1 week) reduced weed biomass by up to 34% compared with that under normal seedbed preparation. Forage yield was increased by 9–14% under the use of a false seedbed with shallow tillage at 2 weeks.

Saulic et al. studied the effects of 2- and 3-year crop rotations with or without fertilization on weed flora. Mixed-model analysis suggested that over 50 years of using these management practices, the interactions of crop sequence × fertilizer, crop sequence × fertilizer × soil depth, and crop sequence × soil depth were the significant factors in determining soil seed bank populations.

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The main objective of the study conducted by Pinke et al. was to evaluate the efficiency of using tine harrow and clopyralid herbicide to reduce weed abundance and biomass in a phacelia field in Hungary. The surveys revealed that mechanical control, particularly the use of tine harrow, could significantly decrease weed density and biomass.

2.2. Precision Agriculture, Remote Sensing-Based Methods and Frameworks and Novel Weed Management Techniques and Approaches

Novel methods based on the rapidly evolving technology of sensors and deep learning, nanotechnology, laser and microwave use, and the hidden potential of biostimulants certainly belong to the future of weed and crop management [5,6]. Within the context of precision agriculture, Kanatas et al. proposed the measurement of weed and crop NDVIs with a specific methodology as a rapid and reliable way to evaluate the herbicide efficacy and selectivity of wheat crops.

Jin et al. discussed the feasibility of using deep convolutional neural networks (DCNNs) to detect weeds growing on turfs. One of the major challenges for an autonomous precision herbicide sprayer is to rapidly and accurately distinguish weeds and this is possible with the use of DCNNs.

The aim of the study by Scavo et al. was to study, in situ, the efficacy of a disulfide bioherbicide mimic (DiS-NH2) applied as a nanoparticle formulation and specifically to evaluate the achieved levels of weed control and wheat crop selectivity (or potential injury). Their findings revealed the high weed-suppressive ability of the compound nano-encapsulated at high rates in parallel with an increased wheat grain yield and enhanced yield parameters; they also confirmed the promising potential of nano-enabled weed management [7].

Treating weeds with multiple laser beams without harming non-target plants could also comprise an alternative approach. Experiments conducted by Mwitta et al. confirmed the potential of using the diode laser as an efficient weed control method and highlighted the importance of factors such as laser power, stem diameter and treatment duration on overall efficacy.

Slowinski et al. focused on the serious invasive species *Heracleum sosnowskyi*, particularly on the efficacy of electromagnetic (microwave) radiation against it. Kanatas et al. reviewed the potential interaction between herbicides and biostimulants and their effects on weed growth, crop yield and quality parameters. In some cases, the combined use of biostimulants with herbicides can result in yield increases of up to 14.7%, and this is a highly promising finding.

New sensor-based methods for the in-season and in situ rapid evaluation of applying herbicide, hot foam, electrical weeding and other non-chemical alternatives also represent novel approaches and indicate the potential future direction of weed management [8–10].

2.3. The Potential Role of Allelopathy and Nature-Based Compounds

While a huge number of case-specific and dose–response experiments have been conducted, the phenomenon of allelopathy has not been fully exploited in terms of its potential as a weed management method [11]. Pytlarz and Gala-Czekaj proposed seed meals from crops such as *Sinapis alba* as potential bioherbicides against biotypes of wild oat (*Avena fatua* L.) with different herbicide susceptibility behaviors.

In another study conducted by Kanatas et al., the knockdown effect of pelargonic acid against both barnyardgrass and johnsongrass was confirmed along with the intermediate efficacy of caraway microcapsules. The addition of a commercial adjuvant improved the efficacy of caraway essential oil but not that of pelargonic acid, which was already high, in full agreement with previous studies [12].

It has to be noted that various compounds of natural origin have been assessed in terms of their efficacy and suggested as alternatives of herbicides [13–15]. In our Special Issue, Antony and Karuppasamy studied phytotoxins from plants and microorganisms

as novel herbicides and identified sinigrin as a promising compound against the ACCase enzyme, as other researchers have concluded in the past [16,17].

3. Conclusions

This Special Issue involves a wide range of approaches in the context of integrated and agroecological weed management. Methods and approaches such as those presented in the papers published here including cultural practices, allelopathy, nature-based compounds, smart farming, remote sensing-based methods and frameworks and novel weed management techniques and approaches are at the core of the present research focusing on a achieving a reduction in the reliance on chemical herbicides. Future research endeavours should certainly (a) combine some of these methods, evaluate them under various pedoclimatic conditions and overcome any limitations; (b) enrich them with others (sensor-based methods, hot foam, electric weeding, etc.); and (c) optimize all the strategies not only in terms of their agronomic performance (efficacy in weed management and selectivity to the crops) but in terms of the ecosystem services that they may provide.

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