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Editorial

Weed Ecology and New Approaches for Management

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1. Introduction

The rich biodiversity of agricultural fields and their surroundings enhances natural ecosystems and has a positive impact on their productivity and resistance, e.g., by maintaining a balance between crop pathogens and pests, ensuring pollination and nutrient cycles [1]. Segetal flora, commonly known as weeds, are present in all types of crops, and their composition, density and biomass depend on many factors, including the species of crop, habitat conditions, the performance of crop management procedures, and the time of year [2]. From the point of view of human management, weeds are undesirable species in fields, because their presence reduces the yield of crops and contributes to the deterioration of the crop quality. Some weeds are also harmful because they can be hosts of pests or crop pathogens, parasites or semiparasites, or have poisonous properties towards animals and humans. However, apart from the negative aspects, weeds also have many positive functions in agrocenoses, such as increasing the number of pollinators, providing habitats and food for beneficial insects, and some secrete substances that inhibit the development of pests [3].

Weed control is important in growing systems, requiring the integration of different plant protection strategies and methods. The Special Issue "*Weed Ecology and New Approaches for Management*" contains 14 original research articles and 1 review article covering topics related to the biology and damage of weeds, especially related to the health and yielding of crops and the biodiversity of segetal weeds, as well as integrated methods of weed control and herbicide resistance. It includes articles related to the effects of tillage and management intensity on species diversity and weed abundance in winter cereals [4,5] and legumes e.g., soybean [6], pea [7] and lupine [7,8]. Several articles have shown that crop species and habitat conditions significantly affect the abundance and botanical composition of the associated flora (segetal weeds) [4,5,9]. Moreover, it was found that the effectiveness of the use of plant protection products in wheat cultivation depended on the cultivar [10]. Increasing the intensity of the production also affects the yields of lupine [8] and spelt wheat [10], as well as the health of soybean [6] and chamomile [11]. In perennial crops (willow), segetal weeds are the dominant flora, although with the age of the plantation their number decreases in favor of apophytes [12]. Dangerous to the native flora are invasive species that require monitoring, such as exotic *Tamarix* species, introduced to South Africa as ornamental plants [13]. Two articles on potato cultivation stated that good results in weed control can be achieved by combining mechanical and chemical methods [14] or by the pre-emergence application of the mixture of herbicides with an adjuvant [15]. In turn, la Cruz et al. [16] identified glyphosate resistance in a new species of *Amaranthus viridis* in citrus orchards. Furthermore, it was confirmed that the level of damage after herbicide application and the regeneration rate of camelina plants depended on the cultivar [17]. The review article presents the ecosystem advantages of legume cover crops, including their effect on weed control [18].

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2. Biodiversity of Weeds and Tillage Systems

During the period of the intensive development of conventional agriculture, human activity was directed mainly at the elimination of undesirable flora in crops, therefore many weed species are now threatened with extinction. Studies carried out in eight European countries on the effects of pesticides on the biodiversity of segetal flora showed a negative relationship between grain yield and weed diversity. Changes in agricultural production occurring in the last 50 years resulted in a threefold reduction in the diversity of weeds in wheat cultivation [19]. The studies by Chamorro et al. [20] carried out in Catalonia showed not only a reduction in total weed infestation (69%), but also the frequency of weeds (58%) and species richness (47%) over a period of about 50 years, with the most dramatic decreases in the groups of segetal (75%) and rare species (87%).

An opportunity for the maintenance of the population of segetal flora is the promotion of the idea of sustainable and organic agriculture, in which the aim is to reduce the number of species accompanying cultivated plants to such a level that they do not significantly reduce crop yields [21]. On organic farms, weed infestation is limited without the use of herbicides, e.g., through crop management practices. Farmers on organic farms are also allowed to use biostimulants, organic foliar fertilizers which can increase the resistance of cultivated plants to stressful conditions, improve the health of plants and even reduce weed infestation [22], as can be seen from the use of Herbagreen Basic and Bio-algeen, which reduced the infestation chamomile by pathogens and reduced the number and increased biodiversity of weeds [11]. In the organic cultivation of soft-stemmed species, it is good practice to use low support plants that do not compete for with the main crop for light, protect it against lodging and, by taking up additional space, increase its competitiveness, and effectively reduce weed and fungal pathogen pressure [23].

On a correctly managed organic farm, the occurrence of weeds is effectively reduced but, in principle and in practice, they are not completely eliminated. It is considered that the greater the diversity in the species composition of a weed community, the less harmful it is to the crop [24,25]. Berbeć et al. [4] showed higher species diversity and weed abundance in the ecological system than in the conventional low-input system, but in both farming systems the Shannon–Wiener diversity index had high values, while the Simpson dominance index had low values, indicating their high importance for biodiversity.

The germination rate of weed seeds and their subsequent growth and competitiveness against the crop depend on the tillage [26]. In intensive ploughing systems, weed seeds are evenly distributed in the arable layer, while in reduced tillage systems, a large number of them are concentrated in the surface layer of the soil [27]. Feledyn-Szewczyk et al. [5] showed that weed infestation and soil weed seed bank in winter wheat were considerably higher in simplified systems (reduced tillage, direct sowing) than in the ploughing system, although not in all years of the study. Bojarszczuk and Podleśny [7] showed that simplified tillage significantly increased the weed infestation in legume. The high importance of the tillage system on the biodiversity of the segetal flora was confirmed by the biodiversity indices. Gawęda et al. [6] found that the abundance and dry weight of the weeds in the soybean cultivated in the no-till system was higher than in the conventional plough system. Tillage simplification also contributes to changes in the species composition of weeds [28], and to an increase in plant infection by fungal pathogens in soybean [6].

3. Biodiversity of Weeds in Annual Crops

There is a conflict between the productivity of the crop and the weeds, which compete with the crop for limited environmental resources. Oerke [29] found that potential yield losses due to competition between weeds and crops can amount to around 34%. The most unfavorable situation occurs when there is dominance of one or several weed species, e.g., in fields treated with herbicides. Weed compensation may consequently lead to a significant decrease in the yield of the cultivated crop [30]. Faligowska et al. [8] showed that the seed yield and its quality (protein content) of lupine was determined mainly by the intensity of farming. The yield and quality of narrow-leaved lupine seeds in the conventional system

was higher than in a low-input or a medium-input system. The low-input technology provided the lowest seed production cost and the highest income, despite the fact that the weed infestation in lupines in this cropping system was higher than in conventional cropping [8,31].

The large percentage of cereals in the structure of crops in Poland facilitates the growth of segetal plants in arable fields, but the abundance and botanical composition of the associated flora depend primarily on the crop species and habitat conditions [4,5]. Assessment of the diversity of the segetal flora carried out by Sawicka et al. [9] showed a higher abundance of weeds in spring wheat and triticale than in winter wheat. In turn, the highest species diversity was observed in triticale, and the lowest in winter wheat cultivation.

Haliniarz et al. [10] showed that the effectiveness of the use of plant protection products in the cultivation of spelt wheat depended on the cultivar. Under intensive cultivation, lower weed infestation and higher yields were obtained for the cultivar Rokosz compared to Schwabenspelz. Further, Andruszczak [32] showed that the chemical protection of spelt wheat improved yield and quality of grains, but this depended significantly on the wheat cultivar.

4. Biodiversity of Weeds in Permanent Crops

A relatively new agricultural practice is the cultivation of perennial species on arable land for energy purposes. However, replacing annual with perennial crops has an impact on biodiversity in terms of the genetic, species and habitat levels [33]. Feledyn-Szewczyk et al. [34] conducted a study assessing the impact of perennial energy crops on the diversity of associated flora, and showed changes in the flora communities, which consisted in an increase in the proportion of perennial species at the expense of annual species typical for agricultural crops, and an increase in the abundance of species characteristic for ruderal habitats, meadows and forests.

In perennial plantations, the accompanying flora have different development conditions than in annual crops due to different cultivation technologies. In the case of trees and bushes intended for energy purposes, the long period between harvests (2–3 years) influences the habitat conditions related to temperature, humidity and limited light, which determine the species composition and abundance of weeds. The age of the crop and soil conditions are also important [35]. The study of Janicka et al. [12] showed that a significant proportion of the flora in cultivation *Salix viminalis* constituted segetal weeds occurring commonly in cereals and root crops. With an increase in the age of the plantations, the number of segetal species decreased in favor of apophytes. Salix plantation included several medicinal and melliferous species important for humans and biodiversity, but also invasive species dangerous for native flora that need monitoring. Examples of plants with high invasive potential are the exotic species *Tamarix*, which were introduced to South Africa as ornamental plants and are now threatening riparian ecosystems over 10 million ha of land [13]. Setshedi et al. [13] state that in order to protect local biodiversity, the continuous monitoring of these species and the constant and consistent removal of dangerous plants are needed to restore native ecosystems.

5. Chemical and Nonchemical Methods of Plant Protection

To successfully manage weeds it is important to understand the interactions between weed control methods and the weed spectrum, and to properly manage the cultivation system to prevent weed emergence and keep the weed seed bank in the soil low [36]. Proper cultivation and agricultural practices, including a well-planned crop rotation, sowing cover crops, early sowing dates and optimal row spacing are important aspects of weed management in all farming systems [9].

Chemical weed control, on the other hand, should be based on a detailed knowledge of, among other things, the environmental factors influencing the effectiveness of herbicides, both during and after their application [37]. The factors determining the absorption,

translocation and degradation of active substances in the plant, like air temperature and humidity are also very important [38]. Pszczółkowski et al. [14] confirmed that the variable course of the atmospheric conditions in the years of the study affected the effectiveness of the herbicides, which differentiated both the abundance of monocotyledonous and dicotyledonous weeds, their dry and fresh weight and the species composition of segetal weeds.

The selection of herbicides, or combinations of herbicides, doses, and timing of applications should be adapted to the degree of the weed infestation, with the aim of controlling a wide range of weeds [37]. In the study of Pszczółkowski et al. [14], good effects in reducing weed infestation in potato cultivation were obtained by combining mechanical and chemical methods (linuron and clomazone). In turn, Barbaś et al. [37] showed that the pre-emergence application of herbicides (metribuzin and rimsulfuron) with an added adjuvant (SN oil) can contribute to better weed control, reduce herbicide dosage, environmental impact and costs and above all, provide a broader spectrum of the active substance action as compared to mechanical weed control.

At the same time, the use of covers (polyethylene film or polypropylene agrotextile) in very early potato cultivation caused an increase in the number and weight of weeds and enriched the species composition of segetal weeds, probably due to higher air and soil temperature [14].

During the action of herbicides on weeds, a selection process occurs by which the least sensitive plants survive, but each weed population is more or less uniform and the process of resistance development can vary in intensity and speed [39]. La Cruz et al. [16] identified glyphosate resistance in a new species, *Amaranthus viridis*. Based on the enzymatic activity tests, it was found that at least one target site-type mechanism was involved in the resistance mechanism. Therefore, a number of procedures should be used to prevent or significantly delay weed resistance to herbicides [15].

The toxicity and rate of degradation of biocides depend primarily on the rate and the structure of the active substance, which is the primary plant protection product [40]. In addition, determining the effects of herbicides on crop development is also important in the context of different cultivars, which is related to their intraspecies variability, which can be observed in the example of *Camelina sativa* [17]. Sobiech et al. [17] showed that camelina cultivar Przybrodzka showed the lowest level of damage after herbicide application, and that plant damage after p-ethyl quizalofop and propakisafop completely disappeared (after 42 days). Herbicides can directly reduce photosynthetic activity or indirectly damage plants, which in turn reduces photosynthetic efficiency [41]. Sobiech et al. [39] found that picloram contributed the most damage to camelina, which also had the biggest effect on PSII function. However, the level of chlorophyll fluorescence parameter values of the plants indicated little damage to PSII for all substances and the possibility of subsequent regeneration of the plant.

The benefits of agricultural conservation practices have increased farmers' interest in cropping legume cover crops (CCs) [42]. Legume CCs are considered a systemic approach to weed control. They reduce weeds and provide other benefits to farming systems, such as improving soil quality [43]. In particular, the wider use of legume CCs is justified in cropping systems with the limited use of mineral fertilizers and pesticides [18].

6. Conclusions

It can be expected that further popularization of the idea of sustainable and organic agriculture, in which the abundance of segetal weeds in agricultural crops is kept at a sufficiently low level, will bring measurable effects by obtaining yields at an acceptable level and by maintaining the biodiversity of arable fields. Attention should also be paid to solutions that allow for a better understanding of the interactions between weed control methods and the extent of their occurrence, which is helpful for effective weed management in plant crops. In chemical protection, weed resistance is an important problem that has

increased in recent years and is directly linked to the effectiveness of the crop protection, so research should be intensified to address this issue.

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