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Editorial

Plant Breeding Supporting the Sustainable Field Crop Production

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The population of Earth exceed eight billion in 2022 and it is growing even faster. The most important challenge for humankind will be providing food and ensuring catering not only in developed countries, but in underdeveloped regions as well. Agriculture is one of the main pollution sources, and non-appropriate farm management could degrade the environment seriously [1]. Therefore, in the future, the productivity of the sector must be improved to be able to produce enough food, but reducing the ecological and environmental footprints must be in the focus. Sustainability means efficient usage of inputs in the long term and reducing the impacts of production on the environment and landscape. Reserving the capabilities of the cropping areas, efficient and reasonable utilization of the nutrients, water, and other inputs become especially important [2]. The problem could be approached from many aspects, but the two major topics are cultivation practices and plant materials. Various water and nutrient-sawing technologies are available, but these could be used efficiently if the harvested plants could contribute to implementing the goal of sustainability [3]. Abiotic and biotic stress tolerance would be key requirements because various environmental factors endanger food security such as drought and heat, and the spreading of invasive weeds, pests, and diseases harm the yield.

Plant breeding supports new varieties and hybrids for farmers. The potential yielding capacity of the genotypes is higher and higher, but the real productivity is limited by various factors. The maximization of the yield required intensive technologies, active pest and disease management, and a high amount of inorganic fertilizers. Improving the abiotic and biotic stress tolerance and the adaptability of the genotypes can contribute to achieving sustainable farming. Yield maximization is not feasible in sustainable farming but the role of the breeding would be to provide plant materials that could produce enough food even in organic and integrated farm management systems [4].

This Special Issue aims to highlight how plant breeding could contribute to strengthening sustainability in field crop production by integrating the application of modern technologies and tools.

Water shortage is one of the most important impacts of the changing climate in many parts of the world. Typically, the arid and semi-arid regions are affected, but the intensity of the extreme drought becomes more intense and frequent in other areas. Even the Carpathian Basin in Central Europe is exposed to drought in the Spring and Summer [5].

Roots have a key role in the water and nutrition cycle in the soil-plant-atmosphere system. The root system, its development and turnover during the vegetation period is a less studied topic because of its complexity. However, the root structure could be the driver of drought resistance. Drought resistance is a complex phenomenon, and it develops through the interaction of various plant properties that are determined by several genes, including dwarfing genes, such as *Rht1*, *Rht2*, *Rht8*, etc. [6]. Dwarfing genes reduce plant height, can increase the harvest index, and improve lodging resistance. The presence of these genes in the genome not only reduces the plant height but can also negatively impact the intensity of root development and root morphology. The impacts of the water withdrawal and the elevated CO_2 level on the root structure of three winter wheat cultivars carrying different dwarfing genes were studied by using in situ root scanning technology [7]. The water shortage induced intensive root development in the deeper soil layers and under elevated CO_2 concentration, the distribution of the root system was more homogeneous in the whole soil profile. The maximum root length was detected at the beginning of the heading, and this period took longer under elevated CO_2 concentration [7].

Seedlings are the most sensitive to the stresses and damage in this phenophase, which could lead to serious yield losses. Winter wheat seedling's vigour is an important parameter that was examined by Khaeim et al. [8] under drought stress in combination with high temperatures. In agronomic practice, the determination of the germination percentage is an important parameter for calculating the sowing rate. A new methodology had been developed to optimize the circumstances of the germination process in the lab [8]. The ideal temperature for seedling development was 20 C. Germination of various percentages can occur in a broad range of water quantities commencing at 0.65 mL, which represents 75% of thousand kernel weight, but the optimal range for germination is 4.45–7.00 mL, representing 525–825% of the thousand kernel weight [8].

Besides water, the other substrate of photosynthesis is carbon dioxide. It was confirmed that the elevation of the CO_2 could be positive to plant development and production and the CO_2 enrichment could counterbalance the negative impact of drought [9]. The responses of various cereal varieties to elevated CO_2 concentration were studied under optimum and limited water availability [10]. The CO_2 treatments were combined with the simulation of drought in two phenophases of cereals and the productivity of the plants as well as the water use efficiency was determined. Genotypic variations had been determined and it was concluded that the examined winter barley react positively to the CO_2 enrichment, but negative responses had been detected for oat [10].

Salinity is a serious phenomenon that limits field crop production [11]. The high salt content in the soil, high evaporation rate, or non-appropriate quality of irrigation water could induce the enrichment of salt in the upper soil layers. Improving the growing potential of wheat on solonetz would be important in Serbia [12]. Ten winter wheat and one triticale cultivar were tested in a field experiment and phosphogypsum was applied in two doses for soil reclamation. Stable genotypes were selected that could be grown successfully on solonetz and it was determined that the effect of the applied amelioration measure depended on the meteorological conditions of the growing season [12].

Rice is the second leading staple food in the world. Rice is more sensitive to environmental stresses compared to other cereals. The plants are very sensitive to cold stress at the seedling stage and their critical period is the reproductive stage [13]. Phenotypic observations combined with genotypic characterisation of near-isogenic breeding lines were evaluated by Akter et al. [14] aiming to support rice breeding with potential crossing partners to improve cold tolerance. A high variability in cold susceptibility was determined in the test assessment and nine lines could be identified that showed strong tolerance to cold. The results of the authors highlighted that cold tolerance can be in pair with a high- yielding capacity, therefore, an accurate pre-breeding could propose efficient parental lines for breeding programs [14].

Changing climatic conditions favour to spreading of invasive weed species [15]. Weeds usually have a stronger adaptive capacity to the harsh environment than cultivated plants, therefor more intense weed competition occurs under stress conditions. Another important problem would be that weeds could become resistant to herbicides and the management of these weeds would be a key issue in the infested areas [16]. The resistance of rigid ryegrass to pyroxsulam was studied by Kutasy et al. [17]. This species is one of the most serious herbicide-resistant annual grass species which cause problems in agricultural land worldwide. In [17] RNA-seq approach had been applied to identify sequences coding resistance to riazolopyrimidines. It was concluded that diagnosing the presence of target-site resistance and multiple target-site resistance mutations could improve the efficiency of weed management and the effectiveness of the traits becomes more predictable [17]. Nowadays, glyphosate is the most widely applied herbicide in the world even glyphosate resistance had been described for many weed species [18] and even GM crops [19] can degrade the active ingredients of these herbicides. Glyphosate and its metabolite (aminomethylphosphonic acid) accumulate in the soil and environment. Both chemicals are considered to be carcinogens and mutagens. An evaluation of sunflower established whether the plants can uptake from the contaminated soil herbicide residues and what kind of morphological changes in the above and belowground organs of the plants could induce [20]. It was confirmed that the plant absorbed glyphosate from the soil, and it became detectable in the roots and leaves. Higher concentrations of glyphosate induced a reduction in root length and thickness, but the dry biomass of the plants increased [20]. The presence of glyphosate in the biomass could harm human health directly and cause problems when the plants were used as fodder for animals.

The changing environmental conditions favour the breakdown of serious plant diseases [21]. Net blotch disease is becoming an important leaf pathogen of cereals, especially barley. Antioxidant enzymes are elements of the defensive system of plants. Abiotic and biotic stressors induce the accumulation of reactive oxygen forms in plant cells and antioxidants such as superoxide dismutase or peroxidase, and these enzymes have important roles in controlling and signalling metabolic and developmental processes. The connection between the infection severity of Pyrenophora teres f. teres and the level of the superoxide dismutase was analysed in barley genotypes [22]. A significant increase in superoxide dismutase activity can be determined in the inoculated population but the reactions were genotype and isolate-dependent. The results of Kunos et al. [22] proposed an early detection method for net blotch disease based on the measurements of the superoxide dismutase activity in the leaves.

Plant resistance breeding has century-old history, but it is still relevant. The changes in the environmental conditions could contribute spreading of plant pathogens because the vigour of plants could be lowered by non-favourable conditions and could serve favourable ecological conditions for epidemics [23]. Pepper is one of the most important horticultural crops in Hungary. The general defense response of pepper was analyzed by Szarka et al. [24]. The leaves were inoculated artificially with Xanthomonas vesicatoria and Pseudomonas phaseolicola and the symptoms were evaluated. Specific hypersensitive response genes do not protect but destroy the cells affected by pathogens [25]. The nonpathogen-specific GDR plays the role of the plant immune system due to its low stimulus threshold and high reaction rate [26]. Tissue retention capacity can be increased by breeding to a level where the GDR alone can provide adequate protection for the plant. In this case, the presence of specific hypersensitive reaction genes is unnecessary; sometimes it is even a burden to the plant [26]. Another important pathogen bacteria of pepper is bacterial spot disease caused by Xanthomonas hortorum p. gardneri, which causes star-shaped necrotic lesions on the foliage, stem, and fruit. The infection decreases the yield potential of plants as well as the quality of the fruits. The bacteria infect greenhouse- and field-grown plantations as well. Resistance breeding programs successfully developed commercial pepper lines with hypersensitive and quantitative resistance to various Xanthomonas species. The new sources of resistance identified in [26] provide a basis for further work on breeding disease-resistant varieties. It was documented that the different genotypes of Capsicum. baccatum differed in their response to wilt caused by Xanthomonas, which also demonstrated that the tested collection offered a valuable public source of resistance for pepper breeders to develop varieties resistant to bacterial spots.

Nematodes are important pests in horticulture. Application of root-specific resistance genes would be an efficient and sustainable way of protecting against nematodes. Tóth et al. [27] proposed an efficient methodology for transforming target genes by Agrobacterium rhizogenes using tomatoes as a model plant. The transformation efficiency was over 90% and the presence of *NeoR/KanR* and *DsRed* genes in the transformed plants were confirmed by PCR. The long-term effectiveness of the transformed genes had been confirmed after three months as well. The proposed method improves the ability to study root-specific genes and could be used for molecular studies of root–pathogen interactions [27].

Conflicts of Interest: The authors declare no conflict of interest.

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