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Editorial

Abiotic Stresses, Biostimulants and Plant Activity

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1. Introduction

Contemporary agriculture is characterized by a highly intensive nature and productivity. Furthermore, this activity is denoted by the substantial impact on natural ecosystems caused by water consumption and the use of fertilizers, plant growth promoters and herbicides/pesticides. In addition, it should also be considered that along the entire supply chain, such activity produces large quantities of waste and causes the emission of significant amounts of greenhouse gases (GHG) [1]. This places agriculture among the anthropogenic activities that contribute significantly to climate change. At the same time, agriculture is seriously affected by these processes, suffering the impact of abiotic stresses such as salinity, drought and high temperatures.

Abiotic stresses can significantly decrease plant growth and development, as well as negatively influence crop quality and productivity. As a result of climate change, abiotic stresses will be characterized by increasing intensity and frequency in the coming years and will put more intense pressure on agricultural systems. Consequently, crop production could dramatically decline, an especially worrisome prospect considering that agricultural systems must also cope with the food needs of the world ever-growing population. For these reasons, new or effective low or no climate-impacting measures need to be considered and developed to maintain/increase crop production and the resilience of agricultural systems, while working to minimize the impact of abiotic stresses.

An agronomic tool of increasing interest is the use of different formulations of certain organic materials and microorganisms, defined by the term biostimulants. Biostimulants are usually grouped into different families based on the raw materials used for their production: humic substances, complex organic materials, beneficial chemical elements (e.g., silicon), inorganic salts, algae and plant extracts, protein hydrolysates, chitin and chitosan derivatives, antiperspirants (e.g., kaolin), amino acids and other compounds [2]. These substances can improve plant stress tolerance, crop nutrient use efficiency, the bioavailability of nutrients in the soil or rhizosphere and quality traits. For the abovementioned reasons, biostimulants can benefit crops when applied under optimal environmental conditions and in states of abiotic and biotic stress.

In this context, the aim of this Special Issue *Agriculture*, entitled "Abiotic Stresses, Biostimulants and Plant Activity", was to advance knowledge on the effect of biostimulants, both in crops grown under normal conditions and in the presence of abiotic stress conditions. We focused, in particular, on heat, salt, drought stress, potentially toxic metals, multiple stresses, and improving plant tolerance. Therefore, this Special Issue paid attention to scientific contributions regarding the stimulatory and protective effects of different biostimulants on crops, their mechanism of action, and their qualitative, economic, and environmental benefits.

2. Special Issue Overview

Related to the use of plant extracts capable of promoting beneficial effects in crops grown in non-stressful conditions, interesting experimental evidence has emerged regarding two plant extracts obtained from Moringa and *Lemna minor*. In particular, a foliar extract of Moringa (*Moringa oleifera* L.) was tested on different barley accessions [3]. The leaf extract positively influenced the crop growth and yield, albeit with different strengths in the different accessions considered. The greatest effect of Moringa extract was ascertained on total crop yield, followed by increases recorded in straw weight and number of tillers per plant. This research, therefore, showed that the foliar application of Moringa extract could be an effective solution to stimulate growth and yield in barley.

Another study proposed the use of an extract from duckweed (*Lemna minor* L.), a free-floating aquatic species, to promote beneficial effects in olive plants. The foliar application of the extract stimulated plant growth and improved physiological and biochemical traits in the treated samples [4]. Indeed, the extract positively influenced leaf net photosynthesis, stomatal conductance, sub-stomatal CO_2 concentration and chlorophyll content. Furthermore, the duckweed extract increased the uptake of nutrients like nitrogen (N), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe) and zinc (Zn). The broad diversity of bioactive compounds (including phytohormones, phenolics and glutathione) found in the extract, through untargeted metabolomic profiling, explained the stimulatory effect observed on the olive plants.

Heat, found among the abiotic stresses exacerbated by climate change, is expected to affect plant growth, crop yields, and product quality. The negative effects of this environmental stress can also impact the characteristics of olive pollen. In this context, the potential of selenium–methionine (Se-met) to mitigate the negative effects of heat stress on olive pollen germinability, morphology and cytosolic Ca^{2+} content was investigated [5]. A temperature of 40 °C caused a marked reduction in the olive pollen germination rate, changes in the morphology of the external pollen wall, and a decreased response to Ca^{2+}-agonist agents. The adverse effects of heat stress were counteracted by Se-met, which improved the germination rate, and Ca^{2+}-cytosolic homeostasis, containing the hydrogen peroxide toxicity.

Since heat stress can influence the metabolic processes that enable callus formation, a study investigated the effect of rapid high-temperature (RHT) treatment at 50, 65, and 80 °C on sweet potato tubers [6]. The results showed that appropriate RHT treatment at 65 °C can stimulate the metabolism of reactive oxygen species (ROS) at the injury site of sweet potato on the first day. However, significant ROS formation and scavenging activity were maintained within five days after RHT treatments. Consequently, ROS induced the phenylalanine ammonia-lyase (PAL), 4-coumarate-CoA ligase and cinnamate-4-hydroxylase activities of the phenylpropane metabolic pathway and promoted the rapid synthesis of chlorogenic acid, p-coumaric acid, rutin, and caffeic acid at the injury site, which stacked to induce callus formation. These results evidenced that appropriate high-temperature rapid treatment can promote sweet potato callus formation through ROS modulation and phenylpropane metabolism. Moreover, antioxidant enzymes, PAL, and chlorogenic acid appeared to be key factors in promoting the metabolic pathways involved in the sweet potato callus formation.

Salt stress is one of the abiotic factors that cause significant problems for crops, and it has been estimated to be responsible for more than 50% of crop losses worldwide. Moreover, its impact is increasing, especially in arid and semi-arid regions or coastal areas, a phenomenon also due to climate change. In recent years, the application of nanotechnologies in agriculture has gained particular attraction since specific nanomaterials can show stimulatory effects on crops and increase their capacity to cope with environmental stress. In particular, green synthesized nanoparticles (NPs) can be used as eco-friendly and cost-effective methods to counteract salt stress, thanks to their potential to exert biostimulant effects. The efficacy of zinc oxide nanoparticles (ZnO NPs), synthesized using *Agathosma betulina*, to mitigate severe salt stress was investigated in *Sorghum bicolor* [7]. Salt negatively affected *S. bicolor* growth, causing severe deformation on the epidermis and vascular bundle tissue anatomical structure, while increasing the Na^+/K^+ ratio, oxidative stress (ROS and malondialdehyde content), the activity of some antioxidant enzymes and the content of proline and soluble sugars. Seed priming with ZnO NPs counteracted the negative effects of the salt stress, promoting plant growth, allowing plants to recover a well-organized anatomical structure, decreasing the Na^+/K^+ ratio and reducing the cellular oxidative stress.

Since salinity can affect seed germination and the early stages of plant development that shape the entire life of the crop, the use of biostimulants or plant extracts containing bioactive compounds is a strategic way to counteract the adversity caused by this stress. In this vein, a study published in this Special Issue sheds light on the negative effect exerted by salt stress on wheat in terms of seed germination, plant growth and yield. An interesting method, proposed by the authors of this research, is the priming of wheat seeds with Moringa leaf extract [8]. This approach positively influenced the seed development and germination parameters, seedling growth and nutrient uptake in salt stress conditions. This effect resulted from the Moringa extract capacity to control and reduce the concentrations of Na and ROS, stimulating, at the same time, nutrient uptake.

Again, related to salinity stress, the effects of different water table depths and groundwater salinity levels under irrigated and rainfed conditions were investigated in wheat, studying some quality parameters (hectoliter weight, fat ratio, starch ratio, protein content, Zeleny sedimentation, wet gluten content, ash ratio, acid detergent fiber (ADF), and neutral detergent fiber (NDF)) [9]. Water table depths positively influenced the quality traits of the above crop, while increased salinity levels resulted in decreases in hectoliter weight, fat ratio, starch ratio, and NDF values and increases in protein ratio, sedimentation value, wet gluten content, ash ratio, and ADF values.

The use of a *Chaetomorpha antennina* aqueous extracts was investigated to decrease the detrimental effects of salt stress on rice [10]. As a result, the seaweed extract promoted rice seed germination, plant growth, leaf water, and photosynthetic pigments, while also reversing the negative impact on protein and phenol content, as well as superoxide dismutase (SOD) activity. Moreover, the extract improved grain protein content and enhanced rice nutritional profile and marketability.

Biostimulants can be efficiently used also against the detrimental effects of drought stress. Indigenously isolated *Bacillus* spp. strains were used in *Zea mays* L., which had been subjected to drought stress, in order to promote plant growth characteristics, including mineral uptake and phytohormone profile [11]. The obtained results, especially those regarding biochemical properties, lipid peroxidation and antioxidant responses, suggested that the amelioration of plant capacity to cope with stress depended on a specific plant–strain interaction. Furthermore, oak leaf extract, biofertilizer, and soil containing oak leaf powder were successfully used to enhance growth and biochemical traits in four tomato genotypes under water stress [12]. The use of oak leaf powder and the extract is particularly interesting since they are low-cost substances, simple to use and represent an environmentally sustainable technique for enhancing tomato resistance to drought. Two methods were evaluated for assessing *Miscanthus* (a high-yielding, warm-season C_4 grass) tolerance to drought stress: a dry-down treatment and a system where soil moisture content (SMC) was maintained at fixed levels using an automatic irrigation system [13]. Since the dry-down treatment simulates the water-stress conditions in the field, it appears to be the more suitable method for selecting drought-tolerant genotypes. On the other hand, the SMC can be used to understand the physiological responses of plants to a certain level of drought stress.

Another highly relevant and complex topic concerns the presence of pollutants in the environment that, if present in cultivated areas, can also be absorbed in high amounts by crops. In this context, the effect of nitrate (N) on Al toxicity and accumulation in the roots of two wheat genotypes, Shengxuan 6 hao (SX6, Al-tolerant genotype) and Zhenmai 168 (ZM168, Al-sensitive genotype), was investigated in a hydroponic experiment with four treatments (control without N or Al, N, Al, and Al+N, respectively) [14]. The results showed that N increased the inhibition of root elongation and aluminium accumulation in roots. The Al-sensitive genotype suffered more serious Al toxicity than its Al-tolerant counterpart. Histochemical observation clearly showed that Al prefers binding on the root apex 7–10 mm zones, and that the Al-sensitive genotype accumulated more Al in these zones. Compared with other treatments, the Al+N treatment had significantly higher O_2^-, superoxides dismutase (SOD), catalase (CAT), peroxidase (POD) activities, H_2O_2, Evans blue uptake, malondialdehyde (MDA), ascorbic acid (AsA), pectin, and hemicellulose 1 (HC1) contents in both genotypes. Under Al+N treatment, O_2^- activity, Evans blue uptake, MDA, and HC1 contents of SX6 were significantly lower than those of ZM168, but SOD, CAT, and POD activities and AsA content exhibited an opposite trend. Therefore, aluminum toxicity and accumulation were aggravated in the roots of wheat seedlings by nitrate.

Climate change can also result in a combination of different abiotic stresses detrimental to plant growth. Two *Brassica* species: *B. oleracea* L. and *B. juncea* were exposed to different abiotic stresses: CO_2, UV-B, temperature (T), CO_2+UV-B, CO_2+T, and CO_2+UV-B+T [15]. Plant growth and development were significantly decreased by each of these stresses and their combinations in both species, except in the case of elevated CO_2 concentrations. On the contrary, increasing CO_2 concentrations alleviated some deleterious impacts of high temperature and UV-B stresses.

3. Conclusions

This Special Issue of *Agriculture*, entitled "Abiotic Stresses, Biostimulants and Plant Activity", includes studies conducted on the impact of some abiotic stresses on widely grown crops and how the use of biostimulants could represent an effective and environmentally friendly means of counteracting the aforementioned adversities. The Academic Editors of this Special Issue hope that this collection of research articles will significantly increase knowledge and further stimulate research in this key area for future agriculture, especially in view of ongoing climate change that will increasingly exacerbate the effects of abiotic stresses on crops.

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