agronomy

MDPI

Editorial

Miscellaneous Sets of Abiotic Stresses and Plant Strategies to Cope with Them

Sara Álvarez [1,*] and José Ramón Acosta-Motos [2,3,*]

[1] Instituto Tecnológico Agrario de Castilla y León (ITACYL), 47071 Valladolid, Spain
[2] Campus de los Jerónimos, Universidad Católica San Antonio de Murcia (UCAM), 30107 Guadalupe, Spain
[3] Group of Fruit Biotechnology, Department of Fruit Breeding, CEBAS-CSIC, P.O. Box 164, 30100 Murcia, Spain
* Correspondence: alvmarsa@itacyl.es (S.Á.); jracosta@ucam.edu (J.R.A.-M.)

Plant stress can be defined as any adverse situation or agent that can damage or block the metabolism, growth or development of a plant. The responses of plants can vary according to the frequency and intensity of the stress, as well as the growth phase of the plant under stress.

Throughout their life cycle, plants are subjected to a wide variety of conditions or potential stress factors. One of the main characteristics of plants is that they do not have the ability to travel, and therefore, they remain fixed to the substrate and they are planted through their root systems. In other words, adult individuals do not have the capacity to displace, but they are able to move and respond to stimuli such as light (phototropism) or the effect of gravity (gravitropism). This means that they are unable to escape from unfavourable conditions such as abiotic stress caused by non-living agents, which are differentiated from living agents such as herbivores, fungi, bacteria or viruses which cause biotic stress.

Depending on the kind of causative agent involved, abiotic stress may be divided into physical or chemical types of stress. Physical stress includes salinity (due to its osmotic component), water shortage, temperature extremes, excessive or insufficient irradiation, anaerobiosis caused by waterlogging or flooding, mechanical stress caused by wind or excessive soil compaction and stress induced by wounds or injuries. Chemical stress can be due to salinity (due to its ionic or toxic components), a lack of mineral nutrients and environmental contaminants. In addition to the particular damage caused by each of these stresses, they all facilitate the overproduction of reactive oxygen species (ROS) such as superoxide anions, hydrogen peroxide or hydroxyl radicals associated with oxidative stress. Plants have developed a series of adaptive responses against abiotic stresses and oxidative metabolisms to cope with the environment in which they live. More specifically, they have developed resistance mechanisms, which include avoidance mechanisms and tolerance mechanisms.

Throughout this Special Issue, some of the stresses mentioned above, as well as the resistance mechanisms implemented at different stages of the vegetative and reproductive cycles of plants (seed, seedling, adult plant or fruit), will be discussed, including: a review regarding oxidative stress, ageing and methods of seed invigoration; a study on how to control the availability of water in substrate and water deficit responses in variegata, a type of ornamental plant; an analysis of the postharvest quality of peach fruit under optimal and stressful temperatures; a review concerning nutritional disorders related to the macronutrient calcium and strategies to avoid them, such as soilless production systems; the salt stress resistance of soapwort, a native Chinese plant; responses to heat stress in basil plants; drought stress responses of Chinese *Melia azedarach* of different origins; responses to UV and cold stress in rice plants associated with the expression of genes associated with the production of phytoalexins; an electron microscopy analysis of histological changes in wheat plants due to salinity; an analysis of the resilience of oilseed grown in greenhouses

Citation: Álvarez, S.; Acosta-Motos, J.R. Miscellaneous Sets of Abiotic Stresses and Plant Strategies to Cope with Them. *Agronomy* **2022**, *12*, 2727. https://doi.org/10.3390/agronomy12112727

Received: 17 October 2022
Accepted: 1 November 2022
Published: 3 November 2022

under stress conditions which simulate the future climate change scenario, using a variety of techniques; and a study of the different responses of field bean to the application of electromagnetic fields [1–12].

Adetunji et al. focus on the description of different strategies to enable seed invigoration. The maintenance of the quality of seeds during long processes of the conservation of plant genetic resources is key to avoid the expected food crises due to climate change and the increase in the global population. It is therefore imperative to effectively implement these invigoration techniques without neglecting other equally important agronomic practices, such as plant cultivation, fertiliser supply and pest and disease monitoring. In general, these techniques fall into one of two groups: (1) the priming or pre-hydration of seeds in a solution to improve yields after harvest, or (2) reinvigoration after storage, which often consists of soaking seeds recovered from storage in a solution. Seed priming methods are further divided into traditional methods (e.g., hydropriming, osmopriming, redox priming or priming with biostimulants) and innovative methods (e.g., nanopriming, magnetopriming and priming with other physical agents) [1].

Bañón et al. sought to increase farmers' awareness of the need to avoid excessive water use, which can damage plants due to water and salt stress. Moreover, these bad practices not only result in damage to plants, but they can also result in leaching into soil, which is harmful to the ecosystem and leads to increases in production costs. With these premises, the authors conducted a study under greenhouse conditions regarding the morphological and physiological responses of *Hebe andersonii* to three volumetric water contents in substrate (49%, 39% and 32%). In addition, due to the type of irrigation applied, which consisted of adding small volumes of water, they avoided drainage through the pots, and by using dielectric sensors, they monitored the humidity of the substrate and thus ensured that the amount of water provided was correct for each treatment. By way of conclusions, the authors demonstrated better growth and water use efficiency in variegata when humidity (and therefore water supply to the substrate) is low and there is no drainage [2].

Alonso-Salinas et al. carried out a study framed within the search for solutions to food wastage, specifically by extending the shelf life of a climacteric fruit such as peach. The concept that allows us to differentiate between climacteric and non-climacteric fruits is fundamental in important aspects such as harvesting, marketing, and postharvest preservation systems. Climacteric fruits are able to continue ripening once separated from the plant, assuming they have reached a level of development characterised by its maximum size (physiological maturity). Non-climacteric fruit, on the other hand, only ripen on the plant, and irreversibly stop their ripening process once separated from the plant. The physiological processes related to the ripening of climacteric fruits are characterised by an initial autocatalytic production of ethylene accompanied by an increase in the production rate of carbon dioxide, which accelerates the respiration of these fruits and therefore their ripening, which may culminate in the premature deterioration of the product, which has to be avoided. The authors implemented a highly efficient system of ethylene elimination using machines that combine the use of two types of eliminators of this phytohormone: by oxidation, namely potassium permanganate incorporated in filters and patented by the company ("Nuevas Tecnologías Agroalimentarias" (KEEPCOOL), patent No. 2548787 (2016)), and ultraviolet radiation. The use of this system is shown to be efficient both at low temperatures and at high temperatures, for the conservation in peach, extending its shelf life [3].

In a review, Birlanga et al. summarised the physiological mechanisms involved in the leaf necrosis of lettuce leaves known as tipburn, and the apical rot of tomato fruit, known as blossom end rot. Both physiopathologies are due to the deficient translocation of calcium from the root system to the leaves and fruit, but their effects are aggravated by abiotic stresses related to climate change, such as drought, salinity and temperature extremes. Subsequently, the advantages and disadvantages of the different soilless cultivation systems were also assessed, as they allow for the use of remote sensors and their automation for the precise monitoring and control of nutritional balance throughout the crop cycle. Finally, they described a set of solutions to deal with the physiopathologies discussed above. At the level of a soilless cultivation system, the authors concluded that it is very important to know the tools that currently are available for more exhaustive control of the environmental conditions, as well as the precise physiological control of crops. The use of intelligent management practices and their digitalisation allow us to monitor not only the environmental conditions inside the greenhouse, but also possible critical states at the plant level, evapotranspiration, water and nutrient consumption and even pathogen detection. At the nutritional level, these solutions include the use of organic fertilisers, the exogenous application of calcium or the use of nanoparticles to achieve more precise nutrition and a reduction in the amount of nutrients supplied. At the physiological level, it is important to analyse the behaviour of certain phytohormones in the vascular system of a plant and their influence during its growing cycle. At the genetic level, the use of genomic tools has allowed the identification of quantitative trait loci (QTL) in several populations of recombinant inbred lines and the subsequent development of molecular markers linked to these QTL [4].

Xu et al. used a plant named *Saponaria officinalis*, which is native from China, as one of the best ways to improve the salinity level of soil, as more than 70% of the soil in the north-eastern area in China is currently affected by salinity. In this way, it is possible to avoid the use of physical and chemical methods, which are expensive and can also lead to the secondary salinisation of soils. In addition, they also built their work on the known evidence of the positive role of salicylic acid (SA) in regulating resistance to salt stress in plants. Considering that the exogenous effect of SA on *S. officinalis* subjected to salt stress has not been studied so far, the authors analysed the resistance of this plant to salt stress in pot trials by using different concentrations of NaCl and spraying different concentrations of SA on leaves. The results indicated that SA enhances the salt resistance capacity of *S. officinalis* by regulating its photosynthetic rate, osmoprotectant levels, antioxidant concentrations, and ionic homeostasis. In spite of this, the efficacy of SA was not linearly related to its concentration. Taken together, the authors' insights suggest that the use of 0.6 mmol L^{-1} of SA under salt stress conditions could be effective in reducing the injury caused in *S. officinalis* by saline soils [5].

Qin et al., due to the observed increase in heat stress as a consequence of global warming and its negative effect on plant growth and yield, decided to perform a novel assay on the morphological, metabolic and transcriptional responses of basil—a medicinal and edible plant with important nutritional and economic value—to heat stress. The results revealed that heat stress led to severe oxidative damage and a decrease in the photosynthesis of basil. Metabonomic screening indicated that, compared to the control group, 29 differentially accumulated metabolites (DAMs) were found after one day of heat treatment, and 37 DAMs were identified after three days of heat treatment. Furthermore, a transcriptomic analysis revealed that 15,066 and 15,445 differentially expressed genes (DEGs) were present after one and three days of heat treatment, respectively. Of these, 11,183 DEGs were common response genes under one and three days of heat treatment, including 5437 down-regulated and 6746 up-regulated DEGs. All DEGs were significantly enriched in various KEGG (Kyoto Encyclopedia of Genes and Genomes) pathways. Taken together, all of these responses generated useful information which improved our knowledge regarding plants' response mechanisms to heat stress, which in turn could be useful for crop breeding [6].

Han et al. studied the mechanisms of drought resistance in *Melia azedarach*, a tree native to China, by selecting eight provenances as research subjects and applying four levels of drought stress as treatments. The overall results, after the analysis of individual parameters such as seedling height, root–shoot ratio, soil diameter, relative water content, transpiration rate, gas exchange parameters, chlorophyll, malondialdehyde and superoxide dismutase contents, and linear combinations of all the variables studied by means of principal component analysis, revealed that the drought resistance of Henan Shihe and Jiangxi Xihu was stronger, while the drought resistance of Guangdong Luogang and Hubei

Shayang was weaker. The authors, based on the results obtained, could select provenances with strong or weak drought resistance for transcriptome sequencing in order to screen for drought-resistant genes and perform an extensive study at the molecular level [7].

Hoang Anh et al. conducted the first study demonstrating that momilactones A (MA) and B (MB) contribute, in addition to their well-known role in protecting rice crops against pathogens, to the resistance of rice to environmental stresses, including ultraviolet radiation and chilling conditions. Although momilactones with valuable biological activities have been identified in recent decades, the catalytic steps in the biosynthetic pathway of these compounds are poorly understood. This is especially true when the genes encoding the hydrolysis of MA to MB in rice are unknown. The discovery of these unclear concepts may result in new research approaches to enhance rice's resistance to adverse conditions. In addition, further research regarding the existence of new secondary compounds and relevant gene expressions also offers the potential to achieve other valuable results. For instance, phenolics and momilactones show potential for the treatment of several human diseases. Consequently, the concurrent accumulation of phenolics and momilactones in rice may hold significant potential for medicinal and pharmaceutical applications. The authors hope that this new study will contribute to the sustainable development goals of guaranteeing healthy lifestyles and ending world poverty and starvation, particularly in developing countries [8].

Fedoreyeva et al. analysed the responses to the salinity of wheat of a sensitive variety such as Zolotaya and a tolerant variety such as Orenburgskaya 22. In the sensitive variety, a higher accumulation of phytotoxic ions was accompanied by a higher level of ROS production. At a 150 mM NaCl concentration, there was an increase in the expression level of *TOR*, which is a negative controller of autophagosome generation (their formation contributes to protect a plant against salinity). The level of *TOR* expression in Zolotaya was higher in roots and leaves than in Orenburgskaya 22. The build-up of ROS generation resulted in autophagy and programmed cell death (PCD). PCD biomarkers indicated DNA ruptures in nuclei and chromosomes in metaphase, superficial phosphatidylserine localisation at the cellular level, and cytochrome c liberation in the cytoplasm, suggesting a mitochondrial route for cell death during salinity events. Based on findings from electron microscopy, the incidence of mitophagy in the root and leaf cells of wheat under salinity conditions was demonstrated [9].

Pineda and Baron analysed the behaviour of oilseed rape grown under environmental conditions that simulated severe and intermediate climate changes, establishing the current climatic conditions as the control treatment, with the principal goal being to assess the effect of climate change on the health status of this crop of agronomic relevance. Two approaches were applied (invasive and non-invasive techniques). Invasive quantitative methods relate to the absorbance of biochemical compounds. Non-invasive methods, such as the use of thermal, multi-colour fluorescence and hyperspectral reflectance sensors, are focused on the spectral properties of plants. The results show changes in lipid peroxidation, altered pigment content, photosynthesis, transpiration and secondary metabolite synthesis, which are more pronounced in severe treatments. In addition, the new metric, diseased broccoli index 3, could reveal the extent of lipid peroxidation in leaves, while the climatic stress index for brassicas showed early symptoms of stress caused by climate change in oilseed rape plants [10].

Conesa et al. investigated the postharvest susceptibility of early-ripening nectarines to water stress. Apart from a well-irrigated treatment (T-0), three water shortage treatments (by retention of irrigation) were implemented: T-1: early postharvest from June to July, T-2: late postharvest from August to September, and T-3: water stress during the entire postharvest period, from June to September. Throughout the study, soil water content (θ_v) and midday stem water potential (Ψ_{stem}) were determined. During winter dormancy, L-arginine, starch and phosphorus contained in the roots were studied. At harvest, the yield, fruit quality and metabolites were measured. The most interesting treatment, according to the results obtained, was T-2, which showed the highest percentage of cracked fruit.

Additionally, significantly lower values in leaves (−2.3 MPa) were observed in T-2. In a similar way, lower values of L-arginine and phosphorus were obtained in the roots of the T-2 trees, as compared to the T-0 trees. This allowed the authors to conclude that, despite the fact that the early postharvest stage is key for the implementation of regulated deficit irrigation approaches, the late postharvest period was also a period sensitive to water restriction, as the build-up of winter root reserves was depleted, resulting in limited yields [11].

Pawełek et al. analysed the exposure of young and old bean seeds to electromagnetic fields (EMFs) (50 Hz, 7 mT) and studied seed germination and seedling growth in different situations. The results obtained showed the stimulation of germination and early root growth of old seeds, sown in Petri dishes in continuous darkness, and the inhibition of the germination of young seeds sown in pots under long day conditions. The root growth of two-week-old seedlings of young seeds sown in pots was stimulated by an EMF treatment, while stem growth was suppressed. In conclusion, the results indicated that the EMF (50 Hz, 7 mT) priming of bean seeds might be a critical factor that influences germination, early growth, and cell processes, and it may have a positive influence on the capability of bean plants to grow and develop in more stressful conditions at later stages [12].

Presently, due to the palpable effects of anthropogenic climate change, some of the abiotic stresses plants suffer from are being aggravated. Abiotic stresses that are more closely related to climatic change are drought, salinity and extreme temperatures. Human activities are the main cause of the global warming observed since the mid-20th century. The latest intergovernmental panel on climate change (IPCC) report has estimated that 23% of total greenhouse gas emissions generated between 2007 and 2016 mainly came from agriculture, forestry and other anthropogenic uses of land resources. Concern about global climate change and the search for measures that minimise its environmental impact has brought about new strategies for the use and consumption of natural resources. The modernisation of agricultural practices, as well as the digitisation of farming activities and the development of new varieties that grow more efficiently and are better adapted to adverse conditions such as climate change, are the main focus of farmers' efforts to achieve sustainable agriculture.

Author Contributions: Both authors contributed equally to the writing of this editorial. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: The second author would like to thank the UCAM-Santander Chair in Agri-Food Entrepreneurship for its financial support and Mario Fon for his help with English editing.

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

References

1. Adetunji, A.E.; Adetunji, T.L.; Varghese, B.; Sershen; Pammenter, N.W. Oxidative Stress, Ageing and Methods of Seed Invigoration: An Overview and Perspectives. *Agronomy* **2021**, *11*, 2369. [CrossRef]
2. Bañón, D.; Lorente, B.; Bañón, S.; Ortuño, M.F.; Sánchez-Blanco, M.J.; Alarcón, J.J. Control of Substrate Water Availability Using Soil Sensors and Effects of Water Deficit on the Morphology and Physiology of Potted *Hebe andersonii*. *Agronomy* **2022**, *12*, 206. [CrossRef]
3. Alonso-Salinas, R.; Acosta-Motos, J.R.; Núñez-Delicado, E.; Gabaldón, J.A.; López-Miranda, S. Combined Effect of Potassium Permanganate and Ultraviolet Light as Ethylene Scavengers on Post-Harvest Quality of Peach at Optimal and Stressful Temperatures. *Agronomy* **2022**, *12*, 616. [CrossRef]
4. Birlanga, V.; Acosta-Motos, J.R.; Pérez-Pérez, J.M. Mitigation of Calcium-Related Disorders in Soilless Production Systems. *Agronomy* **2022**, *12*, 644. [CrossRef]
5. Xu, L.; Chen, H.; Zhang, T.; Deng, Y.; Yan, J.; Wang, L. Salicylic Acid Improves the Salt Tolerance Capacity of *Saponaria officinalis* by Modulating Its Photosynthetic Rate, Osmoprotectants, Antioxidant Levels, and Ion Homeostasis. *Agronomy* **2022**, *12*, 1443. [CrossRef]
6. Qin, L.; Li, C.; Li, D.; Wang, J.; Yang, L.; Qu, A.; Wu, Q. Physiological, Metabolic and Transcriptional Responses of Basil (*Ocimum basilicum* Linn. var. *pilosum* (Willd.) Benth.) to Heat Stress. *Agronomy* **2022**, *12*, 1434. [CrossRef]
7. Han, C.; Chen, J.; Liu, Z.; Chen, H.; Yu, F.; Yu, W. Morphological and Physiological Responses of *Melia azedarach* Seedlings of Different Provenances to Drought Stress. *Agronomy* **2022**, *12*, 1461. [CrossRef]

8. Hoang Anh, L.; Van Quan, N.; Quang Lam, V.; Takami, A.; Dang Khanh, T.; Dang Xuan, T. Rice Momilactones and Phenolics: Expression of Relevant Biosynthetic Genes in Response to UV and Chilling Stresses. *Agronomy* **2022**, *12*, 1731. [CrossRef]
9. Fedoreyeva, L.I.; Lazareva, E.M.; Shelepova, O.V.; Baranova, E.N.; Kononenko, N.V. Salt-Induced Autophagy and Programmed Cell Death in Wheat. *Agronomy* **2022**, *12*, 1909. [CrossRef]
10. Pineda, M.; Barón, M. Health Status of Oilseed Rape Plants Grown under Potential Future Climatic Conditions Assessed by Invasive and Non-Invasive Techniques. *Agronomy* **2022**, *12*, 1845. [CrossRef]
11. Conesa, M.R.; Conejero, W.; Vera, J.; Ruiz-Sánchez, M.C. Root Reserves Ascertain Postharvest Sensitivity to Water Deficit of Nectarine Trees. *Agronomy* **2022**, *12*, 1805. [CrossRef]
12. Pawełek, A.; Wyszkowska, J.; Cecchetti, D.; Dinka, M.D.; Przybylski, K.; Szmidt-Jaworska, A. The Physiological and Biochemical Response of Field Bean (*Vicia faba* L. (partim)) to Electromagnetic Field Exposure Is Influenced by Seed Age, Light Conditions, and Growth Media. *Agronomy* **2022**, *12*, 2161. [CrossRef]