stresses

Editorial

Stress Responses in Crops

Mirza Hasanuzzaman [1,*], Luigi Sanità di Toppi [2] and Tika Adhikari [3]

1 Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh
2 Department of Biology, University of Pisa, Via Luca Ghini 13, 56126 Pisa, Italy; luigi.sanita@unipi.it
3 Department of Entomology and Plant Pathology, North Carolina State University, 1575 Varsity Drive, VRB, Module #6, Raleigh, NC 27695, USA; tbadhika@ncsu.edu
* Correspondence: mhzsauag@yahoo.com

Plants undergo a simultaneous interaction with numerous environmental stresses in the ever-changing climate, making sustainable crop production for the increased global population more challenging [1]. Ensuring food security for the increasing global population is one of the challenges in the coming decades. As frontiers of crop production, plant biologists and agronomists are the most responsible for the steady improvement of crop production. However, various abiotic and biotic stresses hinder crop production [2,3]. Both biotic and abiotic stresses combinedly or sequentially induce plants' physiological adaptation for combating one stress, increasing their susceptibility to another stress [2]. However, the effect of environmental stresses on crop plants varies with the degree of stress, different accompanying stresses, genotypes, and growth stages.

Hossen et al. [4] showed that indica and japonica rice showed differential physiology under salinity and drought stress. Importantly, their tolerance is dependent on osmotic adjustment, oxidative stress, antioxidant defense, and methylglyoxal detoxification. While comparing three genotypes (indica cvs. BRRI dhan29 and BRRI dhan48; and japonica cv. Koshihikari), they found that BRRI dhan48 showed the highest tolerance which has been connected to a lower Na^+/K^+ ratio, an increase in proline (Pro) content, and improved performance of the glyoxalase system and antioxidant protection for scavenging of reactive oxygen species (ROS). This study [4] provided insight into probable responses to single or combination salinity and drought stress in rice genotypes.

Genotype-dependent differences in salt tolerance in lettuce were also observed by Adhikari et al. [5]. Although this crop has a threshold salinity of 1.3–2.0 dS m^{-1}, some of the genotypes viz. PI 212099, Buttercrunch-1, and PI 171676 showed higher tolerance to salt (100 mM NaCl), which was due to the improved physiological, morphological, and biochemical attributes [5].

The main impacts of these stresses on different morphophysiological and biochemical features of plants include reduced photosynthetic activity, altered oxidative metabolism, membrane instability, stomatal conductance, altered root growth, decreased leaf area, and disturbed water relations resulting in diminished growth and yield [2].

Barickman et al. [6] reported that drought stress negatively affects plant morphology and physiology but the drought-induced reduction in crop growth and productivity can be compensated by increasing atmospheric carbon dioxide (CO_2). They showed that the elevated CO_2 (eCO_2) helps alleviate the adversity of drought stress in basil by increasing anthocyanin and chlorophyll, the photosynthetic system, and by decreasing stomatal conductance and leaf transpiration rate. Supplying eCO_2 in drought-stressed plants also upregulated the peroxidase and ascorbate activity [6].

Plants produce a certain amount of different ROS naturally due to cellular activities. Under stressful environmental conditions, overproduction of ROS occurs, leading to increased antioxidant enzyme activities to ensure overall cellular protection against

check for updates

Citation: Hasanuzzaman, M.; Sanità di Toppi, L.; Adhikari, T. Stress Responses in Crops. *Stresses* **2022**, *2*, 231–233. https://doi.org/10.3390/stresses2020016

Received: 7 May 2022
Accepted: 16 May 2022
Published: 23 May 2022

stress [3,7]. Nevertheless, various environmental factors, plants' genetic make-up, adaptation capacity of plants against stress, etc., affect plants' overall stress responses [2].

A comprehensive review of the literature on Arsenic-Induced Oxidative Stress and Antioxidant Defense in Plants was published by Nahar et al. [8]. Unlike other stresses, arsenic (As) also causes the excess generation of ROS which damages cells by disintegrating the structure of lipids, proteins, and DNA. Therefore, enhancing the antioxidant defense system is vital for As tolerance. They [8] suggested that various crop management practices such as exogenous application of nutrients, hormones, antioxidants, osmolytes, signaling molecules, different chelating agents, microbial inoculants, organic amendments, etc., can be effective against As toxicity in plants. Understanding the mechanism of As-induced responses will make understanding the current knowledge, knowledge gap, and future guideline to be worked out for the development of As tolerant plant cultivars as suggested by Nahar et al. [8].

One of such mechanisms is the use of plant nutrients. Akter et al. [9] reported the positive effect of zerovalent iron (ZVI) in modulating the influence of As-contaminated soil on the growth, yield, and grain quality of rice. They found that the application of ZVI had little or no effect on thousand-grain weight, phosphorus, potassium, zinc, and manganese of rice grains but iron content in rice grains was increased by ZVI treatments in a dose-dependent manner. The grain As content was non-significantly reduced by the ZVI application [9].

Plant stress tolerance is determined by the activation of molecular networks involved in stress detection, signal transduction, expression of specific stress-related genes, and stress-related enzyme production [3]. However, the majority of plant stress tolerance mechanisms remain unknown. Therefore, it is crucial to understand plant stress physiology more precisely to mitigate the negative effects of environmental stresses and for maintaining sustainable crop production. Plant stress tolerance can be increased by using chemical priming agents, molecular approaches such as genetic engineering, agronomic practices such as adjusting sowing time, nutrients and organic matter management, conservation tillage, irrigation management, well-drainage system, and the use of tolerant varieties, as well as the application of various types of biostimulants and phytohormones.

In their investigation, Majid et al. [10] assessed the role of abscisic acid (ABA; 25 μM) and/or nitrogen (N; 10 mM) in the alleviation of salinity (NaCl; 100 mM)-induced damages in mustard (*Brassica juncea* L.). Salt stress caused oxidative stress (higher hydrogen peroxide content and lipid peroxidation), and impaired photosynthetic activity and growth. On the contrary, the application of ABA under a controlled condition negatively affected photosynthesis and growth. However, ABA, when combined with N, minimized oxidative stress and mitigated the salinity-inhibited effects by increasing the activity of superoxide dismutase, glutathione reductase, ascorbate peroxidase, and Pro content. They concluded that the combined application of 10 mM N and 25 μM ABA may be an important strategy for enhancing the photosynthetic potential of *B. juncea* under salinity [10].

The enhanced antioxidant defense system of crop plants has a significant role in enhancing their stress tolerance mechanisms. Multifarious approaches have been used for this purpose, such as the use of exogenous protectants, the addition of plant nutrients (e.g., N; sulfur, S; calcium, etc.), phytohormones (e.g., ethylene, ETH; salicylic acid, SA; etc.), signaling molecules (e.g., nitric oxide, NO; hydrogen sulfide, H_2S; etc.), and use of soil amendments to induce plant stress tolerance.

Jahan et al. [11] revealed the coordinated role of NO, ETH, N, and S in plant salt stress tolerance. Being signaling molecules, both NO and ETH modulates several defense systems in plants and upregulates the antioxidant enzymes. Moreover, N and S had several vital roles in regulating plant growth and metabolism. Their review [11] focused on providing an overview of the potential mechanisms underlying the role of gaseous signaling molecules and mineral nutrients in salt stress tolerance and particular discussion on the coordinating role of NO and ETH along with N and S concerning salt stress tolerance [11].

Fertilization with trace elements is one of the finest ways in improving stress tolerance in crop plants. In this regard, Grašič et al. [12] observed that the fertilization of cucumbers with silicon (Si) showed a variety of positive effects, which increased the vitality of cucumber plants. Although both drought and UV radiation harmed various morphophysiological parameters, the application of potassium silicate reversed those adverse effects. Fertilization with potassium silicate increased the level of plant-available Si in the soil and leaf Si content and exerted little impact on the production parameters of cucumbers exposed to drought and ambient UV radiation [12].

This Special Issue, "Stress Responses in Crops" published six original research works and two review articles that discuss the various aspects of crop responses and tolerance to abiotic stress, which will help to serve as a foundation for climate change adaptation in agriculture. Thus, articles published in this Special Issue show further directions for the development of crop plants that are tolerant to environmental stress in the era of climate change.

Author Contributions: Conceptualization, M.H., L.S.d.T. and T.A.; writing—original draft preparation, M.H.; writing—review and editing, M.H., L.S.d.T. and T.A. All authors have read and agreed to the published version of the manuscript.

Funding: This editorial received no external funding.

Data Availability Statement: Not applicable.

Acknowledgments: We would like to thank all contributors for their submission to this Special Issue and the reviewers for their valuable input in improving the articles. We also thank the editorial office for their helpful support during the compilation of this Special Issue. The authors acknowledge Ayesha Siddika and Md. Rakib Hossain Raihan for their help during the organization of the studies and necessary formatting.

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

References

1. Zandalinas, S.I.; Balfagón, D.; Gómez-Cadenas, A.; Mittler, R. Responses of plants to climate change: Metabolic changes during abiotic stress combination in plants. *J. Exp. Bot.* **2022**, erac073. [CrossRef]
2. Hasanuzzaman, M.; Hossain, M.A.; da Silva, J.A.T.; Fujita, M. Plant responses and tolerance to abiotic oxidative stress: Antioxidant defenses is a key factor. In *Crop Stress and Its Management: Perspectives and Strategies*; Bandi, V., Shanker, A.K., Shanker, C., Mandapaka, M., Eds.; Springer: Berlin/Heidelberg, Germany, 2012; pp. 261–316. [CrossRef]
3. Hasanuzzaman, M.; Bhuyan, M.H.M.B.; Zulfiqar, F.; Raza, A.; Mohsin, S.M.; Mahmud, J.A.; Fujita, M.; Fotopoulos, V. Reactive oxygen species and antioxidant defense in plants under abiotic stress: Revisiting the crucial role of a universal defense regulator. *Antioxidants* **2020**, *9*, 681. [CrossRef]
4. Hossen, M.S.; Karim, M.F.; Fujita, M.; Bhuyan, M.H.M.B.; Nahar, K.; Masud, A.A.C.; Mahmud, J.A.; Hasanuzzaman, M. Comparative physiology of indica and japonica rice under salinity and drought stress: An intrinsic study on osmotic adjustment, oxidative stress, antioxidant defense and methylglyoxal detoxification. *Stresses* **2022**, *2*, 156–178. [CrossRef]
5. Adhikari, B.; Olorunwa, O.J.; Wilson, J.C.; Barickman, T.C. Morphological and physiological response of different lettuce genotypes to salt stress. *Stresses* **2021**, *1*, 285–304. [CrossRef]
6. Barickman, T.C.; Adhikari, B.; Sehgal, A.; Walne, C.H.; Reddy, K.R.; Gao, W. Drought and elevated CO_2 impacts photosynthesis and biochemicals of basil (*Ocimum basilicum* L.). *Stresses* **2021**, *1*, 223–237. [CrossRef]
7. Hasanuzzaman, M.; Nahar, K.; Alam, M.M.; Roychowdhury, R.; Fujita, M. Physiological, biochemical, and molecular mechanisms of heat stress tolerance in plants. *Int. J. Mol. Sci.* **2013**, *14*, 9643–9684. [CrossRef] [PubMed]
8. Nahar, K.; Rhaman, M.S.; Parvin, K.; Bardhan, K.; Marques, D.N.; García-Caparrós, P.; Hasanuzzaman, M. Arsenic-induced oxidative stress and antioxidant defense in plants. *Stresses* **2022**, *2*, 179–209. [CrossRef]
9. Akter, S.; Rahman, G.K.M.M.; Hasanuzzaman, M.; Alam, Z.; Watanabe, T.; Islam, T. Zerovalent iron modulates the influence of arsenic-contaminated soil on growth, yield and grain quality of rice. *Stresses* **2021**, *1*, 90–104. [CrossRef]
10. Majid, A.; Rather, B.A.; Masood, A.; Sehar, Z.; Anjum, N.A.; Khan, N.A. Abscisic Acid in coordination with nitrogen alleviates salinity-inhibited photosynthetic potential in mustard by improving proline accumulation and antioxidant activity. *Stresses* **2021**, *1*, 162–180. [CrossRef]
11. Jahan, B.; Rasheed, F.; Sehar, Z.; Fatma, M.; Iqbal, N.; Masood, A.; Anjum, N.A.; Khan, N.A. Coordinated role of nitric oxide, ethylene, nitrogen, and sulfur in plant salt stress tolerance. *Stresses* **2021**, *1*, 181–199. [CrossRef]
12. Grašič, M.; Germ, M.; Vogel-Mikuš, K.; Ojdanič, N.; Gaberščik, A.; Golob, A. Fertilisation with potassium silicate exerted little effect on production parameters of cucumbers exposed to UV and drought. *Stresses* **2021**, *1*, 142–161. [CrossRef]