Editorial

Manoj Prasad^{1,2} · Muthappa Senthil-Kumar¹

Published online: 11 November 2021

© The Author(s), under exclusive licence to Society for Plant Biochemistry and Biotechnology 2021

The impact of different stresses on plants due to climatic changes is steadily increasing, and this challenges the multiple securities relished by the global population. Any stress, either natural or artificial, imposed on agriculture will have a disastrous outcome. This warrants intense and advanced basic research to understand the diverse mechanisms that operate in plants during stresses, enabling fine-tuning the molecular circuitry to enhance the stress resilience traits. Using state-of-the-art tools, several national and international laboratories are working on this area to gain insights into the stress response at morpho-physiological, biochemical, and molecular levels. In India, the research focuses on delineating the roles of different molecules, including small RNAs, transcription factors, transporters, stress-responsive genes, aquaporins, and signalling molecules, in response to individual and combined biotic and abiotic stresses. The current special issue is a timely attempt to collect the contributions made by Indian researchers to stress biology. Thus, the special issue encompasses four commentaries, twelve reviews and research articles each, and four short communications. The contributors of the special issue consist of internationally and nationally renowned scientists, emeritus professors, and mid- and early-career researchers doing outstanding research in plant molecular stress responses. Also, three international groups have contributed, making this special issue a highly informative resource to the research community working on different aspects of stress biology.

Among the commentaries, Prasad et al. (2021) provide insights into how sophisticated molecular mechanisms play

roles in determining the fitness of plants to diverse stresses. Mangrauthia et al. (2021) summarize diverse plant viruses with varied host ranges, their genomic nature, organization, and strategies for replication. The authors have discussed how evolution shapes the virus as well as the plants to derive resistance or susceptibility to infections. Asati et al. (2021) had given an outlook on flavonoids biosynthesis, metabolism, and their involvement in stress response in ethnobotanically important desert legumes such as *Prosopis cineraria*, *Cyamopsis tetragonoloba*, *Acacia senegal*, etc. The role of NAC transcription factors in regulating multiple stress tolerance in legume species was reviewed by Srivastava and Sahoo (2021). The article suggests the NAC-mediated strategies for attaining tolerance to multiple stresses in important legumes without yield penalty. Venkateswara et al. (2021) had explained how light and ethylene signals coordinate to optimize seedling establishment and how this knowledge can contribute to stress resilience in plants under changing climatic conditions.

A review by Rustgi et al. (2021) enumerates the recent progress made towards using heat-induced membrane lipid unsaturation as an indicator of heat tolerance in oilseed crops. The review further discusses the heat-induced changes in the expression pattern of the fatty acid desaturase (FAD) gene as a marker for heat tolerance. Another review on the ion transporters illustrates their role in salt uptake and exclusion and how ion homeostasis is maintained during salt stress (Malakar and Chattopadhyay 2021). The article also highlights the lack of information on ion sensors, ion transporters, and their regulatory roles during salt and other stresses. Similarly, Thounaojam et al. (2021) has provided a detailed review on the involvement of several transporters (phosphate transporters, nodulin 26-like intrinsic proteins, plasma membrane intrinsic proteins, tonoplast intrinsic proteins, C-type ATP binding cassette transporters, arsenical resistance 3 transporter, inositol transporters (INTs), multidrug and toxic compound extrusion transporters, and natural resistance-associated macrophage protein transporters) in regulating arsenic toxicity. In line with this, Samanta and Roychoudhury (2021) showed the application of nanoparticles of different

✉ Manoj Prasad
manoj_prasad@nipgr.ac.in
Muthappa Senthil-Kumar
skmuthappa@nipgr.ac.in

¹ National Institute of Plant Genome Research, Aruna Asaf Ali Marg, New Delhi 110067, India

² Department of Plant Sciences, University of Hyderabad, Hyderabad, Telangana 500046, India

metal or metal oxides in regulating arsenic toxicity. The article also discusses the risks and risk assessment related to the use of nanoparticles to alleviate arsenic toxicity. These highlights the importance of studying heavy metal stress, and in this context, Dubey et al. (2021) reviewed the functional roles of metal-regulated miRNAs and their respective target genes in heavy metal tolerance and homeostasis.

Among the other regulatory molecules, the role of inositol and its metabolic derivatives in providing broad-spectrum stress tolerance was discussed by Basak and Majumder (2021). The article also emphasizes the importance of *cis*-acting regulatory elements, followed by a phylogenetic analysis of the regulatory signatures inducing inositol production and its metabolism. The mechanistic insights into plant hormones mediated signaling to orchestrate a fine balance of the primary and secondary stress responses were provided by Kapoor et al. (2021). The review also hints at the emerging roles of novel molecules, small RNAs, and epigenetic regulators that could be potential moderators of hormonal crosstalk. In the area of plant-pathogen interaction, a review by Kumar and Chakraborty (2021) neatly summarizes the discovery, biogenesis, and roles of long non-coding RNAs (lncRNAs) in regulating plant-virus pathogenesis, and Kundu and Vadassery (2021) reviewed the role of WRKY transcription factors in regulating the response to herbivore attack. The article nicely summarizes the recent developments on transcriptional, post-transcriptional, and epigenetic regulation of WRKYs in response to herbivory attacks. A comprehensive review on the involvement of stress-associated proteins during biotic and abiotic stresses was provided by Shukla et al. (2021). The review categorically explains the multitude of roles of stress-associated proteins in regulating the molecular stress response and conferring tolerance to the stresses. Similarly, the response of plants to phosphate starvation was reviewed by Srivastava et al. (2021). The article summarizes the challenges and environmental consequences of phosphate-intensive fertilization, response and adaptive strategies of plants to phosphate starvation, the role of microbes and phosphate-nanofertilizer for nutrition. Altogether, the reviews published in the special issue on contemporary topics give a broad outlook to the studies on the molecular stress response and will serve as a source of information for further studies in this direction.

In sorghum and tomato, Puli et al. (2021) and Bansal et al. (2021) identified the microRNAs that were expressed during individual heat and drought stress and a combination of both. These studies identified several novel miRNA candidates that have a potential role in regulating the tolerance to combined and individual stresses in both species. Further, the involvement of heat shock proteins and heat

shock factors in regulating heat and other abiotic stresses has been shown by Rao et al. (2021) and Tiwari et al. (2021). During salt stress, the different parameters (morpho-physiological, biochemical, and molecular) were checked in mango plants by Laxmi et al. (2021). The study shows the role of osmotic stress alleviation and redox regulation in salt tolerance, particularly in Indian cultivars. In another interesting work, Kiani et al. (2021) produced the amphidiploid (allooctaploid) plants derived from the crosses between common wheat and *Aegilops cylindrica*, followed by salt tolerance analysis of the amphidiploid plants and backcross lines. A genome-wide study of aquaporin gene family in pomegranate by Kumawat et al. (2021) underlines the importance of aquaporins in salinity tolerance. Similar genome-wide analyses were performed in tomato for two other gene families, namely WOX transcription factors (Li et al. 2021) and SnRK genes (Khurana et al. 2021). The former study checked the expression levels of WOX transcription factors in different tissues, developmental stages, and stresses (drought, salt, cold, abscisic acid, indole-3-acetic acid, jasmonic acid, gibberellin, and salicylic acid treatment). The latter study studied the expression of candidate SnRK genes under phosphate starving conditions. Altogether, both the studies showed the putative involvement of WOX and SnRK genes in regulating multiple stress responses and phosphate starvation in tomato.

In the area of biotic stress response, Chakraborty et al. (2021a) had tested a biotic elicitor in tomato to improve the innate immunity of the elicitor-treated plants to *Fusarium oxysporum* infection. The biotic elicitor fraction obtained from *F. oxysporum* has been shown to boost the immunity by regulating the nitric oxide signaling cascade. Another study by Chakraborty et al. (2021b) demonstrates the use of deep learning architecture based on a Convolutional Neural Network to detect begomovirus infection in tobacco plants. This approach appears to be promising in detecting different virus infections in plants at the early stages to deploy appropriate preventive measures. In another work by Samiappan et al. (2021), the effectiveness of arbuscular mycorrhizal fungi (*Glomus mosseae* and *Glomus intraradices*) in improving the soil moisture after mycorrhizal treatment in maize has been tested. The study showed the drought-resistant capacity of maize plants treated with arbuscular mycorrhizal fungi, which warrants further studies in this direction to scale up the use of mycorrhizal fungi for alleviating drought stress.

Among the short communications, a study by Choudhary and Senthil-Kumar (2021) used a combination of bioinformatic and data-guided approaches to identify major biological pathways, transcription factor network, and novel motifs that are involved in the combined stress-specific responses. The study further dissects the role of

AtMYB96 in combined stress response, as revealed from expression studies and mutant analysis. Another study by Kar et al. (2021) reports the origin, evolution and functional conservation of MATE transporters through the sequence and phylogenetic analysis. The study also highlights MATE transporters' role and their potential usage to enhance plant stress resilience. Similarly, Biswas et al. (2021) showed the stress-induced flowering in bamboo, wherein ABA level was observed to be increased in the young leaf from flowering culm than a leaf from the non-flowering culm. The authors also reported that fire and pruning could induce flowering in several bamboo species. Another interesting study on the role of naturally occurring endophytes in stimulating induced systemic resistance (ISR) has been reported by Singh et al. (2021). The work suggests that endophytes grown in plants under the natural environment play a significant role in generating broad-spectrum resistance against soil microbes. These endophytes may be selectively used to induce ISR in plants.

Taken together, the special issue is a compendium of several interesting commentaries, reviews, research articles, and short communications that advance the current scientific understandings of plant-stress interaction at molecular levels. We acknowledge all the authors for their valuable contributions in this special issue. This special issue would not be possible without the support and encouragement of the Editor-in-Chief, Dr. Ramamurthy Srinivasan. The Editors of the special issue also acknowledge the support received from Dr. Mamta Kapila (Executive Editor), Dr. Karen Grace Corpuz (Journal Editorial Office), Ms. Jeyapradha Saravanan (Production Editor) and their team members at Springer. The assistances received from the expert reviewers in assessing the manuscripts submitted to the special issue and providing valuable suggestions to authors for improving their work are also gratefully acknowledged.

References

- Asati V, Deepa PR, Sharma PK (2021) Silent metabolism and not-so-silent biological activity: possible molecular mechanisms of stress response in edible desert legumes. *J Plant Biochem Biotechnol* (in press)
- Bansal C, Balyan S, Mathur S (2021) Inferring the regulatory network of the miRNA-mediated response to individual and combined heat and drought stress in tomato. *J Plant Biochem Biotechnol* (in press)
- Basak P, Majumder AL (2021) Regulation of stress-induced inositol metabolism in plants: a phylogenetic search for conserved cis elements. *J Plant Biochem Biotechnol*. <https://doi.org/10.1007/s13562-021-00708-7>
- Biswas S, Sarkar A, Kharlyngdoh E, Somkuwar BG, Biswas P, Dutta S, Guha S, Das M (2021) Evidence of stress induced flowering in bamboo and comments on probable biochemical and molecular factors. *J Plant Biochem Biotechnol*. <https://doi.org/10.1007/s13562-021-00719-4>
- Chakraborty N, Sarkar A, Acharya K (2021a) Biotic elicitor induced nitric oxide production in mitigation of Fusarium wilt of tomato. *J Plant Biochem Biotechnol*. <https://doi.org/10.1007/s13562-021-00705-w>
- Chakraborty S, Kodamana H, Chakraborty S (2021) Deep learning aided automatic and reliable detection of tomato begomovirus infections in plants. *J Plant Biochem Biotechnol* (in press)
- Choudhary A, Senthil-Kumar M (2021) Investigation of the novel transcriptional changes under combined drought and bacterial stress underpins the role of AtMYB96 in imparting tolerance. *J Plant Biochem Biotechnol* (in press)
- Dubey S, Shri M, Chakraborty D (2021) MicroRNA mediated regulation of gene expression in response to heavy metals in plants. *J Plant Biochem Biotechnol*. <https://doi.org/10.1007/s13562-021-00718-5>
- Kapoor B, Kumar P, Sharma R, Kumar A (2021) Regulatory interactions in phytohormone stress signaling implying plants resistance and resilience mechanisms. *J Plant Biochem Biotechnol* (in press)
- Kar D, Bhagavatula L, Dutta A, Datta S (2021) Conserved functions of MATE transporters and their potential to enhance plant tolerance to aluminium toxicity. *J Plant Biochem Biotechnol* (in press)
- Khurana A, Akash, Roychowdhury A (2021) Identification of phosphorus starvation inducible SnRK genes in tomato (*Solanum lycopersicum* L.). *J Plant Biochem Biotechnol*. <https://doi.org/10.1007/s13562-021-00701-0>
- Kiani R, Arzani A, Maibody SAMM, Rahimmalek M, Ayers T (2021) Hybridization of wheat and *Aegilops cylindrica*: development, Karyomorphology, DNA barcoding and salt tolerance of the amphidiploids. *J Plant Biochem Biotechnol* (in press)
- Kumar K, Chakraborty S (2021) Roles of Long non-coding RNAs in plant virus interactions. *J Plant Biochem Biotechnol*. <https://doi.org/10.1007/s13562-021-00697-7>
- Kumawat S, Aggarwal B, Rana N, Mandlik R, Mehra A, Shivaraj SM, Sonah H, Deshmukh R (2021) Identification of aquaporins and deciphering their role under salinity stress in pomegranate (*Punica granatum*). *J Plant Biochem Biotechnol* (in press)
- Kundu P, Vadassery J (2021) Role of WRKY transcription factors in plant defense against lepidopteran insect herbivores: an Overview. *J Plant Biochem Biotechnol* (in press)
- Laxmi, Kamal A, Kumar V, Muthukumar M, Bajpai A (2021) Morphological indicators of salinity stress and their relation with osmolyte associated redox regulation in mango cultivars. *J Plant Biochem Biotechnol* (in press)
- Li H, Li X, Sun M, Chen S, Ma H, Lin J, Sun Y, Zhong M (2021) Molecular characterization and gene expression analysis of tomato WOX transcription factor family under abiotic stress and phytohormone treatment. *J Plant Biochem Biotechnol*. <https://doi.org/10.1007/s13562-021-00723-8>
- Malakar P, Chattopadhyay D (2021) Adaptation of plants to salt stress: the role of the ion transporters. *J Plant Biochem Biotechnol* (in press)
- Mangrauthia SK, Ramesh SV, Sahana N, Praveen S (2021) Rhythm of a life within life: role of viral suppressors in hijacking the host Cell. *J Plant Biochem Biotechnol* (in press)
- Prasad A, Senthil-Kumar M, Prasad M (2021) Complex molecular mechanisms determine fitness of plants to biotic and abiotic stresses. *J Plant Biochem Biotechnol* (in press)
- Puli COR, Zheng Y, Li Y-F, Jagadeeswaran G, Suo A, Jiang B, Sharma P, Mann R, Ganesan G, Gogoi N, Srinivasan A, Kakani A, Kakani VG, Barakat A, Sunkar R (2021) MicroRNA profiles in Sorghum exposed to individual drought or heat or their combination. *J Plant Biochem Biotechnol* (in press)

- Rao S, Das JR, Mathur S (2021) Exploring the master regulator heat stress transcription factor HSFA1a-mediated transcriptional cascade of HSFs in the heat stress response of tomato. *J Plant Biochem Biotechnol*. <https://doi.org/10.1007/s13562-021-00696-8>
- Rustgi S, Kakati JP, Jones ZT, Lwe ZSZ, Narayanan S (2021) Heat tolerance as a function of membrane lipid remodeling in the major US oilseed crops (soybean and peanut). *J Plant Biochem Biotechnol* (in press)
- Samanta S, Roychoudhury A (2021) Recent trend in nanoparticle research in regulating arsenic bioaccumulation and mitigating arsenic toxicity in plant species. *J Plant Biochem Biotechnol*. <https://doi.org/10.1007/s13562-021-00727-4>
- Samiappan SC, Mahalakshmi P, Pandiyan R (2021) Impact of mycorrhizal soil fertility proteins and arbuscular mycorrhizal application to combat drought stress in maize plants. *J Plant Biochem Biotechnol* (in press)
- Shukla V, Choudhary P, Rana S, Muthamilarasan M (2021) Structural evolution and function of stress associated proteins in regulating biotic and abiotic stress responses in plants. *J Plant Biochem Biotechnol*. <https://doi.org/10.1007/s13562-021-00704-x>
- Singh P, Sharma A, Nandi AK, Nandi SP (2021) Endophytes from *Argemone mexicana* and *Datura metel* activate induced-systemic resistance in multiple hosts and show host- and pathogen-specific protection. *J Plant Biochem Biotechnol* (in press)
- Srivastava R, Basu S, Kumar R (2021) Phosphorus starvation response dynamics and management in plants for sustainable agriculture. *J Plant Biochem Biotechnol*. <https://doi.org/10.1007/s13562-021-00715-8>
- Srivastava R, Sahoo L (2021) Balancing yield trade-off in legumes during multiple stress tolerance via strategic crosstalk by native NAC transcription factors. *J Plant Biochem Biotechnol* (in press)
- Thounaojam TC, Khan Z, Meetei TT, Srivastava S, Panda SK, Upadhyaya H (2021) Transporters: the molecular drivers of arsenic stress tolerance in plants. *J Plant Biochem Biotechnol* (in press)
- Tiwari LD, Kumar R, Sharma V, Sahu AK, Sahu BK, Naithani SC, Grover A (2021) Stress and development phenotyping of Hsp101 and diverse other Hsp mutants of *Arabidopsis thaliana*. *J Plant Biochem Biotechnol* (in press)
- Venkateswara K, Ravindran N, Bhagavatula L, Datta S (2021) Molecular mechanisms to sense soil overlay and optimize emergence in plants. *J Plant Biochem Biotechnol* (in press)

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.