Protective Chemical Agents in the Amelioration of Plant Abiotic Stress

Biochemical and Molecular Perspectives

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Sugars and Sugar Polyols in Overcoming Environmental Stresses

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4.1 Introduction

Plants require an array of abiotic factors such as sunlight, temperature, moisture, water, mineral salts, nutrients, as well as O_2 and CO_2 in order to attain optimal growth. Each of these abiotic factors has a precise effect on plant growth and development, which depends on its magnitude and concentration. Any deviation in the intensity of these optimal abiotic factors in their chemical or physical environment may lead to a condition known as abiotic stress (Bray et al. 2000; Paul and Roychoudhury 2019). Under natural environments, plants are very often exposed to these abiotic stresses that adversely affect plant growth, development, and reproduction (Rosa et al. 2009; Roychoudhury et al. 2009). Drought, salinity, heat, and freezing temperature are important examples of such environmental adversities that restrict the plants from displaying their full genetic potential and account for extensive crop loss (Cramer et al. 2011; Keunen et al. 2013; Roychoudhury et al. 2008).

In plants, abiotic stress involves three primary phases comprising stress sensing, signaling, and exhaustion. Early phases of stress involve sensing or perception of the adverse abiotic stimuli through various sensors and induce a signaling cascade that relays the stress signal to the interior of the cell (Roychoudhury and Banerjee 2017). This eventually leads to an alteration in gene expression, thereby changing the host physiology and metabolism referred to as exhaustion (Rosa et al. 2009; Duque et al. 2013). Additionally, a fourth phase known as regeneration may come into existence that involves partial or total normalization of the physiological aspects of the plants upon removal of the stress factors. Continuous agitations of these stress factors may result in reduced photosynthesis, impaired water transport, osmotic imbalance, disturbed ion homeostasis, membrane instability, and oxidative stress through excessive generation of reactive oxygen species (ROS) that collectively hinder growth and development of plants (Rosa et al. 2009; Van den Ende and El-Esawe 2014; Roychoudhury et al. 2016).

To counter the impact of these hostile environmental conditions, plants have evolved complex molecular and physiological stratagems that aid in their survival under these

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Green Synthesis and Application of Biogenic Nanomaterials as a Blueprint in Mitigation of Abiotic Stress in Crop Plants: A Conceptual Review

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Abstract

Plants being sessile, constantly encounter environmental perturbations that restrict their growth, development, and crop yield. Abiotic stressors like salt, heavy metals, drought, flooding, cold, and elevated temperatures impose heavy yield penalties yearly. The environmental fluctuations resulted in stress conditions impelled the scientific community to focus on developing stratagems to sustain the development and growth of a plant under adverse environmental conditions. Due to the constantly changing global climatic conditions, developing dependable and eco-friendly approaches to overcome the production barrier are of paramount importance. Phyto-nanotechnology is therefore considered as a viable alternative in mitigating environmental stresses with minimum negative repercussions. Conventional synthesis of nanomaterials (NMs) based on physical and chemical means became matters of concern due to their possible environmental emissions, which could have come up with detrimental effects on the ecosystem. Therefore, the synthesis of NPs from green sources has been projected as a safe and environment-friendly method of nanoparticle (NP) synthesis. The biogenic NPs derived from various organisms like bacteria, algae, fungi, and higher plants evade the use of chemical stabilizers owing to their intrinsic stability, thereby reducing toxic emissions to the environment. Here, we have elaborated the latest developments of NP biogenesis of various sizes and shapes synthesized using the reducing power of secondary metabolites in natural extracts. This chapter also discussed the recent advances in biogenic NPs in ameliorating abiotic stress response, improving plant defense mechanisms, restoring crop yield, and improving growth and development. Therefore, biogenic NPs might come up with a future roadmap for the agricultural community to improve stress-resilience and sustainable development of crop plants.

Keywords

Abiotic stress · Crop plant · Green synthesis · Nanotechnology · Nanoparticle · Tolerance

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