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Plant Bio-Regulators (PBRs) and Abiotic Stress Tolerance in Rice

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Rice (*Oryza sativa*. *L*) is one of the most widely grown staple food crop worldwide. Global warming is having an adverse impact on rice fields, resulting in many forms of abiotic stress viz., salinity, water scarcity, and high temperatures. (Appiah et al., 2018). Plants have evolved several mechanisms of resilience, such as physiological, biochemical, and molecular reprogramming, to deal with such abiotic stress factors induced by climate change. (Wassmann et al.,2009). Comprehensive mechanistic understanding of adaptive plant responses is of prime importance especially when they are grown under stressful conditions. In this context, numerous previous studies have conclusively shown that exogenous application of plant Bio-Regulators(PBRs) and hormones are essential for the growth, development, and yield of crops. PBRs are effective tools for enhancing production and quality as well as raising farmers' net income. For the economic benefit of the grower, PBRs have been employed for a long time to modify the behaviour of agricultural and horticultural crops. The best examples of regulation with exogenous PBR applications include control of seedling vigour, stimulation of flowering, reduction in flower and fruit drop, and delay or stimulation of fruit maturation and ripening.

Exogenous PBR application has a significant impact on a plant's ability to respond to abiotic stress, either separately or in concert with other exogenous PBR applications. Numerous PBRs interact with signalling pathways one another's, increasing plants' ability to withstand abiotic stresses. To achieve the desired tolerance, many researchers connected the redox signalling route among various PBRs. For example, it has been discovered in numerous investigations that ABA-induced stomatal closure is mediated by nitric oxide (NO) (Garcia-Mata and Lamattina, 2007). PBRs also encourage the absorption and metabolism of nutritional components.

Thiourea is one of the most widely used molecules among PBRs. It has two functional groups, "thiol," which is crucial for oxidative stress response, and "imino," which partially satisfies the nitrogen requirement. Other than thiol compounds there are several other chemicals including plant growth regulators viz., prohexadione-calcium (Pro-Ca)6-benzyladenine(BA), 2,4-dichlorophenoxyacetic acid (2,4-D), N-2-chloro-4-pyridinyl-N-phenylurea (CPPU), amino ethoxy vinyl glycine (AVG), 3,5,6-trichloro-2-pyridyloxyacetic acid (3,5,6-TPA), and, Potassium Nitrate (KNO3), Dithiothreitol (DTT), , Thiourea (TU), Silicon (Si), Salicylic Acid (SA) products were used to a small extent to determine whether they can raise agricultural productivity without lowering quality of the crop produce. PBRs stimulate the antioxidant system, enhance the biosynthesis of osmolytes, and increase the expression of stress-responsive genes in plants when applied exogenously at the appropriate amounts. (Srivastava et al., 2016; Knorzer et al., 1999).

Mitigating abiotic stress impacts through application of PBRs in Rice

Water stress causes severe physiological and biochemical malfunctions in plants, including a decrease in cell turgor, growth, photosynthetic rate, stomatal conductance, and cellular component destruction. SA has a significant potential to increase the abiotic stress tolerance of agriculturally important crops. However, a number of variables, including the amount of SA applied, method of application, and the stage of plant development, affect its efficacy. At higher concentrations SA induces oxidative stress and at low concentration it has been found to alleviate abiotic stress (Miura and Tada, 2014). Rafiq et al (2021) Showed that priming of rice seeds with SA (225 ppm) can be recommended for enhanced germination and early crop establishment in direct seeded rice (DSR) system and other study conducted by Anwar et al (2013) has showed that seed preconditioning with salicylic acid 20mg L^{-1} has enhanced the rice seedling vigor under DSR system. High salinity causes major metabolic disruptions in plants such as increased production of ROS, which upsets the cellular redox balance of the cells, this oxidative stress can harm DNA, inactivate the enzyme system, which ultimately results in membrane lipid peroxidation. Siringam et al., (2013) showed that the exogenous application of 11.8 mM KNO_3 improved salt-tolerance via the maintenance of water use efficiency, photosynthetic pigments structure, enhancement of chlorophyll a fluorescence, and stimulation of growth characters in salt sensitive PT1 rice cultivar grown under 342mM NaCl salinity. Foliar-supplemented Thiourea (6.5 mM) improved the growth and yield attributes of the rice plants grown under 50mM NaCl salt stress (Pandey et al., 2021). Many such studies were conducted by the various researchers using PBRs to improve the abiotic stress tolerance capacity in rice, which are listed in the below given table.

S. No.	PBRs	Dose	Abiotic stress	Method of application	References
1	Salicylic Acid	225ppm	Drought	Seed priming	Rafiq et al.,2021
2	Salicylic Acid	1.0 mmol/L	Salinity	Seedling pre-treatment	Jini and Joseph,2017
3	Potassium Nitrate (KNO_3)	11.8 mM	Salinity	Media supplementation	Siringam et al.,2013
4	KNO_3	2.5% and 5%	Drought	Seed priming	Ali et al.,2021
5	Salicylic Acid	1 mM and 2.5 mM	Drought	Seed priming	Ali et al.,2021
6	KNO_3	2%	Drought	Foliar application	Sharma et al.,2018
7	Thiourea (TU)	2.0mM	Drought	Media supplementation	Mahadi et al.,2020
8	Thiourea (TU)	6.5 mM	Salinity	Foliar application	Pandey et al.,2021
9	Gamma-AminoButyric Acid (GABA)	1.0mM	Heavy metal toxicity	Foliar application	Ashraf et al.,2022

Conclusion

Although PBR-based research has advanced significantly in recent years, most of these advances have been constrained by the yield data or underlying molecular mechanisms. Information on residual grain concentration human toxicity, nutritional imbalance, and ecological bio-safety is not available for the majority of PBRs, because of which they are not approved for use in farmer's field. Therefore, there is an ample need to give attention to these issues so that one can increase the chance of converting more and more PBR based research into actual farmer friendly technology that can be reached easily to farmer's field.

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