

Salicylic Acid Under Abiotic Stress: A Key Player in Plant Defence Mechanisms

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Abiotic stress factors have detrimental effects on plant physiology, including impaired photosynthesis, altered water relations, oxidative damage, and disrupted cellular metabolism. In response to these stressors, plants trigger a range of biochemical and molecular processes to enhance stress tolerance and minimize damage. Salicylic acid, a naturally occurring phenolic compound, has emerged as a critical signalling molecule involved in the regulation of plant defence responses against abiotic stress.

Role of Salicylic Acid

- **Activation of Defence Genes:** Salicylic acid plays a crucial role in activating defence-related genes, including those involved in antioxidant metabolism, osmoprotection, and stress signal transduction pathways. These genes collectively contribute to enhancing plant stress tolerance and minimizing stress-induced damage.
- **Antioxidant Activity:** Abiotic stress often leads to the production of reactive oxygen species (ROS), which can cause cellular damage. Salicylic acid acts as a potent antioxidant, scavenging ROS and minimizing oxidative stress. Additionally, SA stimulates the activity of antioxidant enzymes, such as superoxide dismutase (SOD) and catalase (CAT), to enhance the plant's antioxidant defence system.
- **Osmotic Adjustment:** Under abiotic stress conditions, plants experience osmotic imbalances due to altered water availability. Salicylic acid helps regulate osmotic balance by

promoting the accumulation of compatible solutes, such as proline and sugars, which maintain cellular turgor and stabilize cellular structures.

- **Hormonal Crosstalk:** Salicylic acid interacts with other plant hormones, including jasmonic acid (JA) and abscisic acid (ABA), to modulate plant responses to abiotic stress. While SA is primarily associated with defense against biotic stresses, it also plays a role in mitigating the effects of abiotic stress by regulating hormone signaling pathways.

Role of salicylic acid under salt stress:

- **Ion Homeostasis:** Salt stress disrupts ion homeostasis, resulting in the accumulation of toxic ions, particularly sodium (Na⁺) and chloride (Cl⁻), in plant tissues. SA has been shown to alleviate salt-induced ion toxicity by regulating ion transporters, such as sodium/hydrogen exchangers (NHXs), potassium transporters (HKTs), and plasma membrane H⁺-ATPases, thus promoting ion balance and minimizing ion toxicity.
- **Osmotic Regulation:** Salt stress imposes osmotic stress on plants, leading to water deficit and cellular dehydration. SA assists in osmotic regulation by promoting the accumulation of compatible solutes, such as proline, glycine betaine, and sugars, which help maintain cellular water balance and prevent cellular dehydration.

- **Antioxidant Defense:** Salt stress induces the generation of reactive oxygen species (ROS), causing oxidative damage to plant cells. SA acts as a potent antioxidant, scavenging ROS and stimulating the activity of antioxidant enzymes, including superoxide dismutase (SOD), catalase (CAT), and peroxidases, to protect plants from oxidative stress-induced injury.
- **Gene Expression Regulation:** SA influences the expression of numerous genes involved in salt stress responses. It upregulates the expression of stress-responsive genes, such as those encoding late embryogenesis abundant (LEA) proteins, heat shock proteins (HSPs), and antioxidant enzymes. Additionally, SA enhances the expression of genes involved in signal transduction pathways, leading to improved salt stress tolerance.

Conclusion

Salicylic acid acts as a central player in plant defence mechanisms against abiotic stress. Through its multifaceted functions, SA regulates gene

expression, acts as an antioxidant, contributes to osmotic adjustment, and modulates hormonal crosstalk to enhance plant stress tolerance. Understanding the molecular mechanisms underlying the involvement of salicylic acid in abiotic stress responses will help in developing strategies to improve crop productivity under challenging environmental conditions. Further research is warranted to explore the precise regulatory mechanisms of SA and its interactions with other signalling molecules to unlock the full potential of this remarkable plant defence compound. Salicylic acid emerges as a critical modulator of salt stress tolerance in plants. Through its involvement in ion homeostasis, osmotic regulation, antioxidant defence, and gene expression regulation, SA helps plants mitigate the harmful effects of salt stress. Understanding the precise mechanisms underlying SA-mediated salt stress tolerance will contribute to the development of strategies for improving salt stress resilience in crops, ultimately enhancing agricultural productivity in saline environments.

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