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Role of Salicylic Acid in Seeds Under Abiotic Stress Conditions

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Introduction

Salicylic acid (SA), an endogenous plant growth regulator has been found to generate a wide range of metabolic and physiological reactions in plants that have an impact on their growth and development. Salicylic acid (SA) derived from Latin Salix, willow tree, also known as ortho-hydroxybenzoic acid, is a phenolic derivative widely distributed in the plant kingdom and is known as a regulator of several physiological and biochemical processes such as thermogenesis, plant signaling or plant defense, and response to biotic and abiotic stressincluding cold tolerance, chilling tolerance, Ozone, heat and heavy metal stress and salinity tolerance. Chemically speaking, SA is a member of a broad class of plant phenolics with the formula $C_7H_6O_3$ and an aromatic ring with a hydroxyl group or its functional derivative. SA may be isolated from plants in both free and conjugated form. The conjugated form, in particular, results from the aromatic ring's methylation, hydroxylation, and glycosylation. Johan Buchner isolated Salicin (glucoside of salicylic alcohol), one of the natural SA derivatives, from the bark of the willow tree (*Salix* sp.) in 1828.SA is found in plants in amounts of a few m g/g fresh weight or less, either free or in the form of glycosylated, methylated, glucose-ester, or amino acid conjugates (Lee *et al*., 1995). SA is found in the free state as a crystalline powder with a melting point of 157-159^{0}C and a pH of 2.4. (Qaiser*et al.*, 2010).

Biosynthesis of salicylic acid

Salicylic acid is produced via two distinct pathways (Fig.1). ICS (isochorismate synthase) converts chorismate to isochorismate, and IPL (isochorismate pyruvate lyase) catalyses the conversion of isochorismate to SA (Hao *et al.* 2018). In Arabidopsis, Nicotiana benthamiana, and tomato, this is the primary pathway for SA synthesis (Catinot *et al.* 2008). Another route begins with phenylalanine, which is deaminated by PAL (phenylalanine

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ammonia lyase) to produce cinnamic acid. Cinnamic acid is converted to SA through O-coumaric acid or benzoic acid. BA2H (benzoic acid 2-hydroxylase) is the enzyme that catalyses the conversion of benzoic acid to SA (Fig.1) (Mustafa et al. 2009).

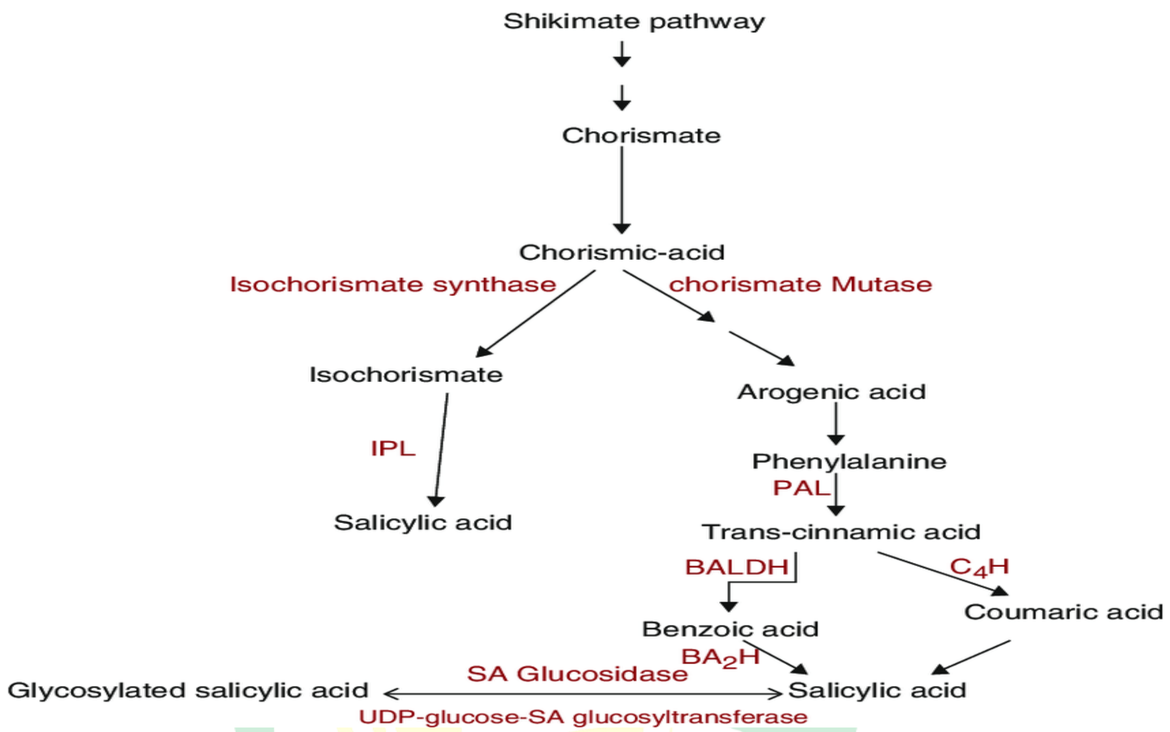

Fig 1: Salicylic acid biosynthesis

Role of salicylic acid in seeds under abiotic stress conditions

Salicylic acid in seeds under salinity stress

High salinity causes serious metabolic disruptions in plants by producing ROS, which disrupt the cellular redox system in favour of oxidised forms, resulting in oxidative stress, which can damage DNA, inactivate enzymes, and cause lipid peroxidation.Salicylic acid potentially alleviates the toxic effects, generated by salinity presumed to be due to the enhanced activation of some enzymes viz. aldose reductase and ascorbate peroxidase and to the accumulation of certain osmolytes such as proline. SA also prevented the lowering of IAA (Indole acetic acid) and cytokinin levels in salinity stressed wheat plants, resulting in improved cell division in the root apical meristem and thus increased plant growth and productivity. It also reduced the level of active oxygen species, and thus the activities of Superoxide Dismutase (SOD) and POX (Peroxidase) in the roots of young seedlings (Jini*et al.*, 2017).

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Salicylic acid in seeds under temperature stress

Heat stress causes an increase in reactive oxygen species (ROS), which causes cellular injuries and even the collapse of cellular organisation. Heat stress has been linked to photosynthesis inhibition due to structural organisation impairment and a decrease in photosystem II (PSII) activity. Heat stress causes damage to PSII's oxygen-evolving complex and impairs electron transfer within PSII reaction centres. SA combined with hardening at 45°C for 1 hour increased H_2O_2 levels while decreasing catalase (CAT) activity, increasing plants' ability to withstand heat stress. It aids in the protection of plants against oxidative damage. It also significantly increased the protein, proline, and ethylene contents while simultaneously inducing various stress enzymes such as POX and Ascorbate peroxidase (APX). However, the CAT activity was found to be reduced (Iqbal *et al*., 2013).

Salicylic acid in seeds exposed to heavy metal stress

Metals and metalloids with atomic density more than 6 g cm^{-3} are defined as heavy metal (HM). The increased amount of heavy metals in soil leads to greater uptake by plants that can reduce plant growth, biomass, photosynthesis, crop yield, and quality in plant, disruption of ATPase activity. The major outcome of metal toxicity is the peaked production of ROS due to impairment of photosynthetic process by Heavy metal. Heavy metal stress also induced up-regulation of H_2O_2 metabolizing enzymes such as catalase (CAT), ascorbate peroxidase (APX), superoxide dismutase (SOD), glutathione peroxidase (GPX), glutathione reductase (GR) and peroxidase (POD). The salicylic acid lowered level of lipid peroxidation, lesser production of H_2O_2, reduction in the generation of superoxide radicals and maintaining the stability of membranes. SA also alleviated the inhibitory effects of cadmium on the activities of enzymes RUBP carboxylase and PEP carboxylase and also enhanced the activities of antioxidative enzymes APX and SOD with a concomitant reduction in the activities of enzyme CAT in plants (Anket*et al.*, 2020).

Salicylic acid in seeds exposed to water stress/Drought

Drought stress is a major abiotic factor that limits photosynthesis by causing damage to the chloroplast and inactivating electron transfer reaction which in turn result in the formation of active oxygen species (AOS) that can lead to photo-oxidative damage. The activity of antioxidant enzyme, namely, catalase (CAT), peroxidase (POX), superoxide dismutase (SOD), glutathione reductase (GR) exhibits a significant increase in response to

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water deficit. Moreover, it also causes damage to the membrane stability index which in turn causes many physiological and biochemical alterations in plant.Salicylic acid is significantly increased the proline content by upregulating the expression of genes encoding pyrroline-5-carboxylate synthase (P5CSA and P5CSB) and downregulating the expression of gene encoding proline dehydrogenase (PDH) and it also increases plant productivity due to the enhanced osmotic potential and chlorophyll content. SA also alleviates the oxidative damage by increasing the activity of antioxidant enzymes accompanied by reduction in O_2, H_2O_2, and MDA content (Shamsul *et al*., 2008).

Salicylic acid in seeds to UV radiation or ozone stress

UV-B encroaches most of the aspects of photosynthesis such as damages to ultra-structure of chloroplast and light harvesting complex, decrease in the activity of Rubisco, decline in the oxygen evolving and CO2 fixation, reduction in the chlorophyll and starch content. main target of UV-B is PS-II which is comprised of two proteins, namely D1 and D2, which forms the core of PS-II. These two proteins are very sensitive against UV-B and UV-B driven degradation of D1 and D2 protein leads to impairment of PS-II, which can be measured in terms of decreased oxygen evolution or variable chlorophyll florescence.SA enhanced photochemical efficiency and the activities of antioxidant enzymes CAT and SOD which were greatly reduced by UV-B exposure. The treatment also increased the anthocyanin and tocopherol contents in the UV-B stressed plants (Kshama *et al*., 2017).

Salicylic acid under cold stress

Plants are affected by low-temperature stress in a variety of morphological, cytological, physiological, and biochemical ways. The modification caused by low-temperature stress at these levels of attributes has a negative impact on plant growth and development. SA acts as a remedy in mitigation and regulation of growth and productivity in cold stress by transducing signals through several components of signal transduction pathways. Major components include Ca, ROS, ABA, NO, MAPKs, cGMP, and phospholipid cascades. This SA mediated signal in cold stressed plant leads to the activation of various transcription factors that causes the expression of genes essential for plant survival in low-temperature stress. The genes induced to express in cold stressed plant by SA mediated signaling involves enhancement in activity of antioxidants, more accumulation of compatible solutes and various other cold responsive proteins like AFPs, HSPs, LEA, and

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dehydrins, PR proteins and various other proteins that regulate growth and development (Saleem *et al.*, 2021).

Conclusion

Among different plant growth regulators, salicylic acid (SA) is a very promising compound plays a diverse role in improving several morphological, cytological, physiological, and biochemical attributes in the plants facing both biotic and abiotic stresses. An integrated approach combining the knowledge of genetics, molecular biology, biochemistry, genomics, and bioinformatics techniques is a useful tool to study the functioning of SA in plants. Clear understanding of the biosynthesis and catabolic pathway and other unanswered question are vital to exploit SA as a potent Phyto protectant molecule to improve abiotic stress tolerances.

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