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Salicylic Acid and Jasmonates: Approaches in Abiotic Stress Tolerance

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Rapid increase in industrialization and population together has resulted in natural and anthropogenic release of pollutants responsible for degradation of quality of the environment and imminent threat to flora and fauna. Stressful environments are now being recognized as a potential agricultural threat for the sustainable agriculture. It has been estimated that increasing salinization of arable land will result in 30% land loss within the next 25 years, and upto 50% by 2050 [1]. Similarly, contamination of water and soil over the years by heavy toxic metals has become a major concern to the environment. Among gaseous pollutants, the increase in CO_2 concentration is considered a major threat to the environment. The concentration of CO_2 is expected to rise to as much as 500-1000 ppm by the year 2100 [2] leading to increase in global mean temperature by approximately 1°C to 3°C above the present value by 2025 and 2100, respectively [3]. These environmental changes could result in about 15-37% extinction of plant and animal species [4]. The research efforts of agricultural scientists are to provide mechanisms that could help in the survival of plants under the changing environments.

Plant hormones play important roles in regulation of developmental processes and signaling networks in plants under abiotic stresses. Recent researches have shown potential of phytohormones in reducing or eradicating the negative effects of abiotic stress [5-9]. In the list of known classical plant hormones, salicylic acid (SA) and jasmonic acid (JA) have been recently added and have shown as potential tool in enhancing tolerance of plants to abiotic stress. SA is a phenolic growth regulator, which participates in the regulation of physiological and molecular mechanisms to adjust plants in adverse environmental conditions. It is believed to play a role in plant responses to abiotic stresses including osmotic stress, drought, salt, heat and UV stress [9-11]. Recently, it has been shown that SA-induced expression of 59 proteins in cucumber which were identified for their involvement in various cellular responses and metabolic processes, including antioxidative reactions, cell defense, photosynthesis, carbohydrate metabolism, respiration and energy homeostasis, protein folding and biosynthesis [12].

JA and methyl jasmonate (MeJA) are collectively known as jasmonates and are important cellular regulators involved in diverse developmental processes from seed germination to fruit ripening, and senescence [13]. JA is also believed to play a role in plant responses to abiotic stresses including drought, salt, and heat stress [5, 14-15]. Recently, Chen et al. [16] have suggested that plants treated with MeJA show change in its protein profile and differentially expressed proteins were identified that participated in various plant physiological processes. They also showed repression of photosynthesis and carbohydrate anabolism with up-regulation of catabolism along with some proteins involved in JA biosynthesis, stress defense and secondary metabolism.

By several ways the plant hormone pathways interact and regulate the metabolic process and development of plants. However, signaling by phytohormones to regulate abiotic stress depends on the intensity, nature and timing of exposure of plants to stress. SA and JA are biochemically linked that can be triggered by abiotic stresses and function as necessary signaling molecules responsible for defense responses in plants [17]. They show antagonistic interactions which affect the expression of pathogen-related (PR) protein genes. SA induces PR genes whereas JA inhibits the expression [18]. Recently, Khan et al. [17] reviewed the possible interaction between SA and JA at biosynthetic level and in signaling under stressful conditions. Mitogen-activated protein kinase 4 (MAPK4) has been identified as a key component involved in mediating the antagonism between SA and JA-mediated signaling in Arabidopsis. Results indicate that MAPK4 acts as a negative regulator of SA signaling and positive regulator of JA signaling in Arabidopsis [19]. SA inhibits transcription of allene oxide synthase, which mediates the conversion of lipoxygenase-derived fatty acid hydroperoxides to unstable allene epoxides and then to JA precursors [20]. These two hormones could be used as target points in plant metabolism for abiotic stress tolerance.

Reports are available showing contrary effects of SA and JA to each other, but the research on the interplay between these two hormones in modulation of metabolic pathways is still in its infancy. Therefore, the biosynthetic pathways of the two hormones in plants facing challenged environment can be tailored to divert the metabolites production to meet the requirements for abiotic stress tolerance and sustainable agriculture.

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