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RESEARCH ARTICLE

RESILIENCE BY SALICYLIC ON PLANT GROWTH – A MINI REVIEW

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ABSTRACT

Salicylic Acid (SA) is a phenolic compound and nomenclature of it being called as SA is because it was first isolated from the bark of willow plant bearing the taxonomic name, *Salix alba*. SA has been extensively studied for their physiological roles on growth and metabolism of plants, stress-protective properties against numerous abiotic stresses like heat, chilling, freezing, drought, flooding, oxidative, salt, radiation, heavy metals stresses and biotic stresses. The present review is to understand the role of SA as a potential plant growth regulator (PGR).

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INTRODUCTION

It is a well-known fact that salicylic acid (SA) is a phenolic compound and was named so as it was first isolated from the bark of willow plant, *Salix alba*. Salicylic acid is a chemically a mono hydroxyl benzoic acid which is basically a type of phenolic acid comprising of a beta hydroxyl acid. SA is renowned as an important PGR modulating various aspects of plant. (Dogra, and Kukreja, 2025) and is capable of translocation from the site of supplementation to the different sites of usage (Fang *et al.*, 2025). The biosynthesis of salicylic acid occurs through the shikimate pathway by two metabolic routes. In the first discovered way called as phenylalanine way, which generally occurs in the cytoplasm of the cell, the enzyme phenylalanine ammonia lyase (PAL) converts phenylalanine (Phe) to *trans*-cinnamic acid (t-CA), which further gets oxidized to benzoic acid. Subsequently, the enzyme benzoic-acid-2-hydroxylase catalyzes the hydroxylation of benzoic acid aromatic ring and leads to salicylic acid formation which requires hydrogen peroxide (León *et al.*, 1995). The second way is called isochorismate pathway which occurs in the chloroplast (Garcion *et al.*, 2008). Chorismate is transformed to isochorismate and then to salicylic acid which is catalyzed by two enzymes viz., isochorismate synthase and isochorismate pyruvate lyase. Recent studies carried on *Arabidopsis thaliana* demonstrated that more than 90% of salicylic acid is produced from isochorismate way and the rest 10% is by cytosolic PAL pathway (Lefevre *et al.*, 2020).

SALICYLIC ACID AND SEED GERMINATION AND SEEDLING GROWTH: The germination of seed is a complex process which consists of molecular, epigenetic, morphological and

biophysical concepts. Torabian (2010) studied that treating the seeds of *Medicago sativa* with salicylic acid resulted in increased percentage of germination and seed vigor index subjected to salinity stress. Exogenous treatment of salicylic acid at 50 parts per million showed significant enhancement in seed germination of *Arachis hypogaeae* plants (Jadhav and Bhamburdekar, 2011). Murtaza and Asghar (2013) reported that pre-treatment of pea seeds with salicylic acid for nearly 6 hours exhibited enhanced rate of seed germination as well as seedling growth. Earlier research emphasized that supplementation of salicylic acid has modulated various aspects of physiology and biochemical features in *Zea mays* L. seedlings subjected to salinity toxicity (Gautam and Singh, 2009; Purcarea and Cachita-Casma, 2010). Alonso-Ramírez *et al.* (2009a) observed that salicylic acid treatment to sodium chloride stressed *Arabidopsis thaliana* resulted in enhanced percentage in the germination of seeds amounting to 80% compared to untreated controls. Further, supplementation of salicylic acid as exogenous spray also partially reverted the inhibitory effect of oxidative and heat stress on the seed germination of *Arabidopsis thaliana* (Alonso-Ramírez *et al.*, 2009b).

SALICYLIC ACID AND PLANT GROWTH: Esposito *et al.* (2025) studied in poinsettia (*Euphorbia pulcherrima* Willd) rooted poinsettia cuttings treated with three salicylic acid concentrations (10^{-3} , 10^{-4} , 10^{-5} M) applied via foliar or root application was found to increase the morphological parameters, colorimetric traits and canopy development. Application of salicylic acid to plants resulted in promotion of cell division as well as cell enlargement (Hayat *et al.*, 2013). It was observed by earlier researchers that plant growth and development is the result of different internal as well as external stimuli mostly attributing to the PGRs and salicylic acid given as

foliar spray was found most efficient in growth promotion (Muhali and Solanki, 2015). Foliar treatment of salicylic acid positively increased the growth in terms of root, shoot and foliar aspects of cotton crop (Vardhini and Venkatesh, 2015). Hayat *et al.* (2009) observed that salicylic acid played a critical role in the different physiological and biochemical mechanisms of plants endogenously and when given as exogenous foliar spray. Kang *et al.* (2012) observed that salicylic acid treatment enhanced the plant height, shoot length, fresh and dry weight of shoot and root in *Arabidopsis thaliana* grown in hydroponic cultures. Foliar treatment of salicylic acid (0.25mM, 0.50mM and 1.00 mM) for three consecutive days enhanced the growth of *Calendula officinalis* L. plants (Pacheco *et al.*, 2013). Even, Bideshki and Arvin (2010) reported that salicylic acid enhanced the root growth in terms of fresh and dry weight of *Allium sativum* grown in plots grown under water deficit stress. Salicylic acid supplemented at 0/5 and 1 mM ameliorated salt stress in *Cynara scolymus* L. by surged foliage growth in terms of length, width, fresh and dry weights of leaves, total plant length and fresh as well as dry weights of roots (Aminallah *et al.*, 2015). Further, Waseem *et al.* (2006) reported that application of salicylic acid to the roots of *Triticum vulgare* cultivar MH-97 resulted in enhanced shoot dry weight when subjected to water deficit stress. Treatment of salicylic acid to *in vitro* salinity - stressed shoe flower species mitigated the stress and increased multiplication of shoot growth, root formation, root elongation and plant survival rate (Sakhanokho and Kelley, 2009). Further, Najafian *et al.* (2009) reported that application of salicylic acid to *Thymus vulgaris* plants exhibited increased growth of shoots and roots when subjected to salinity stress.

SALICYLIC ACID AND PLANT YIELD: Imran *et al.* (2007) observed that treatment of salicylic acid played a crucial role in delaying the onset of senescence in *Pyrus pyrifolia* flowers as well as stopped early dropping-off of non-fully formed flowers or immature flowers. Application of amino-oxyacetic acid, a PAL inhibitor to *Pharbitis nil*, a short-day plant (SDP) resulted in reduction of flowering which was restored by supplementation of salicylic acid (Wada and Takeno, 2010; Wada *et al.*, 2010). Hegazi and El-Shrayi (2007) reported that salicylic acid had the capability to increase different physiological mechanisms related to growth and development of plants and played a prominent role in inducing the onset of flowering in various herbaceous species. Foliar spraying of salicylic acid at different concentrations for three consecutive days positively increased the flowering of pot marigold (Pacheco *et al.*, 2013). The present study addressed the effects of salicylic acid priming at varying concentrations (0.10, 0.25, 0.50, 0.75, and 1.00 mM) on the physiological and biochemical attributes of aged (10-, 11-, 12-, 13-, and 14-month-old) tomato seeds. Results revealed that 0.50 mM salicylic acid priming significantly enhanced the seed vigor index-I (SVI-I) from 19.6% to 41.3% over the control in 10- and 14-month-old seeds, respectively and protein levels were increased by 27%, dehydrogenase (29%) and α -amylase (19%) compared to the control (Dalapati *et al.*, 2025).

Arfan *et al.* (2007) also observed that foliar treatment of salicylic acid to two cultivars of *Triticum vulgare* namely salt tolerant (S-24) and a moderately salt sensitive (MH-97) subjected to sodium chloride stress exhibited enhanced grain yield. Asghari and Aghadam (2010) observed that treatment of salicylic acid exogenous treatment SA at 100 mg/L, 200mg/L and 400 mg/L with co-application of ascorbic acid to *Triticum* species showed increased yield related parameters in terms of number of tillers as well as spikes, length of spikes yield and straw yield (Amin *et al.*, 2008). Treatment of salicylic acid exhibited improved yield of safflower plants when grown under field conditions (Ebrahimzadeh *et al.*, 2009). Exogenous application of 0.1 mM, 0.5mM, or 1.0 mM salicylic acid as foliar spray to *Vigna radiata* L. cultivar *Pusa Vishal* plants grown under sodium chloride stress resulted in not only amelioration of sodium chloride stress but increased yield in terms of pods/plant (Khan *et al.*, 2010). Foliar supplementation of salicylic acid with co-application of brassinolide resulted in accelerated degradation of chlorophylls, growth inhibitor in *Pyrus bretschneideri* fruits (Zhang *et al.*, 2015). Abdel-Salam (2016) observed that exogenous treatment of salicylic acid in

co-application with some micronutrients to *Vitis vinifera* cultivar (*Bez El Naka*) resulted in enhanced yield parameters like fruit cluster weight, berries weight and juice volume. Iqbal *et al.* (2023) documented that application of salicylic acid at 75ppm positively increased the physiological growth traits in green gram crops.

SALICYLIC ACID AND PHOTOSYNTHESIS: Salicylic acid is capable of monitoring different physiological mechanisms like photosynthesis (Uzunova and Popova, 2000), structure of leaves and chloroplast (Uzunova and Popova, 2000), stomatal closure (Melotto *et al.*, 2006), levels of chlorophylls and carotenoids (Chandra and Bhatt, 1998). Application of 0.1 mM salicylic acid to roots protected *Solanum lycopersicum* plants from 200 mM sodium chloride stress by enhanced rate of photosynthesis and reduction in the rate of transpiration and activity of stomata (Stevens *et al.*, 2006). Further, it was also reported that application salicylic acid resulted in regulation of photosynthesis wherein photosystem II (PS-II), photosynthetic pigments, and RUBISCO and carbonic anhydrase were effectively modulated under normal and also under metal stress conditions (Al-Whaibi *et al.*, 2012; Noriega *et al.*, 2012; Zhang *et al.*, 2015). Foliar applications of salicylic acid at 10^{-4} M or 10^{-3} M to mustard plants showed greater dry mass, improved net photosynthetic rate and effective carboxylation compared to untreated plants (Fariduddin *et al.*, 2003). Foliar treatment of salicylic acid as spray ameliorated the inhibitory effect of paraquat (Pq) induced - oxidative stress in barley seedlings (Ananieva *et al.*, 2002) and heavy metal cadmium stress in maize plants by increasing the rate of photosynthetic machinery (Krantev *et al.*, 2008).

Gharib (2006) observed that foliar application salicylic acid with co-application of sulfosalicylic acid at 10 M enhanced the number of stomata and density of stomata per leaf on the lower side of *Capsicum annum* plants. Exogenous application of salicylic acid as foliar spray improved the contents of chlorophylls in *Triticum* species (Iqbal *et al.*, 2006). Supplementation of salicylic acid to *Lens esculentum* roots by drenching them protected against sodium chloride stress which eventually led to increasing the processes of photosynthesis (Steven *et al.*, 2006; Poor *et al.*, 2011). Palma *et al.* (2013) observed that the application of salicylic acid mitigated the inhibitory effect of sodium chloride stress by enhanced photosynthesis in alfalfa or lucerne cultivated in symbiosis with *Sinorhizobium meliloti*. Application of salicylic acid increased the photosynthesis, transpiration, activity of stomata, carbon-di-oxide levels in stomata concentration, levels of chlorophyll 'b' as well as carotenoids in two varieties of *Zea mays* cultivated under sodium chloride stress (Gunes *et al.*, 2007). Further, Nazar *et al.* (2011) observed that salicylic acid alleviated the decreases in photosynthesis under salt stress by enhancing nitrogen and sulphur assimilation and antioxidant metabolism differentially in two mungbean cultivars. Application of salicylic acid through the rooting medium mitigated the adverse effects of salinity on tomato (*Solanum lycopersicum*) cv. Marmande by improved osmotic potential, stomatal conductance, transpiration rate and photosynthetic rate as well as contents of photosynthetic pigments (Mimouni *et al.*, 2016). Yin *et al.* (2018) reported that salicylic acid-mediated alleviation in NO₂ phytotoxicity correlated to increased expression levels of the genes related to photosynthesis and carbon metabolism in *Arabidopsis thaliana*.

SALICYLIC ACID AND RESPIRATION: Application of salicylic acid as foliar spray contributed to maintain the cellular redox homeostasis in plants by modulation of the alternative respiratory pathway (Moore *et al.*, 2002) and also regulation of gene expression through induced RNA-dependent RNA polymerase which could have resulted in increased RNA content in plants (Xie *et al.*, 2001).

SALICYLIC ACID AND ENVIRONMENTAL STRESSES: Salicylic acid is a signalling molecule known to participate in defence responses against variety of environmental stresses in plants like temperature, water, salt, heavy metals, light etc. that pose serious threats to crops and eventually result in heavy losses to agricultural sectors (Jayakannan *et al.*, 2015a; Chen *et al.*, 2023) and PGRs play an important role in crop tolerance against harsh environments and

pave way for sustainable food production across the globe (Vardhini and Anjum, 2015). Salicylic acid interacts with other plant growth regulators and signal molecules in response to stressful environments in plants (Kaya *et al.*, 2023). Salicylic acid is a naturally occurring PGR capable to influence different physiological and biochemical functions in plants to overcome abiotic stress (Khan *et al.*, 2015). Salicylic acid is known to play an important role in mitigating stresses in plants by positively monitoring its growth (Syed *et al.*, 2011).

SALICYLIC ACID AND BIOTIC ORGANISMS: Salicylic acid is a central phytohormone that orchestrates genetic and physiological responses involving defense mechanisms against pathogens (Salinas *et al.*, 2025). Salicylic acid plays a predominant multifaceted role as a PGR to combat diseases that attack plants (Vlot *et al.*, 2009). Plants have adapted themselves to survive under worst possible harsh conditions and have learnt to overcome and thrive if attacked by living pathogens (Vardhini *et al.*, 2025). Salicylic acid is classified as an important PGR capable and necessary in signal transduction to establish the local and systemic disease resistance responses of plants subjected to pathogen stress (Alvarez, 2000). Luo *et al.* (2019) observed that the integrated transcriptome analysis revealed that PGRs like jasmonic acid and salicylic acid coordinate the growth and defense responses of fungal infection stress in poplar. In *Arabidopsis*, the pathogen-inducible pipecolate and SA pathways due to biotic stress were activated by the common and distinct regulatory elements and the direct induction of SAR gene expression, signal amplification with SA signalling paved way for elevated plant immunity (Hartmann and Zeier, 2019) suggesting that SA is effective against biotic stresses in plants. Fang *et al.* (2025) studied the biosynthesis, metabolism, and signaling pathways of salicylic acid, and salicylic acid-mediated defense responses against pathogens and herbivores, thereby providing theoretical perspectives on the regulatory mechanism of SA-mediated immunity under biotic stress and improving the plant fitness and resistance to diseases caused by biotic factors.

SALICYLIC ACID AND ABIOTIC STRESSES: Farhangi-Abriz and Ghassemi-Golezani (2018) reported that salicylic acid and jasmonic acid are capable of mitigating abiotic stress (salinity) in soybean plants. Studies reported that the NPR1-dependent salicylic acid signalling pathway is pivotal for enhanced salt and oxidative stress tolerance in *Arabidopsis* (Jayakannan *et al.*, 2015b) and the ectopic expression of JcWRKY transcription factor confers salinity tolerance via salicylic acid signalling (Agarwal *et al.*, 2016). Jayakannan *et al.* (2015) clarified that salicylic acid played a pivotal role overcoming salinity stress by modulating the signal transduction. Treatment of salicylic acid resulted in ameliorating various abiotic stresses in plants viz., drought (Alam *et al.*, 2013; Karimi and Ghasempour 2019), chilling (Mutlu *et al.*, 2013), salinity stress (Miura and Tada, 2014; Favez *et al.*, 2014) heavy metal tolerance (Krantev *et al.*, 2008; Ahmad *et al.*, 2011), heat (Khan *et al.*, 2013), UV radiation (Bandurska and Cieslak, 2013) etc. Salicylic acid analogue (acetylsalicylic acid, ASA) along with salicylic acid induced chilling tolerance in two different chilling-tolerant maize (*Zea mays* L.) inbred lines when applied as seed treatments or as a hydroponic application by increased root length, shoot height, and shoot and root dry weights of seedlings (Wang *et al.*, 2012). Treatment of 2.0 mM salicylic acid as foliar spray enhanced total phenolic synthesis as well as increased the activity of PAL (phenylalanine amino lyase) in *Citrus limon* fruit grown under cold stress (Siboza *et al.*, 2014). Mutlu *et al.* (2013) observed that foliar treatment of salicylic acid exhibited enhanced tolerance to cold-induced stress by increasing the activities of the antioxidative enzymes, ice nucleation activity, and apoplastic protein patterns in *Hordeum vulgare* genotypes. Supplementation of salicylic acid significantly protected the ultra-structures of dwarf banana seedlings grown under cold stress (Kang *et al.*, 2012). Miura and Tada (2014) reported that various aspects related to induction and ongoing cold stress in plants was positively monitored by application of salicylic acid. Foliar application of salicylic acid alleviated heat and high light stress induced photoinhibition in wheat (*Triticum aestivum*) during the grain filling stage by modulating the psbA gene transcription and antioxidant defense (Wang *et al.*, 2014). Khan *et al.* (2013) reported

that foliar application of 0.5 mM salicylic acid to *Triticum aestivum* mitigated the negativity of heat stress and improved the plant growth and development. Salinity stress can be mitigated by the application of a PGR namely salicylic acid (Joseph *et al.*, 2010; Jayakannan *et al.*, 2015a). Salicylic acid is a potential alleviator of salt stress in rice by triggering various physiological mechanisms (Jini and Joseph, 2017; Khan *et al.*, 2019). El-Tayeb (2005) observed that salicylic acid alleviated salinity in barley grains whereas Sajjad *et al.* (2013) reported that foliar application of salicylic acid proved to be a potent inducer of salt tolerance in radish (*Raphanus sativus* L.) plants whereas Liu *et al.* (2016) reported that salicylic acid improved salinity tolerance of *Nitrariatangutorum*. Methenni *et al.* (2018) observed that co-application of salicylic acid and calcium as pre-treatments alleviated the toxic effect of salinity in the *Oueslati* olive variety. Potential benefits of exogenous salicylic acid application (1.0 mM) on tobacco seedlings subjected to saline soil conditions. The foliar spray of salicylic acid partially mitigated these salt-induced effects, as evidenced by a reduction of malondialdehyde content, and improvements of leaf K⁺/Na⁺ ratios, pigment biosynthesis, and electron transport efficiency under NaCl stress. Additionally, salicylic acid increased the contents of total phenolic compound and soluble protein by 16.2% and 28.7% to alleviate NaCl-induced oxidative damage (Song *et al.*, 2025). Ghassemi-Golezani *et al.* (2020) documented that the foliar application of '0.1 μmol' 24-epibrassinolide improved the levels of potassium, calcium, and the potassium/sodium ratio, as well as soluble sugars, chlorophyll 'a' and chlorophyll 'b', and catalase activity in black mustard (*Brassica nigra* L.) under salinity stress. Noreen *et al.* (2011) studied that exogenous application of salicylic acid improved growth and some key physiological attributes in sunflower plants subjected to salt stress. Li *et al.* (2013) reported that salicylic acid not only increased the contents of glutathione and ascorbate but temporally regulated the related gene expression in salt stressed wheat seedlings. Exogenous application of salicylic acid differently impacted ethylene and polyamine synthesis in the glycophyte, *Solanum lycopersicum* and the wild-related halophyte *Solanum chilense* when exposed to mild salt stress (Gharbi *et al.*, 2016). Khan *et al.* (2015) observed that alleviation of salt-induced photosynthesis and growth inhibition by salicylic acid involved the modulation of glycinebetaine and ethylene in mungbean (*Vigna radiata* L.). Rady and Mohamed (2015) observed that supplementation of salicylic acid in combination with leaf extracts of *Moringa oleifera* modulated the inhibitory effect of salt stress and improved the growth, physio-chemical attributes and yield of *Phaseolus vulgaris* L. plants. Application of salicylic acid through the rooting medium mitigated the adverse effects of salinity on tomato (*Solanum lycopersicum*) cv. *Marmande* by improved shoot and root dry mass, leaf area, photosynthetic rates, photosynthetic pigment levels leaf water, osmotic potential, stomatal conductance, transpiration rate and biochemical parameters (Mimouni *et al.*, 2016). Application of salicylic acid alleviated the salinity stress of *Rosmarinus officinalis* L. by increasing the contents of carbohydrates and proline and also stimulation of the antioxidant enzymatic mechanism pathway including catalase (CAT), superoxide dismutase (SOD), and ascorbate peroxidase (APX) as well as increasing the non-enzymatic antioxidants such as free and total ascorbate (El-Esawi *et al.*, 2017). Tufail *et al.* (2013) observed that foliar application of salicylic acid was capable of inducing physiological and biochemical changes in two genotypes of *Zea mays* L. (*Sahiwal-2002* and *EV-20*) subjected to saline stress. Salicylic acid ameliorated the inhibitory effect of sodium chloride stress on tomato by positively modulating the levels of sugars, protein and proline (Zahra *et al.*, 2010). Hayat *et al.* (2014) observed that application of salicylic acid enhanced the efficiency of nitrogen fixation and assimilation in *Cicer arietinum* plants subjected to cadmium stress. Application of salicylic acid altered the physiological processes in *Arabidopsis* plant exposed to cadmium wherein the transcription levels of two electron transport-related genes and two amylase-encoding genes were all up-regulated, implying a significance of the related processes in this genotype against Cadmium stress (Wang *et al.*, 2019). Further, Tamás *et al.* (2015) observed that exogenous application of salicylic acid alleviated the cadmium-induced stress responses by the reducing the production of Cd-induced auxin-

mediated reactive oxygen species in barley root tips. Exogenous application of salicylic acid mitigated the toxicity of cadmium in *Lemna minor* (Lu *et al.*, 2018), *Nymphaea tetragona* (Gu *et al.*, 2018) whereas foliar application of salicylic acid alleviated the cadmium toxicity by modulation the reactive oxygen species in potato (Li *et al.*, 2019). Application of salicylic acid mitigated the toxicity of cadmium in two varieties of Menthol mint (*Mentha arvensis* L.) viz., kushal and kosi and improved growth, photosynthetic parameters, mineral nutrient concentration, and decreased the oxidative stress biomarkers like electrolyte leakage, malondialdehyde, and hydrogen peroxide contents. Further, up-regulation of proline content and antioxidant enzymes was also observed (Ahmad *et al.*, 2018; Zaid *et al.*, 2020). Wei *et al.* (2019) studied that the co-application of salicylic acid, Fe (II) and plant growth-promoting bacteria alleviated the toxic accumulation of cadmium (Cd) in Cd tolerant and sensitive tomato genotypes. Co- application of salicylic acid, epi-brassinolide and calcium alleviated cadmium induced stress in tomato plants by lowering the accumulation of cadmium (Guo *et al.*, 2018). Mostofa *et al.* (2019) observed that co-application of salicylic acid and nitric oxide enhanced rice plants to overcome the toxic effects of cadmium stress. Young maize plants grown under controlled environmental conditions and treated with 0.5 mM salicylic acid or sodium salicylate for 1 day showed increased tolerance to cadmium toxicity by enhanced phytochelatin levels in the roots and increased antioxidant enzyme activity and glutathione-related redox changes. Alyemeni *et al.* (2014) reported that foliar supplementation of salicylic acid at 10^{-5} M showed significant enhancement of growth, photosynthesis, yield and the activity of antioxidant enzymes like catalase, peroxidase and superoxide dismutase in the chickpea plants subjected to cadmium toxicity (0, 25 or 50 mg).

El-Shazoly *et al.* (2019) observed that exogenous application of salicylic acid or thiamine substantially increased the tolerance to boron toxicity stress in wheat plants. Exogenously applied salicylic acid promoted photosynthesis, biomass in watermelon seedlings subjected to boron (10 mg L^{-1}) toxicity by reducing boron accumulation, lipid peroxidation, and the generation of H_2O_2 , while significantly activating antioxidant enzymes, such as superoxide dismutase (SOD), peroxidase (POD), and ascorbate peroxidase (APX) and protecting the seedlings from an ROS induced cellular burst (Moustafa-Farag *et al.*, 2020). Arshad *et al.* (2017) reported that the defensive mechanism of lead affected barley (*Hordeum vulgare* L.) genotypes was attributed to the effect of exogenously applied salicylic acid. Even, the co-application of 24-epibrassinolide and salicylic acid mitigated lead (Pb) toxicity by modulating various metabolites in *Brassica juncea* L. seedlings (Kohli *et al.*, 2018a; b). Exogenous supplementation of salicylic acid as foliar spray ameliorated the lead toxicity in *Pisum sativum* (L.) plants (Ghani *et al.*, 2015). Salicylic acid treatment as foliar spray increased the contents of non-enzymatic components like ascorbate and glutathione as well as enzymatic components like APX, GR, POD and CAT (Hasanuzzaman *et al.*, 2019). Salicylic acid mitigated lead stress and improved plant growth in *Zea mays* L. by regulating free amino acid composition (Zanganeh *et al.*, 2018; 2019) and also improved the growth in wheat plants (Alamri *et al.*, 2018). Salicylic acid improved lead and zinc stress tolerance in maize by enhancement of growth and physiological characters (Shekari *et al.*, 2025). Pre-treatment with 1mM salicylic acid partially alleviated the toxic effect of arsenic on germination parameters in terms of germination rate, root and coleoptile length, fresh and dry weight of roots in wheat seedlings (Zengin, 2015). Mabrouk *et al.* (2019) observed that exogenous application of salicylic acid alleviated arsenic and zinc toxicity through the process of reserve mobilization in germinating fenugreek (*Trigonella foenum-graecum* L.) seeds. Exogenous application of salicylic acid modulated arsenic stress tolerance with enhanced accumulation of secondary metabolites and improved size of glandular trichomes in *Artemisia annua* L (Kumari *et al.*, 2018) which was achieved by modulating the gene expression and proteome profile in *Artemisia annua* L. (Kumari and Pandey-Rai, 2018). Application of salicylic acid mitigated mercury toxicity in lemon balm (*Melissa officinalis* L.) by positively modulating the plant physiological and molecular mechanisms (Safari *et al.*, 2019). Application of salicylic acid and ascorbic acid increased

the drought tolerance in two varieties of *Cicer arietinum* viz., ILC482 and Kurdistan by increasing plant growth (Farjam *et al.*, 2015). Further, Kang *et al.* (2012) also studied that foliar supplementation of salicylic acid mitigated the negative impact of drought stress in wheat plants by enhanced plant growth. Foliar spray of salicylic acid effectively increased the morpho-physiological and biochemical responses of pea (*Pisum sativum* L.) under drought stress (Anwar *et al.*, 2025). Application of salicylic acid could significantly increase the antioxidant enzyme activities of rice seedlings under salt and drought stress, thereby reducing the contents of rice hydrogen peroxide and lipid peroxidation and maintaining the growth of rice seedlings and the expression of genes involved in the response of abiotic stress (Shan *et al.*, 2024). Salicylic acid decreased the inhibitory effects of sodium chloride and drought in *Hordeum vulgare* by enhanced growth, antioxidant activity and K^+ content (Fayez *et al.*, 2013). Even, Habibi (2012) observed that exogenous treatment of salicylic acid to *Hordeum vulgare* showed enhanced net carbon-di-oxide assimilation rate due to enhanced the activity pertaining to stomata. Thus, salicylic acid effectively enhanced *Hordeum vulgare* plant dry mass subjected to drought stress proving the ability of salicylic acid in overcoming the harsh effects of drought stress in crop plants (Habibi, 2012). Exogenous application of salicylic acid as foliar spray proved to positively increase the photosynthesis and flowering in crop plants cultivated under UB-B stress (Karioti *et al.*, 2008; Li *et al.*, 2014). Foliar treatment of salicylic acid mitigated the toxic effect of UV-induced oxidative stress in the leaves of green chillies by increasing the non-enzymatic as well as enzymatic antioxidants (Mahdavian *et al.*, 2007). Further, Mohammed and Tarpley (2009) also reported that foliar treatment of salicylic acid to rice crop plants mitigated the negative effect of UV-B stresses by enhanced photosynthesis related aspects, pollen germination, levels of phenolic compounds as well as crop yield. Even, Ranceliene and Vyšniauskiene (2012) observed that supplementation of salicylic acid reduced the negativity of the stress caused by UV-B radiation and decreased the chromosome aberrations in the meristematic root tip cells of *Crepis capillaris*. The potentially of salicylic acid in playing significant roles in the regulation of various physiological aspects in plant growth viz., ion uptake and transport as well as membrane permeability related aspects is known from the past research studies (Simaei *et al.*, 2012). A field experiment conducted on vegetable crops at Bhubaneswar to standardize the dose of salicylic acid and potassium nitrate application on tomato (*Solanum lycopersicum* L.) under water stress condition wherein five doses of salicylic acid (10 ppm, 25 ppm, 50 ppm, 75 ppm, 100 ppm) and three doses of potassium nitrate (1%, 2.5%, 5%) along with one stress check treatment (drought stress by withholding irrigation) and stress-free control treatment showed positive results (Sahoo *et al.*, 2025). Poór *et al.* (2017) reported that prolonged dark period modulates the oxidative burst and enzymatic antioxidant systems in the leaves of salicylic acid-treated tomato. Subban *et al.* (2019) also reported the ability of salicylic acid as an effective elicitor which significantly improved the taxol production in endophytic fungus *Pestalotiopsis microspora*. Further, Faraz *et al.* (2019) reported that supplementation of showed positive results and citric acid as co-application alleviated cadmium toxicity in *Brassica juncea*. The effectiveness of salicylic acid is usually through its capability to act as a signal transducing molecule. Tajti *et al.* (2019) observed that salicylic acid was capable of inducing changes in the pattern of protein kinase (SIPK) gene expression in wheat grown under cadmium exposure. Thus, salicylic acid can be emphatically quoted as the 7th class of PGR and known to act as an effective PGR on par with the earlier known PGRs. These recent years has shown that extensive research is being carried out to find out the role of salicylic acid on plant growth and metabolism under normal as well as stressful conditions. The individual applications of salicylic acid as well as co-applications of salicylic acid with other PGRs as well as certain organic as well as inorganic molecules are being done. The future studies on the foliar/ exogenous applications of salicylic acid might pave way in understanding the capability of this 7th class of PGR in increasing the growth, productivity as well as stress alleviation capability.

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