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Insight into the Role of Exogenous Salicylic Acid on Plants Grown under Salt Environment

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Abstract: Salicylic Acid (SA) is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plants. It plays an important role in the plant response to adverse environmental conditions such as salinity. Meanwhile, soil salinity is a major constraint to food production because it limits crop yield and restricts use of land previously uncultivated. The SA plays an essential role in preventing oxidative damage in plants by detoxifying super oxide radicals, produced as a result of salinity. A review was highlighted the exogenous application of the lower concentrations of salicylic acid proved to be beneficial in enhancing the photosynthesis growth and various other physiological and biochemical characteristics of plants. Based on the morphology of the plants and parameters investigation it was concluded that SA tolerant plant, made quicker response to abiotic stresses. In the present review, we have focused on the effect of exogenous application of SA ant its protective effects on changing antioxidant enzyme activity for the salt tolerance in plants.

Key words: Salinity, salicylic acid, stress, plants, antioxidant enzymes

INTRODUCTION

Salicylic Acid (SA) is considered as a hormone-like substance, which plays an important role in regulating a number of physiological processes such as growth, photosynthesis, nitrate metabolism, ethylene production, heat production and flowering (Raskin, 1992; Hayat *et al*., 2007) and also provide protection against biotic and abiotic stresses such as salinity (Kaya *et al*., 2002) in plants. A high salinity induces serious metabolic perturbations in plants, as it generates ROS which disturb the cellular redox system in favour of oxidized forms thereby creating an oxidative stress that may damage DNA, inactivate enzymes and cause lipid peroxidation (Smirnoff, 1993). The ameliorative effects of SA have been well documented in inducing salt tolerance in many crops (Aldesuquy *et al*., 1998; El-Tayeb, 2005; Gunes *et al*., 2005; Stevens *et al*., 2006).

Salinity is the most serious threats to agriculture and for more important globally (Sahi *et al*., 2006) water consisted minerals and salt materials are major harmful factors in arid and semi-arid region of worldwide (Joseph *et al*., 2010). During the last 20 years SA drew the attention of researchers due to its ability to induce Systemic Acquired Resistance (SAR) in

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Table 1: Role of salicylic acid in plants

Common name	Scientific name	Role of salicylic acid	Reference
Bean	*Phaseolus vulgaris*	Growth of root and shoot	Gutierez-coronado *et al.* (1998)
Carrot	*Daucus carota*	Growth and antioxidant activity	Eraslan *et al.* (2007)
Coffee	(*Coffea Arabica*)	Cellular growth and enhanced somatic embryogenesis	Quiroz-Figueroa and Mendez-Zeel (2001)
Cucumber	*Cucumis sativus*	Onset and systemic acquired resistance	Matraux *et al.* (1990)
Faba bean	*Vicia faba*	salt stress	Azooz (2009)
False Roselle	*Hisbuscus acetosella*	*In vitro* regeneration	Sakhanokho and Kelley (2009)
Foetid cassia	*Cassia tora*	Aluminium-induced oxidative stress	Yang *et al.* (2003)
Maize	*Zea mays*	Salinity tolerance	Gunes *et al.* (2007)
Ornamental nightshade	*Solanum bulbocastanum*	Salt and osmotic stress	Daneshamnd *et al.* (2009)
Rice	*Oryza sativa*	Cadium tolerance	Guo *et al.* (2007)
		Heavy metals	Mishra and Choudhuri (1999)
Rose Mallow	*Hisbiscus moscheutos*	Toxic metals	Strobel and Kuc (1995)
		Heat stress	Dat *et al.* (1998)
		Low temperature	Janda *et al.* (1999); Mora-Herrera *et al.* (2005)
		Oxidative stress	Strobel and Kuc (1995)
Tomato	*Lycopersicon esculuntum*	Salinity stress	Senaranta *et al.* (2000); Stevens *et al.* (2006)
		Increased the leaf protein level, susceptible to diseases	Zahra *et al.*(2010)
		low and high temperature	Senaratna *et al.* (2000)
Wheat	*Triticum aestivum*	Growth and photosynthetic activity	Arfan *et al.* (2007)
		Drought tolerance	Waseem *et al.* (2006)
		prevent the damaging action of enviroumental stress factors	Sakhabutdinova *et al.* (2003)
		water deficit	Bezrukova *et al.* (2001)

plants to different pathogens, which is manifested in the appearance of pathogenesis Related Proteins (PR), while SA is considered to serve as a signal in the induction of expression of these genes (Sakhabutdinova *et al*., 2003). At the same time at present considerable interest has been aroused by the ability of SA to produce a protective effect on plants under the action of stress factors of different abiotic nature (Sakhabutdinova *et al*., 2003). Thus convincing data have been obtained concerning the SA induced increase in the resistance of plants to salinity. Table 1 summarizes that the role of salicylic acid on plants. Still date number of literature indicates through various researches that exogenous application of salicylic acid to the stressed plants can potentially alleviate the toxic effects, generated by salinity. In the present review, we have focused on the effect of salicylic acid on salt tolerance associated with antioxidant enzymes in plants.

Role of Salicylic Acid in Plants under Salt Stress

The SA, an endogenous plant growth regulator has been found to generate a wide range of metabolic and physiological responses in plants thereby affecting their growth and development (Hayat *et al*., 2010). The role of SA in defense mechanism to alleviate salt stress in plants was studied (Afzal *et al*., 2006; Hussein *et al*., 2007). The ameliorative effects of SA have been well documented in inducing salt tolerance in many crops such as bean (Azooz, 2009; El-Tayeb, 2005; Gunes *et al*., 2007; Stevens *et al*., 2006). Exogenous application of salicylic acid enhanced the photosynthetic rate and also maintained the stability of membranes, thereby improved the growth of salinity stressed barley plants (El-Tayeb, 2005).

The damaging effects of salinity were also alleviated by exogenous application of SA in Arabidopsis seedlings (Borsani *et al*., 2001). Furthermore, foliar spray of SA significantly decreased lipid peroxidation caused by NaCl and improved the plant growth. This alleviation of NaCl toxicity by SA was related to decreases in Na contents, increases in K and Mg contents in shoots and roots and increases in the activities of superoxide dismutase (SOD), Catalase (CAT), Glutathione Peroxidase (GPX) and Dehydroascorbate Reductase (DHAR) and the contents of ascorbate and glutathione (He and Zhu, 2008).

In studies that focus on the application of SA on *in vitro* salt stressed *Hibuscus* species have the effect on shoot growth and multiplication, root formation, root elongation, plant survival rate and proline accumulation (Sakhanokho and Kelley, 2009). The SA treated thyme plants had greater shoot and root dry weights, photosynthetic rates, mesophyll efficiency and water use efficiency when exposed to salt stress (Najafian *et al*., 2009).

Wheat (*Triticum aestivum*)

Wheat grain is a staple food used world wide. Its production is greatly affected by salinity. An enhanced tolerance against salinity stress was observed in wheat seedlings raised from the grains soaked in salicylic acid (Hamada and Al-Hakimi, 2001). The detrimental effects of high salts on the early growth of wheat seedlings may be alleviated by treating seeds with the proper concentration of a suitable hormone such as SA (Shakirova and Bezrukova, 1997). Wheat seedlings accumulated large amounts of proline under salinity stress which was further increased when salicylic acid was applied exogenously, thereby alleviating the deleterious effects of salinity (Shakirova *et al*., 2003). Further, the treatment also lowered the level of active oxygen species and therefore the activities of SOD and Peroxidase (POX) were also lowered in the roots of young wheat seedlings (Shakirova *et al*., 2003). These findings indicate that the activities of these antioxidant enzymes are directly or indirectly regulated by salicylic acid, thereby providing protection against salinity stress (Sakhabutdinova *et al*., 2003). In addition, SA increased the resistance of wheat seedlings to salinity.

The soaking of wheat seeds in 0.05 mM SA reduced the damaging effects of salinity on seedlings growth and accelerated the growth processes (Shakirova *et al*., 2003). The pre-sowing soaking treatment of seeds with SA positively affected the osmotic potential, shoot and root dry mass, K^+/Na^+ ratio and contents of photosynthetic pigments in wheat seedlings, under both saline and non-saline conditions (Kaydan *et al*., 2007). In the past Deef (2007) considered that the influence of SA on salt stress tolerance almost needed during the seed germination of wheat. But the SA reduced the damaging effects of salinity on seedlings' growth and accelerated the growth processes (Mutlu *et al*., 2009). The mitigation effect of SA to abiotic stresses was investigated through SA application either by seed soaking of wheat genotypes (Al-Hakimi, 2006) or through rooting medium of wheat (Arfan *et al*., 2007). While, many studies have been reported that SA induced increases in the resistance of wheat to salinity and oxidative stress, respectively (Shakirova and Bezrukova, 1997; Sakhabutdinova *et al*., 2003; Bhupinder and Usha, 2003; Arfan *et al*., 2007).

Tomato (*Lycopersicon esculuntum*)

The tomato is now grown worldwide for its edible fruits, with thousands of cultivars having been selected with varying fruit types and for optimum growth in differing growing conditions. Soil salinity affects plant production in many parts of the world, particularly on irrigated land (Wang *et al*., 2003). Taken together these two effects was found that SA pre-treatment improved the acclimation of tomato to high salinity (Zahra *et al*., 2010; Szepesi *et al*., 2009). An enhanced tolerance against salinity stress was observed in tomato plants raised from the seeds soaked in salicylic acid and was 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 (Szepesi *et al*., 2005).

Maize (*Zea mays* L.)

Maize is widely cultivated throughout the world and a greater weight of maize is produced each year than any other grain. Maize is considered as a moderately salt-sensitive plant. The mitigation effect of SA to abiotic stresses was investigated through SA application by foliar spray of maize (Khodary, 2004). Many studies supported that SA induced increases in the resistance of maize to salinity and osmotic stress, respectively (Tuna *et al*., 2007). Studies have been employed the effects of salicylic acid on some physiological and biochemical characteristics of maize seedlings under salt stress were derived (Gunes *et al*., 2007; Gautam and Singh, 2009; Purcarea and Cachita-Casma, 2010).

Strawberry (*Fragaria ananassa*)

Strawberry is considered as a salinity sensitive species (Saied *et al*., 2005) and it has been shown to reduce leaf number, leaf area, shoot dry weight and number of crowns and low yield under salt stress (Pirlak and Esitken, 2004). Salt stress negatively affected the growth, chlorophyll content and mineral uptake of strawberry plants. However, plants treated with SA often had greater shoot fresh weight, shoot dry weight, root fresh weight and root dry weight as well as higher chlorophyll content under salt stress (Karlidag *et al*., 2009).

Role of Salicylic Acid in Drought and Salt Stressed Plants

Salt stress afflicts plant agriculture in many parts of the world, particularly irrigated land (Epstein *et al*., 1980). Compared to salt stress, the problem of drought is even more pervasive and economically damaging (Boyer, 1982). Drought and soil salinization in both dry land and irrigated agricultural settings are the most important factors limiting modern agricultural production systems (Cushman and Bohnert, 2000). From the statistical data, the drought and semi-drought areas in the world amount to one-third continent acreage in the globe and a half continent acreage in China. In addition, a salinity areas about 3.6 hundred thousands hectares needs to be reclaimed and utilized in China. Therefore, it is very important to develop new varieties of crops with strong tolerance to drought and salt (Shiqing *et al*., 2005). Application of exogenous SA enhanced the drought and salt stress resistance of plants (Tari *et al*., 2002; Deef, 2007), but the results were contradictory and depended on the developmental phase of plants (Borsani *et al*., 2001) or on the experimental conditions (Nemeth *et al*., 2002). The SA has been suggested to be physiologically important in stress tolerance since exogenous SA brought about plants tolerance to various abiotic stress including drought and salt (Stevens *et al*., 2006).

Relationship of SA with Antioxidant System and its Impact on the Plants Exposed to Stress

Abiotic stress conditions such as salinity and drought favor the accumulation of Reactive Oxygen Species (ROS) such as superoxide radicals($O_2^{\bullet -}$), hydroxyl radicals (OH^-) hydrogen peroxide (H_2O_2) and cause oxidative stress (Panda *et al*., 2003a, b). The peak level of ROS leads in plants to cause oxidative damage in biomolecules such as lipids, proteins and nucleic acids, thus alters the redox homeostasis (Smirnoff, 1993). The SA was found to enhance the activities of antioxidant enzymes, CAT, peroxidase (POX) and superoxide dismutase (SOD), when sprayed exogenously to the salinity stressed plants of *B. juncea* (Yusuf *et al*., 2008). When applied exogenously at suitable concentrations, SA was found to enhance the efficiency of an antioxidant system in plants (He *et al*., 2002).

Furthermore, the treatment with salicylic acid resulted in temporary reduction of catalase (CAT) activity and increased H_2O_2 level takes place in plants (Janda *et al*., 2003) which possibly played a key role of providing the SAR and tolerant capacity against the oxidative stress (Gechev *et al*., 2002) in plants. It was found that inhibition of catalase by SA plays an essential role in the generation of reactive oxygen species (Nemeth *et al*., 2002). By increasing H_2O_2 concentration of the tissues, moderate doses of SA may activate the antioxidative mechanisms. The activities of antioxidant enzymes such as SOD, POX increased by the application of SA but the CAT activity remain unchanged in salt stressed sunflower plants (Noreen *et al*., 2009). Moreover, SA was effective in increasing the activities of enzymes mainly involved in the antioxidant system in salt stressed tomato plants (Szepesi *et al*., 2008).

However, the application of bioregulators such as brassinolide (BR) and Salicylic Acid (SA) as seed soaking and foliar spraying alleviate the harmful effect of salt stress and oxidative stress on maize plants (El-Khallal *et al*., 2009a, b) and the application of SA enhanced the activities of antioxidant enzymes ascorbate peroxidase (APO) and SOD with a concomitant decline in the activity of CAT in maize plants (Krantev *et al*., 2008).

Salicylic Acid and its Role of Protective Effects in Plants

For the last two decades, SA has received much attention because of its involvement in plant defense mechanisms under both biotic and abiotic stresses. The protective effect of SA against abiotic stress factors such as toxic metals (Strobel and Kuc, 1995) heat stress (Dat *et al*., 1998), low temperature (Janda *et al*., 1999; Mora-Herrera *et al*., 2005) oxidative damage (Kusumi *et al*., 2006) and biotic stresses have been demonstrated. Recently, Sakhanokho and Kelley (2009) recorded that the SA typically showed the salt tolerance under *in vitro* conditions in the two botanical medicinal *Hibiscus* species. In order to that SA provided particular interest in positive effect of SA on root formation and growth though some reports on *in vitro* salt tolerance studies suggest that rooting and root growth are not only highly affected by salt but also positively correlate with salt tolerance at the whole plant level (Martinez *et al*., 1996; Cano *et al*., 1998).

Conclusions and Future Perspectives

Hence, it may be resolved from the survey of literature cited above that salicylic acid play's diverse physiological roles in plants and potentially alleviates the devastating effects generated by salt stress. However, this recently introduced phytohormone still demands a lot of work to be carried out to elucidate the exact pathways of its biosynthesis; wheather major or minor, key regulatory points of biosynthesis, mechanism of action and other specific and collaborative regulatory roles played by salicylic acid that have remained elusive till date. The work is also needed on how this plant hormone interacts and being regulated by the cross-talk in harmony with other established phytohormones and plant growth regulators working at long range (auxins, cytokinins, gibberellins, ethylene etc.), short range (NO, jasmonates, brassinosteroids etc.) and very short range (ROS, H_2O_2). One could also argue how the regulated doses of these short range phytohormones mostly produced in-vicinity to biotic infestation and then transported systemically to play their role during broad range abiotic stresses. It is also worthwhile to elucidate the role of aforesaid phytohormone in tissue-specific differentiation and growth of plant parts during growth and development. Biochemical inhibitors of key enzymes of pathways and mutant study might incident some light on such aspects. Locating tissue-specific concentrations during seedling development fusing with reporter genes or radioactive molecules could pave the way in this concern.

In future, the exogenous application of this phytohormone might act as a powerful tool in enhancing the growth, productivity and also in combating the ill effects generated by various abiotic stresses in plants. The future applications of this plant hormone holds a great promise as a management tool for providing tolerance to our agricultural crops against the aforesaid constrains consequently aiding to accelerate potential crop yield in near future.

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