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EFFECT OF SALICYLIC ACID ON PHYSIOLOGICAL AND BIOCHEMICAL CHARACTERIZATION OF MAIZE GROWN IN SALINE AREA

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Abstract

The aim of the present investigation was to determine the effect of exogenously applied salicylic acid (SA) on physiology of maize (*Zea mays* L.) hybrid cv. 3025 grown in saline field (pH 8.4 and EC 4.2 ds/m) as well as on the nutrient status of saline soil. The salicylic acid (10^{-5}M) was applied as foliar spray, 40 days after sowing (DAS) at vegetative stage of maize plants. The salinity significantly increased sugar contents, protein, proline and superoxide dismutase (SOD), peroxidase (POD), catalase (CAT) and ascorbate peroxidase (APOX) activities but the chlorophyll, carotenoid contents, osmotic potential and membrane stability index (MSI) were lower than the control. Foliar application of salicylic acid (SA) to salt stressed plants further augmented the sugar, protein, proline, superoxide dismutase (SOD), peroxidase (POD) ascorbate peroxidase (APOX) activities, endogenous abscisic acid (ABA) , indole acetic acid (IAA) content, and root length, fresh and dry weights of roots whereas, the chlorophyll a/b and ABA/IAA ratio were decreased. The exogenous application of SA significantly decreased the Na^+, Ni^{+3}, Pb^{+4}, Zn^{+2}, and Na^+/K^+ content of soil and roots while increased the Co^{+3}, Mn^{+2}, Cu^{+3}, Fe^{+2}, K^+ and Mg^{+2} content under salinity stress. It can be inferred that exogenous application of SA (10^{-5}M) was effective in ameliorating the adverse effects of salinity on nutrient status of soil. SA (10^{-5}M) can be implicated to mitigate the adverse effects of salinity on maize plants.

Introduction

More than 60% of the total maize production in Pakistan is contributed by Khyber Pakhtoon Khwa province**.** In Pakistan during 2009-2010 maize production was 3,262 thousand tons which was increased to 3,341 thousand tons in 2010-11, showing an increase of 2.4% (Anon., 2011). In Pakistan, maize is the third important crop after wheat and rice. In the year 2010-2011 total area under maize crop in Pakistan was 974.3 thousand hectares with 3706.9 thousand tons of total production (Anon., 2011).

High salts concentration has badly affected about 5% of arable land all around the world which reduces crop growth and yield (Gunes *et al.*, 2007). In Charsada 58% soil is saline sodic having pH 8.4 and EC 4.2 ds/m. In Khyber Pakhtoon Khwa salinity affect 37.6% (6.06 million hectares) of the total 18 million hectares area of Pakistan.

Salicylic acid is known as an important signal molecule for modulating plant responses to environmental stresses (Shakirova *et al.,* 2003). Salicylic acid effects have been studied in pots under control condition but information is lacking on the performance of Salicylic acid applied exogenously for plants growing in saline field because in field the effect observed demonstrate the multiple interaction between the climatic and edaphic factors. The effect of salinity on plants has long been investigated, since a better knowledge of the effect of NaCl on plants is critical for land management in saline areas (Munns, 2005). Besides its role in biotic stresses a large body of literature (Shah, 2003) demonstrate the involvement of SA in responses to several abiotic stresses such as ultraviolet light, drought, salt, chilling and heat. Increasing effects of SA on photosynthetic capacity could be attributed to its stimulatory effects on Rubisco activity and pigment contents.

Essential nutrients are acquired by plants from their root system environment but due to saline habitat, the presence of NaCl alters the nutritional balance of plants, resulting in high ratios of Na^+/Ca^{2+}, Na^+/K^+, Na^+/Mg^{2+}, Cl^-/NO^{-3}, and Cl^-/H_2PO^{-4} (Grattan & Grieve, 1999) which may lead reductions in growth and yield. Major saline ions can affect nutrient uptake through competitive interactions or by affecting the ion selectivity of membranes.

Present investigation was aimed to evaluate the effect of Salicylic acid on growth and physiology of maize grown under saline field condition of Charsada district.

Materials and Methods

Plant material and growing conditions: The experiment was carried out in field using Randomized Complete Block Design (RCBD) with four replicates having plot size of 4x4 m each. The seeds of maize (*Zea mays* L.) obtained from Agriculture Extension Office Dargai, were surface sterilized with 95% ethanol followed by sterilization in 10% chlorox solution for 5min with shaking and cultivated in field under saline conditions. The seeds were also cultivated in separate field under control (non-saline) conditions. The row to row distance was 60 cm and plant to plant distance was 15 cm. The salicylic acid was applied as foliar spray 40 days after sowing (during vegetative stage) using common insecticidal sprayer. The sample collection was made 20 days after the spray of salicylic acid. The intact plant from each treatment was uprooted, washed with distilled water, stored at 4°C for physiological analyses. Similarly soil sample was collected from rhizosphere of maize at a distance of 6 cm from upper surface for physicochemical analyses.

Chlorophyll, carotenoid, protein and sugar contents of leaves were determined following the method of Lichtenthaler *et al*., (1981), Lowry *et al.,* (1951) and Dubois *et al.,* (1956) respectively. The proline contents of leaves were measured by the method of Bates *et al.,* (1973). The osmotic potential was also determined according to the method of Capell & Doerffling, (1993). The ABA and IAA concentrations in leaves were determined following the methods of Kettner & Doerffling, (1995).

The POD activity was determined by the method of Vetter *et al*., (1958) as modified by Gorin & Heidema (1976). Superoxide Dismutase (SOD) activity was determined by measuring inhibition of photochemical reduction of nitroblue tetrazolium (NBT) using method of

Beauchamp & Fridovich, (1971). Ascorbate peroxidase (APOX) activity was determined according to Asada & Takahashi, (1987). Catalase (CAT) activity was measured according to modified method of Chandlee & Scandalios, (1984). The rhizospheric soil was analyzed for macro nutrients Ca, Mg, K, Na, P, and NO_3-N, micronutrients Fe, Cu, Cr, Co, Zn and Mn and heavy metals Ni, Li, Pb and Cd following the Ammonium Bicarbonate-DTPA method developed by Soltanpour & Schwab, (1977).

Statistical analysis: The data were analyzed statistically by Analysis of Variance technique (Steel & Torrie, 1980) and comparison among treatment means was made by Duncan's Multiple Range Test (DMRT).

Results and Discussion

Length, fresh and dry weight of roots: The results revealed that length, fresh and dry weights of roots were not significantly affected by SA under non-saline condition (Table 1). Salinity inhibited the root length by greater than 3x, fresh weight by 5x and root dry weight by 3x. The SA treatment under saline condition partially overcame the salt-induced inhibition in length, fresh and dry weight of root. The better root system and greater biomass of the root may help the plant to adapt under salt stress ,furthermore the root system of the plant also assist in the selectivity of ions uptake, transportation as well maintain the water status of the plants. The salinity has been reported to decrease the root length of *Catharanthus roseus* (Jaleel *et al.*, 2007).

Table 1. Effects of salicylic acid on length (cm), fresh and dry weight (g) of roots.

Treatments	Root length	Fresh weight	Dry weight
Control (no salinity)	26.66 a	84.30 a	16.53 a
Salicylic acid under non-saline condition	27 a	85.80 a	18.4 a
Only saline condition	8 c	15.03 c	5.39 b
Salicylic acid under saline condition	16.66 b	23.62 b	7.36 b
	LSD: 4.17	LSD: 2.97	LSD: 5.56

Effect of salicylic acid on leaf chlorophyll 'a', chlorophyll 'b' (mg/g) and chlorophyll a/b ratio: The results presented in Table 2 revealed that salt stress significantly decreased chlorophyll a and chlorophyll b content of leaves of maize plants as compared to control. Exogenously applied salicylic acid ameliorated the inhibitory effect of salt on chlorophyll *a* content but not on chlorophyll *b* content. The SA treatment under salt stress showed significant increase in chlorophyll 'a' and chlorophyll 'b' content as compared to the plants grown in saline field. Under unstressed condition SA has no significant effect on the chlorophyll'a' content of leaves as compared with the control though the chlorophyll 'b' content was significantly decreased in SA treatment over control. Favorable effect of SA on the chlorophyll content of maize leaves was reported by Khodary (2004).

The data presented in Table 2 showed significantly lower chlorophyll a/b ratio. The SA further decreased the chlorophyll a/b ratio under salt stress. The chlorophyll a/b ratio serves as an index of salinity tolerance. The decrease in chlorophyll content under stress is a commonly reported phenomenon and has been demonstrated to bear positive relationship with membrane deterioration (Ashraf & Bhatti, 2004). The total chlorophyll content was significantly increased due to SA application under salt stress.

Table 2. Effect of salicylic acid on chlorophyll a, chlorophyll b, a/b ratio and carotenoid (mg/g) content of maize leaves after 15 days of salicylic acid application in saline and non-saline fields.

Treatments	Chlorophyll a	Chlorophyll b	a/b ratio	Carotenoid
Control (no salinity)	0.974 a	0.43 a	0.436 a	9.53 a
Salicylic acid under non-saline condition	0.983 a	0.416 b	0.42 ab	9.23 a
Only saline condition	0.501 c	0.206 c	0.403 b	3.13 c
Salicylic acid under saline condition	0.567 b	0.213 c	0.373 c	4.56 b
	LSD: 0.042	LSD: 0.013	LSD 0.026	LSD: 1.27

Osmotic potential (-Mpa) and membrane stability index (%): The results revealed that salinity significantly decreased the osmotic potential as well as membrane stability index of maize leaves respectively as compared to unstressed control (Table 3). However, SA application ameliorated the adverse effect of salinity on osmotic potential as well as membrane stability index. The most observable indirect effect of salinity on plant performance is reduced osmotic potential which result in reduced water availability of plants.

Table 3. Effect of salicylic acid on ABA, IAA ,ABA/IAA ratio (µg/g) content, Osmotic Potential (-MPa) and membrane stability index (%) of maize leaves after 15 days of salicylic acid application in saline and non-saline fields.

Treatments	ABA	IAA	ABA/IAA	Osmotic potential	Membrane stability index
Control (no salinity)	82.66 c	106.01 a	0.774c	0.659 c	25 b
Salicylic acid under non-saline condition	84.03 c	106.66 a	0.785 c	0.709 c	31.69 a
Only saline condition	107.86 b	52.91 c	2.02 a	1.03 b	18.72 c
Salicylic acid under Saline condition	120.40 a	61.90 b	1.92 b	1.29 a	19.39 c
	LSD: 2.03	LSD: 2.13	LSD: 0.045	LSD: 0.053	LSD: 1.96

Salinity reduced the osmotic potential as compared to untreated control (Chinnusamy & Zhu, 2003) which might result in decreased water availability. SA has effectively increased the osmotic potential under salinity stress which is essential to restore the cell turgor. Chinnusamy & Zhu (2003) have suggested that plant survival depend on maintaining a positive turgor, which is indispensable for expansion growth of cells and stomatal opening. The stimulatory effect of SA was also recorded on the membrane stability index. The integrity and functions of biological membranes are very sensitive to environmental stress and stress-induced damage to membranes has been well documented in the plants (Nishida & Murata, 1995).

Leaf carotenoids, sugar, protein and proline contents (mg/g): There was significant decrease in carotenoid content of maize leaves. The SA treatment under saline condition resulted in higher carotenoid content as compared to that of saline condition alone. However, the value was lower as compared to untreated control (Table 2). Carotenoids acts as accessory pigment and activates defense systems but the effect of SA was not evident under unstressed condition. Carotenoids effectively quench singlet oxygen derived from primary photochemical reactions and hence a close correlation was found between the carotenoid contents of the leaves and the foliar biomass production of tomato genotypes under salt stress (Juan *et al.,* 2005). The observed increase in carotenoid content of SA treated leaves of plants under saline condition may indicate the better defense system induced by SA.

Significantly higher soluble sugar content of leaves was found in plants of saline field, SA further augmented the sugar production under salinity stress. SA induced increase was greater than that of without SA under saline condition, although the value was significantly higher as compared to untreated control (Fig. 1). Gemes *et al.,* (2008) have reported that SA application increased the soluble sugar content of tomato plants exposed to salt stress. Sugars are compatible solutes which accumulate in plant tissues that are exposed to abiotic stresses, such as water deficit, extreme temperatures and salt stress. The accumulation of sugars may play an important role in the plant defensive mechanisms of osmoregulation and energy preservation (Morsy *et al.,* 2007). Therefore, it can be inferred that exogenous application of SA improved the osmo protecting system of maize plants.

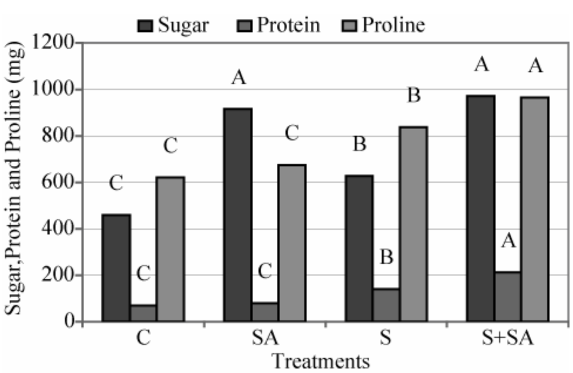

Fig. 1. Effect of salicylic acid on sugar (mg/g), protein (mg/g) and proline (mg/g) content of maize leaves after 15 days of salicylic acid application in saline and control fields.
All such means which share a common English letter are similar, otherwise they differ significantly at $p<0.05$.

Fig. 1 revealed that the soluble protein content of leaves was increased under salinity stress as compared to untreated control. SA treatment under salinity stress further augmented the soluble protein of the plants of saline field. Plants produce proteins in response to abiotic and biotic stress and many of these proteins are induced by Phytohormones including salicylic acid (Naz, 2008).

Non-significant increase in proline content of maize leaves of saline field grown plants was recorded when compared to unstressed control. The SA treatment under saline condition exhibited significant increase in leaf proline content over that of saline field (Fig. 1). Besides its role in osmoregulation proline also function in scavenging and/or reducing the production of hydroxyl radicals in salt-stressed plants (Alia *et al.,* 1993). The exogenous application of SA improved the growth of maize under salinity stress which might have been due to increased accumulation of proline. The increase in proline accumulation by SA application under salt stress has been reported in wheat seedlings by Sakhabutdinova *et al.,* (2003).

Superoxide dismutase (SOD), peroxidase (POD), catalase and a**scorbate peroxidase (APOX) activities of leaves:** The saline condition resulted in significantly higher Superoxide dismutase and Peroxidase activities of leaves of plants. The SA treatment to plants grown in saline field had increased SOD and POD activities over that of saline field (Fig. 2). The SA treatment to plants of saline field showed decrease in catalase activity, while Ascorbate peroxidase activity was increased as compared to that of saline field (Fig. 3). Plants containing high concentrations of antioxidants show considerable resistance to oxidative damage caused by activated oxygen species (Garratt *et al.,* 2002). During the present investigation SA improved the antioxidant system of maize plants by increasing the SOD and POD activities of leaves. The results are in accordance with that of Chen *et al.,* (1997) who reported that SOD and POD activity increases while catalase activity decreases in response to SA application.

ABA, IAA (µg/g) content of leaves: The results revealed that salinity significantly increased the endogenous ABA content of leaves while decreasing the endogenous IAA content of leaves Table 3. The SA treatment to plants of saline field exhibited increase in endogenous ABA and IAA content of leaves over that of saline field. High salt concentrations, triggers an increase in the level of plant hormone ABA (Sakhabutdinova *et al.,* 2003). Abscisic acid is known as the hormone of stress play a major role in mediating adaptive responses of plants to stress (Javid *et al.,* 2011). Almost all aspects of plant life, from seed germination to vegetative growth and flowering are controlled by IAA (Ritchie & Gilroy, 1998).

During the present investigation, the stimulatory effect of SA was studied on endogenous ABA and IAA contents. Salinity significantly increased the ABA/IAA ratio as compared to untreated control, but SA significantly decreased the ABA/IAA ratio under salinity stress though the value was found higher than that of untreated control. The ABA/IAA ratio is an important index of salinity tolerance, the ratio was higher under saline condition but SA treatment significantly decreased the ABA/IAA ratio. The lower ratio of ABA/IAA is due to the balance between the 2 phytohormones both induced by SA and is beneficial for plant growth promotion under stress.

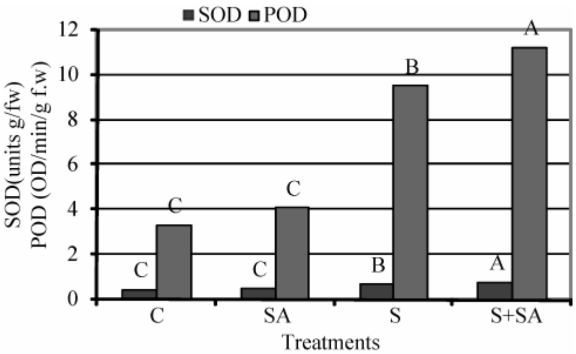

Fig. 2. Effect of salicylic acid on SOD (units g^{-1} f.w) and POD (OD/min/g f.w) of maize leaves after 15 days of salicylic acid application in saline and control fields.
C = Control (no salinity); SA = Salicylic acid under non-saline condition; S = Only saline condition; S+SA = Salicylic acid under saline condition

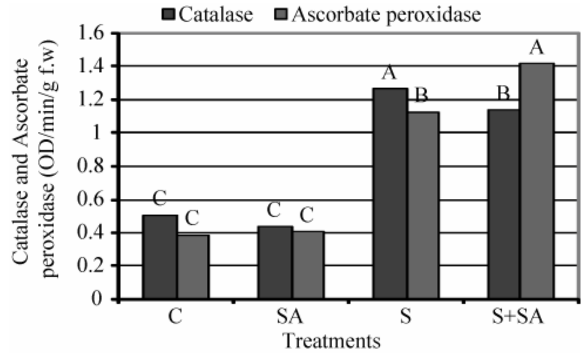

Fig. 3. Effect of salicylic acid on ascorbate peroxidase (OD $min^{-1}g^{-1}$f.w) and catalase (OD $min^{-1}g^{-1}$f.w) of maize leaves after 15 days of salicylic acid application in saline and control fields.
C = Control (no salinity); SA = Salicylic acid under non-saline condition; S = Only saline condition; S+SA =Salicylic acid under saline condition

Macro and micronutrients of soil (μg/g): The soil analyzed after cultivation was sandy loam with pH of 8.4 for saline area and pH 7.4 for control i.e. non-saline area. The rhizosphere of saline area exhibited higher Na^+ , K^+, Mg^{+2}, Ca^{+2}, Zn^{+2} , Mn^{+2} , Fe^{+2} , Cu^{+3} , Cr^{+3} , Cd^{+2} , Pb^{+4} , Ni^{+3} content and lower in Co^{+3} and Li^{+1} content while the rhizosphere soil of non-saline area showed lower Na^+, K^+, Mg^{+2}, Ca^{+2}, , Zn^{+2}, Mn^{+2}, Fe^{+2}, Cu^{+3}, Cr^{+3}, Cd^{+2}, Pb^{+4}, Ni^{+3} content but higher Co^{+3} and Li^{+1} content (Tables 4 & 5). Salinity is one of the major problems that adversely affects the fertility status of soil and inhibit plant growth. The salinity significantly increased Na^+ content of soil. Nevertheless, SA significantly decreased the concentration of Mg^{+2}, K^+, Fe^{+2}, Cu^{+3} and Mn^{+2}content in soil.

In saline and alkaline soils, availability of the cation macronutrients K^+, Ca^{+2}, Mg^{+2} may also be limited (Marschner, 1995). Salinity dominated by Na^+ and Cl^- ions has been shown to decrease the concentration of essential macro and micro elements in several vegetable crops (Yildirim *et al.*, 2008). Sivritepe *et al.*, (2003) has also found that NaCl salinity increased Na^+ content in plant tissue of some crops.

Table 4. Nutrient analysis of micro and heavy metal soil (μg/g) after harvest of maize in saline and non-saline fields.

Treatments	Co^{+3}	Mn^{+2}	Cu^{+3}	Cr^{+3}	Fe^{+2}	Ni^{+3}	Cd^{+2}	Li^{+1}	Pb^{+4}	Zn^{+2}
Control (no salinity)	0.06	0.172	4.321	0.028	0.234	0.0760	0.82	0.036	0.71	0.1262
Salicylic acid under non-saline condition	0.07	0.158	4.386	0.035	0.289	0.0612	0.81	0.031	0.63	0.1264
Only saline condition	0.021	0.232	6.778	0.215	1.063	0.1634	0.125	0.021	1.06	0.1336
Salicylic acid under saline condition	0.034	0.242	8.566	0.132	1.883	0.1110	0.111	0.030	0.94	0.1302

Table 5. Macro nutrient analysis of soil (μg/g) after harvest of maize in saline and non-saline fields.

Treatments	Na^+	Mg^{+2}	K^+	Ca^{+2}
Control (no salinity)	1.1442	0.5066	2.2516	24.327
Salicylic acid under non saline condition	1.8419	0.3332	2.9192	25.544
Saline condition	15.323	7.6159	11.1239	29.158
Salicylic acid under saline condition	13.9559	7.2749	11.8755	28.302

Macronutrients and micronutrients of maize root (μg/g): Under saline condition the roots of maize plants accumulated more than 10 folds Na^+, 2 folds K^+, 7 folds Ca^{+2} and 2 folds Mg^{+2}contents over unstressed control. The salinity has markedly increased Na^+, K^+, Ca^{+2} and Mg^{+2}contents of maize roots .The increase in Na^+, K^+, Ca^{+2} and Mg^{+2}contents were found as compared to unstressed field condition. The application of SA has decreased the Na^+ content where as the K^+, and Mg^{+2}contents showed an increase over that of saline condition. SA application under unstressed condition has no marked effect on any of the macronutrient in plant roots (Table 6).

Table 6. Macronutrient analysis of maize roots (ug/g) after 15 days of salicylic acid application in saline and non-saline fields.

Treatments	Na^+	Mg^{+2}	Ca^{+2}	K^+	Na^+/K+ ratio
Control (no salinity)	169 c	315 c	1084 b	577 b	0.285 c
Salicylic acid under non saline condition	169 c	325 c	1011 b	638 b	0.255 c
Only saline condition	1958 a	578 b	7284 a	1102 a	2.15 a
Salicylic acid under saline condition	1886 b	860 a	7117 a	1182 a	1.55 b
	LSD 21.65	LSD 111.92	LSD 235.97	LSD 95.49	LSD 0.310

The results presented in Tables 7 and 8 revealed that salinity significantly increased the uptake of Co^{+3}, Mn^{+2}, Cu^{+3}, Fe^{+2}, Ni^{+3}, Zn^{+2} and Pb^{+4}. The SA treatment under salt stress exhibited higher Co^{+3}, Mn^{+2}, Cu^{+3}, Fe^{+2}, while showed lower Ni^{+3}, Zn^{+2} and Pb^{+4}content. The SA treatment under stressed condition showed higher amount of Co^{+3}, Mn^{+2}, Cu^{+3}, Fe^{+2}, Ni^{+3}, Zn^{+2} and Pb^{+4} content than unstressed control. The results showed that salinity significantly decreased the availability of Cr^{+3}, Cd^{+2} and Li^{+1} content to plants.

Table 7. Nutrient analysis of micro and heavy metal of maize roots (ug/g) after 15 days of salicylic acid application in saline and non-saline fields.

Treatments	Co^{+3}	Mn^{+2}	Cu^{+3}	Cr^{+3}	Fe^{+2}	Ni^{+3}
Control (no salinity)	8.3 c	80.9 c	297 c	82 a	30.8d	18.1 c
Salicylic acid under non saline condition	8.45 c	81.6 c	298 c	81.5 a	32.65 c	18 c
Only saline condition	20.65 b	141 b	542 b	42.5 b	79.35 b	31.4 a
Salicylic acid under saline condition	22.7 a	143 a	566 a	42.05 b	83.5 a	28.35 b
	LSD 1.47	LSD 1.94	LSD 18.85	LSD 1.74	LSD 1.81	LSD 1.37

Table 8. Nutrient analysis of micro and heavy metal of maize roots (ug/g) after 15 days of salicylic acid application in saline and non-saline fields.

Treatments	Cd^{+2}	Li^{+1}	Pb^{+4}	Zn^{+2}
Control (no salinity)	22 a	10 a	255 b	0.765 c
Salicylic acid under non saline condition	21 a	9 a	252 b	0.755 c
Only saline condition	20 b	7.75 b	320 a	24.09 a
Salicylic acid under saline condition	19 c	7.5 b	315 a	21.12 b
	LSD 0.658	LSD 0.294	LSD 13.20	LSD 0.638

The SA application to plants resulted in the decreased uptake of toxic heavy metals from saline field e.g. Pb^{+4}, Zn^{+2} and Ni^{+3}.The rizosphere soil after harvest of maize also had less residual Pb^{+4}, Zn^{+2} and Ni^{+3}, thus facilitating the growth of subsequent crop in saline field after SA application in maize plants. The observed increased in micro nutrients Co^{+3}, Mn^{+2}, Cu^{+3} and Fe^{+2} in the roots of SA treated maize plants under salinity stress may help in stimulating metabolic reaction of plants which slows down due to osmotic stress. These micro nutrients also assist in enhancing enzymatic activity. These results are consistent with those of Munns (2005) for barley and Gunes *et al* .,(2007) for maize, who found that exogenous SA applications inhibited Na^+ accumulation, but stimulated N, P, K, Mg, Fe, Mn and Cu uptake. An increase in concentration of K and Ca in plants under salt stress could ameliorate the deleterious effects of salinity on growth and yield (Tayeb, 2005). Alteration of mineral uptake from SA applications may be one mechanism for the alleviation of salt stress. Rashid *et al*., (2004) reported that salt stress in mung bean plants accumulation of Na^+ and Cl with decreased K^+ content. Rabie (2005) found that N, P, K and Mg decreased in mung bean under salinity effect.

Na^+/K^+ ratio of maize roots: The results presented in Table 6 showed that salinity significantly increased the Na^+/K^+ ratio of roots as compared to untreated control. However, the exogenous application of SA significantly decreased the Na^+/K^+ ratio under salinity. The SA under control conditions exhibited non-significant decrease in Na^+/K^+ ratio as compared to untreated control. Salam *et al.,* (1999) demonstrated that Na^+ /K^+ ratio could be used to screen for salt tolerance. High Na^+/ K^+ selectivity in plants under saline conditions have been suggested as an important selection criterion for salt tolerance (Ashraf, 2002). Increased K^+ concentrations under saline conditions may help to decrease sodium uptake required for maintaining the osmotic balance (Mahajan & Tuteja 2005).

Conclusion

It is inferred from the results of present investigation that exogenous application of SA mitigated the adverse effects of salinity on maize plants by osmoregulation which is possibly mediated by increased production of sugar as well as proline. By regulating the membrane stability, photosynthetic pigments and lowering ABA/IAA ratio. Further protection under salt stress was achieved through enhanced activities of antioxidant enzymes, SOD and POD etc. Exogenous application of SA reduces the adverse effects of salinity on nutrients status of soil. The Na^+/K^+ ratio was decreased by SA application which helps the plants to overcome the toxic effects of saline soil. SA being economical and environmental friendly can be recommended for farmers to use in their fields for alleviating salt stress; in addition SA induces systemic resistance against diseases.

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