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SALICYLIC ACID INDUCED SALINITY TOLERANCE IN MAIZE (*ZEA MAYS*)

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Abstract

Salicylic acid (SA) a naturally occurring plant hormone is an essential signal molecule recognized to have diverse effects on biotic and abiotic stress tolerance. The present study was planned to investigate the role of SA in salt tolerance of maize. Experiment was conducted to study the SA induce physiological and biochemical changes in two genotypes of maize viz., Sahiwal-2002 and EV-20 in the presence and absence of salt. Salicylic acid @ 0, 0.25 and 0.50 m*M* along with 120 m*M* NaCl and Hogland's nutrient solution were applied as rooting medium to 25 days old plants. Results revealed that application of 0.50 m*M* salicylic acid was most effective to reduce Na^+ but increased K^+ and Ca^{2+} concentration, shoot biomass as well as better yield under salt stress. Exogenous application of different concentrations of SA enhanced photosynthetic rate, transpiration rate, stomatal conductance, sub-stomatal CO_2 concentration, chlorophyll *b* contents and carotenoids in both genotypes of maize under salt stress. In conclusion, the level of 0.50 m*M* SA by rooting medium was more effective as compared to 0.25 m*M* level on growth, gas exchange characteristics, biochemical attributes and yield. Maize genotype Sahiwal-2002 perform better by increasing higher biomass, better gas exchange characteristics as well as higher K^+/Na^+ and Ca^{2+}/Na^+ ratios under salt stress.

Introduction

Salinity is one of the major hazards throughout the world in arid and semi-arid regions which greatly reduced the agricultural productivity in both irrigated and non-irrigated regions of the world (Narusaka *et al*., 2003; Wakeel *et al.*, 2011; Zhang *et al*., 2010; Ashraf, 2010). Salinity causes modification in physiological and biochemical processes in the plants; by the accumulation of higher concentration of Na^+, Cl^- in the leaf tissues, which deteriorate the osmotic potential and restrict the uptake of nutrients like potassium, calcium and phosphorus (Parida *et al.*, 2005; Munns, 2002). Salinity tolerances of plants involve not only Na^+ restriction as well as build up of higher accumulation of K^+, which was reduced by higher Na^+ in the rooting medium (Zhang *et al*., 2010). High salt concentration enhanced ion toxicity which reduces the availability of nutrients by reduction in osmotic potential of plants (Akram & Ashraf, 2011). Maize (*Zea mays* L.) being an important cereal crop of the country is mainly threatened by salinity and drought (Banzigar & Araus, 2007). Salinity causes both, hyperionic and hyperosmotic stress effects and the consequence of these can be plant demise. Most common stress is caused by high Na^+ and Cl^- concentrations in soil solution. It has been reported that salinity affects crop water relations which becomes an osmotic stress for maize plants (Hasegwa *et al*., 2000; Hamayun *et al*., 2010). Salinity significantly reduced different physiological and biochemical processes in wheat (Raza *et al*., 2006), *Brassica* spp. (Nazir *et al*., 2001) and rice (Gurmani *et al.*, 2006). Various physical, biochemical and biological approaches have been made to overcome the salinity in such soils (Ashraf & Foolad 2007; Flowers 2004; Gurmani *et al.*, 2011).

Salicylic acid (SA) a naturally occurring plant hormone is an important signal molecule known to have diverse effects on biotic and abiotic stress tolerance (Khan *et al*., 2010; Borsani *et al*., 2001). Exogenous applications of SA enhance plant growth and photosynthetic capacity in saline conditions (Khan *et al.*, 2012; Afzal *et al*., 2006; Arfan *et al*., 2007; Arfan, 2009). It also participate in the regulation of physiological processes in plant such as stomatal closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and photosynthesis under stress conditions (Shakirova *et al*., 2003; Gunes *et al*., 2005; Waseem *et al*., 2006; Khan *et al*., 2012). It has been reported that SA improves salinity tolerance by increasing antioxidant enzymes activities like superoxide dismutase (SOD), peroxidase (POD) and catalase (CAT) activity (Noreen *et al*., 2009). SA also act as a potential non enzymatic antioxidant in regulating a number of plant physiological processes including photosynthesis (Fariduddin *et al*., 2003; Waseem *et al.*, 2006; Arfan *et al.*, 2007). It was reported that foliar application of SA induced salinity tolerance in sunflower by increasing photosynthetic rate and plant biomass; but there is no change in the sub stomatal CO_2, that represents that stomatal feature were not the main trait for photosynthesis (Noreen & Ashraf, 2008). Furthermore, Karlidag *et al*., (2009) found that application of SA reduces the harmful effect of salinity by stimulate relative water content and increased almost all the nutrients in leaves and roots of strawberry.

Keeping in view the beneficial effects of SA in salinity tolerance of plants, present pot culture experiment was conducted to determine whether application of SA through rooting medium could induce salt tolerance in two different genotypes of maize plants; and to evaluate the association of dry biomass, ion accumulation and photosynthetic attributes to elucidate the mechanism of salinity tolerance in maize by the application of SA.

Material and Method

An experiment was conducted in the wire house of old Botanical Garden, Department of Botany, University

of Agriculture, Faisalabad to study the effect of salicylic acid on various morphological, physiological and biochemical attributes of two maize genotypes i.e., Sahiwal-2002 and EV-20 under saline and non-saline conditions. The seeds were obtained from Ayub Agriculture Research Institute, Faisalabad. Ten seeds of both genotypes were sown in each plastic pot of 28 cm diameter, containing 10 kg of thoroughly washed sand and finally drained with full strength Hoagland's nutrients solution (Epstein, 1972). After germination, seedlings were thinned to maintain six seedlings per pot of almost uniform size. The design of the experiment was Completely Randomized (CRD) with five replications. All pots were irrigated with Hoagland's nutrients solution for 20-days. Afterward, 21 day old plants were salinized with 0 and 120 m*M* NaCl along with three salicylic acid concentrations (0, 0.25 and 0.50 m*M*) were given through rooting medium along with the salinity treatment in Hoagland's nutrients solution. Salinity was applied as increments of 50 m*M* per day along with full strength Hoagland's nutrients solution until the desired concentration of 120 m*M* was obtained at third day and continued till the termination of the experiment whereas the control plants were irrigated only with full strength Hoagland's nutrients solution. The plants were harvested after 25 days of salinity and SA treatment and data of fresh biomass and shoot-root length were measured. Plants were subsequently oven dried at 65^{o}C for 72 h and dry biomass was recorded.

Gas exchange: After 25 days measurements of gas exchange attributes were made on fully expanded 2nd leaf of main column of each plant using an open system LCA-4 ADS portable infrared gas analyzer (Analytical Development Company, Hoddesdon, England). Measurement was performed from 10.00 am to 12.30 pm with the specifications/adjustments: Leaf surface area 11.35 cm^2, ambient CO_2 concentration (Cref) 354.4 µmol^{-1} temperature of leaf chamber varied from 9 to 24^{o}C, leaf chamber gas flow rate (v) 392.8 mL min^{-1}, Molar flow of air per unit leaf area (Us) 404.84 mol m^{-2} s^{-1}, ambient pressure (P) 99.2 kPa, water vapour pressure into chamber ranged from 20.5 to 23.1 mbar, PAR (Q leaf) at leaf surface was maximum up to 1048 µmol m^{-2} s^{-1}.

Determination of ions, chlorophyll and caroteniods: The dried ground material (0.1 g) was digestion with 2 mL of concentrated H_2SO_4. Then ported the tubes in a digestion block and heated up to 350^{o}C until fumes were produced and continued to heat for 30 min, removed the digestion tubes from the block and cooled. Slowly added 2 mL H_2O_2 along the sides of the digestion tubes and placed the tubes back into the digestion block until fumes were produced and material was colorless. The volume of the extract was made 50 mL with distilled water, filtered and used for the determination of mineral elements (Wolf, 1982). Na^+, K^+ and Ca^{2+} were determined with a flame photometer (Jenway, PFP-1).

The Chlorophyll *a* and *b* were determined according to the method of Arnon (1949). The fresh leaves material (0.1 g) was extracted in 5 mL of 80% acetone. The extract was centrifuged at 14000 x g for 5 min and then absorbance was read at 663 and 645 nm using a spectrophotometer (Hitachi-220 Japan). Carotenoid contents from the fresh leaves were determined by determining sample at 470 nm optical density using spectrophotometer (Hitachi-220 Japan) and the caroteniod contents were calculated by the method described by Lichtenthaler & Wellburn (1983).

Statistical analysis: The experiment was designed in Completely Randomized (CRD) with 5 replications. Analysis of variance of all parameters was computed using the CO-STAT (COHORT, soft ware, Berkeley, California). The Least Significance Difference test (LSD) between the mean values was calculated following Snedecor & Cochran (1980).

Results

Salinity adversely affected the shoot dry weight of both the maize genotypes; reduction in shoot dry weight was 30% and 41% in Sahiwal 2002 and EV-20 respectively when compared with non-saline plants. However shoot dry weight was significantly increased by the application of 0.50 m*M* salicylic acid in both the maize genotypes under saline and non saline conditions. Application of SA @ 0.25 m*M* significantly enhanced shoot dry weight in maize genotype EV-20 under salt stress. Maximum increase in shoot dry weight was recorded with 0.50 m*M* SA. Root dry weight was also decrease upon salinity; however exogenous application of SA @ 0.50 m*M* significantly increased root dry weight in both the maize genotypes. Any increase by the application of 0.25 m*M* SA was only significant in EV-20 under saline and non saline conditions (Table 1).

Salinity caused substantial reduction in shoot and root length of both the maize genotypes. The exogenous applications of SA @ 0.50 m*M* significantly enhanced shoot and root length in both genotypes of maize under saline and non saline conditions. However, increase due to applied SA @ 0.25 m*M* was only significant in root length of EV-20 under salt stress (Table 2). Maximum shoot and root length was achieved by the application of SA @ 0.50 m*M* in Sahiwal-2002 under non-saline conditions, while the minimum was recorded with control plants of EV-20.

Salinity caused a considerable increase in Na^+ concentrations in shoot and root of both the maize genotypes. Application of SA @ 0.5 m*M* showed significant reduction in Na^+ concentration in shoot and root of both the maize genotypes under 0 and 120 m*M* NaCl. Percent reduction due to the application of SA @ 0.50 m*M* was 33 and 28% in Sahiwal 2002, while it was 37 and 33% in EV-20 respectively in shoot and root at 120 m*M* NaCl. On the other hand, applied SA @ 0.25 m*M* was significantly reduced Na^+ concentrations only of EV-20 in shoot and root of maize under salt stress (Table 3). Sodium concentrations were relatively higher in shoot than root of both the maize genotypes at 0 and 120 m*M* NaCl.

Table 1. Effects of salicylic acid levels on dry weight (g) of shoot and root in two maize genotypes at 0 and 120 m*M* NaCl stress.

	Shoot				Root			
	0 m*M* NaCl		120 m*M* NaCl		0 m*M* NaCl		120 m*M* NaCl	
Treatments	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20
Control	5.0 ab	3.4 d	3.5 bc	2.0 d	2.2 a	0.9 d	1.2 a	0.63 c
SA @ 0.25	5.2 ab	3.8 cd	4.0 b	3.0 c	1.9 ab	1.3 bc	1.0 a	0.90 ab
SA @ 0.50	5.6 a	4.1 c	5.4 a	3.4 bc	1.7 b	1.2 bc	0.9 ab	0.94 ab
Means	5.2 a	3.7 b	4.3 a	2.8 b	1.9 a	1.1 b	1.0 a	0.8 b

SA: Salicylic acid; Values followed by the same letter (s) are not significantly different at p<0.05 according to LSD test

Table 2. Effects of salicylic acid levels on length (cm) of shoot and root in two maize genotypes at 0 and 120 m*M* NaCl stress.

	Shoot				Root			
	0 m*M* NaCl		120 m*M* NaCl		0 m*M* NaCl		120 m*M* NaCl	
Treatments	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20
Control	102 a	76 c	90.5 ab	69.5de	30.2 a	18.4 c	27.0 a	13.6 d
SA @ 0.25	103 a	79 bc	92.4 ab	73.6 d	28.5 a	20.2 bc	24.0 ab	17.6 c
SA @ 0.50	105 a	82 b	97.2 a	80.6 c	24.4 b	22.0 b	22.2 b	18.0 c
Means	103 a	79 b	93.3 a	74.6 b	27.7 a	20.2 b	24.4 a	16.4 b

SA: Salicylic acid; Values followed by the same letter (s) are not significantly different at p<0.05 according to LSD test

Table 3. Effects of salicylic acid levels on Na^+ concentrations (mg g^{-1} DWt) in shoot and root of two maize genotypes at 0 and 120 m*M* NaCl stress.

	Shoot				Root			
	0 m*M* NaCl		120 m*M* NaCl		0 m*M* NaCl		120 m*M* NaCl	
Treatments	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20
Control	8.3 bc	12.6 a	30.0 bc	45.4 a	5.2 b	8.4 a	21.0 d	38.5 a
SA @ 0.25	7.5 bc	10.8 ab	27.4 cd	40.2 b	4.5 bc	7.6 a	19.4 de	30.8 b
SA @ 0.50	6.0 d	8.4 bc	20.2 d	28.5 bc	3.8 c	5.4 b	15.0 e	25.4 c
Means	7.3 a	10.6 b	25.7 a	38.0 b	4.5 a	7.1 b	17.7 a	31.6 b

SA: Salicylic acid; Values followed by the same letter (s) are not significantly different at p<0.05 according to LSD test

Table 4. Effects of salicylic acid levels on K^+ concentrations (mg g^{-1} D. Wt) in shoot and root of two maize genotypes at 0 and 120 m*M* NaCl stress.

	Shoot				Root			
	0 m*M* NaCl		120 m*M* NaCl		0 m*M* NaCl		120 m*M* NaCl	
Treatments	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20
Control	32.0 ab	25.5 cd	25.1 bc	18.2 d	20.6 b	17.0 c	20.4 b	16.5 c
SA @ 0.25	33.7 ab	28.3 c	27.9 ab	24.0 bc	21.4 b	19.4 bc	21.1 b	17.4 c
SA @ 0.50	35.2 a	32.0 ab	31.1 a	30.5 a	26.2 a	23.3 ab	25.3 a	21.2 b
Means	33.6 a	28.6 b	28.0 a	24.2 b	22.7 a	19.9 b	22.3 a	18.4 b

SA: Salicylic acid; Values followed by the same letter (s) are not significantly different at p<0.05 according to LSD test

Generally, K^+ concentration in shoot and root was diminished under salt stress in both the maize genotypes. Plant raised by applied SA level @ 0.50 m*M* showed significant increase in K^+ concentration in shoot and root of both the maize genotypes under saline and non-saline situations (Table 4). Comparatively higher K^+ concentration was attained in shoot than root under saline and non-saline conditions.

Exogenous application of SA @ 0.25 and 0.50 m*M* were improved Ca^{2+} concentration; however, magnitude of increase was higher with 0.50 m*M* applied SA in shoot and root of both the maize genotypes under saline and non-saline conditions (Table 5). Relatively less Ca^{2+} concentrations were recorded in shoot than root under saline medium in both genotypes.

K^+/Na^+ and Ca^{2+}/Na^+ ratios were notably reduced with salinity in shoot and root of both maize genotypes. Exogenously applied SA @ 0.25 and 0.50 m*M* increased K^+/Na^+ and Ca^{2+}/Na^+ ratios in shoot and root of maize; however, magnitude of increase was higher with 0.50 m*M* applied SA at 0 and 120 m*M* NaCl stress (Table 6 & 7).

Salt stress caused reduction in chlorophyll "*a*" and "*b*" content in both maize genotypes. Application of SA as rooting medium significantly augmented the adverse affect of salinity by increasing chlorophyll "*a*" and "*b*" content in both maize genotypes. Comparatively, higher chlorophyll "*a*" and "*b*" contents were recorded with Sahiwal-2002 under saline and non-saline conditions (Figs. 1 & 2). Similarly, caroteniod contents were also improved due to exogenously applied SA levels under stressed and non-stressed plants of both genotypes, predominantly at 0.50 m*M* SA (Fig. 3).

Salt stress caused reduction in CO_2 assimilation rate (*A*) and stomatal conductance (*gs*) in both the genotypes. Exogenously applied SA @ 0.50 m*M* significantly increased net CO_2 assimilation rate and stomatal conductance in both genotypes under saline conditions. However, genotype Sahiwal-2002 accumulated higher CO_2 assimilation rate (*A*) and stomatal conductance (*gs*) under saline conditions (Figs. 4 & 5).

Transpiration rate (*E*) was significantly declined under salt stress; whereas, genotype Sahiwal-2002 had less transpiration rate under salt stress. Both the applied SA levels reduced transpiration rate in both genotypes especially with higher level (0.50 m*M*) under salt stress (Fig. 6).

Sub-stomatal CO_2 concentration (*Ci*) was uneven in response to salt stress in both genotypes. Maize genotype EV-20 showed significant reduction in *Ci* while the Sahiwal-2002 did not reduced significantly under saline conditions. Sub-stomatal CO_2 concentration (*Ci*) was stayed unaffected due to applied SA levels under both saline and non-saline plants; excluding applied SA @ 0.50 m*M* in Sahiwal-2002, which caused significantly increased *Ci* under salt stress (Fig. 7).

Number of cobs $plant^{-1}$ of both the genotypes was significantly decreased under saline conditions; although magnitude of decrease was higher in EV-20 than Sahiwal-2002. Application of SA @ 0.50 m*M* significantly increased number of cobs $plant^{-1}$ in both maize genotypes under saline medium. In contrast, any level of applied SA was not significantly increased number of cobs $plant^{-1}$ under non-saline conditions in either genotype. Maximum number of cobs $plant^{-1}$ were recorded with the application of SA @ 0.50 m*M* in Sahiwal-2002 under non-saline conditions, while the lowest were recorded with control plants of EV-20 (Fig. 8).

Table 5. Effects of salicylic acid levels on Ca^{2+} concentrations (mg g^{-1} DWt) in shoot and root of two maize genotypes at 0 and 120 m*M* NaCl stress.

	Shoot				Root			
	0 m*M* NaCl		120 m*M* NaCl		0 m*M* NaCl		120 m*M* NaCl	
Treatments	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20
Control	5.3 ab	4.0 c	7.5 b	6.0 c	4.5 ab	3.0 c	5.2 b	4.0 c
SA @ 0.25	5.5 ab	4.7 bc	8.0 ab	7.5 b	4.8 a	3.4 c	5.5 ab	4.6 bc
SA @ 0.50	6.0 a	5.2 ab	9.0 a	8.2 ab	5.0 a	4.5 ab	6.0 a	5.5 ab
Means	5.6	4.6	8.2	7.2	4.8	3.6	5.6	4.7

SA: Salicylic acid; Values followed by the same letter (s) are not significantly different at p<0.05 according to LSD test

Table 6. Effects of salicylic acid levels on K^+/Na^+ concentrations (mg g^{-1} D. Wt) in shoot and root of two maize genotypes at 0 and 120 m*M* NaCl stress.

	Shoot				Root			
	0 m*M* NaCl		120 m*M* NaCl		0 m*M* NaCl		120 m*M* NaCl	
Treatments	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20
Control	3.8 b	2.0 c	0.8 b	0.4 c	4.0 c	2.0 de	0.98 b	0.42 de
SA @ 0.25	4.5 ab	2.6 bc	1.0 ab	0.6 bc	5.0 b	2.6 d	1.1 b	0.56 d
SA @ 0.50	5.9 a	3.8 b	1.5 a	1.1 ab	7.0 a	4.3 c	1.8 a	0.84 bc
Means	4.73 a	2.81 b	1.12 a	0.68 b	5.2 a	2.96 b	1.30 a	0.60 b

SA: Salicylic acid; Values followed by the same letter (s) are not significantly different at p<0.05 according to LSD

Table 7. Effects of salicylic acid levels on Ca^{2+}/Na^+ concentrations (mg g^{-1} DWt) in shoot and root of two maize genotypes at 0 and 120 m*M* NaCl stress.

	Shoot				Root			
	0 m*M* NaCl		120 m*M* NaCl		0 m*M* NaCl		120 m*M* NaCl	
Treatments	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20	Sahiwal 2002	EV-20
Control	0.63 bc	0.31 de	0.25 b	0.13 cd	0.86 b	0.35 c	0.25 b	0.10 c
SA @ 0.25	0.73 b	0.43 d	0.29 b	0.18 c	1.06 ab	0.44 c	0.29 b	0.14 c
SA @ 0.50	1.0 a	0.61 bc	0.44 a	0.28 b	1.31 a	0.83 b	0.42 a	0.21 bc
Means	0.78 a	0.45 b	0.32 a	0.19 b	1.07 a	0.54 b	0.32 a	0.15 b

SA: Salicylic acid; Values followed by the same letter (s) are not significantly different at p<0.05 according to LSD

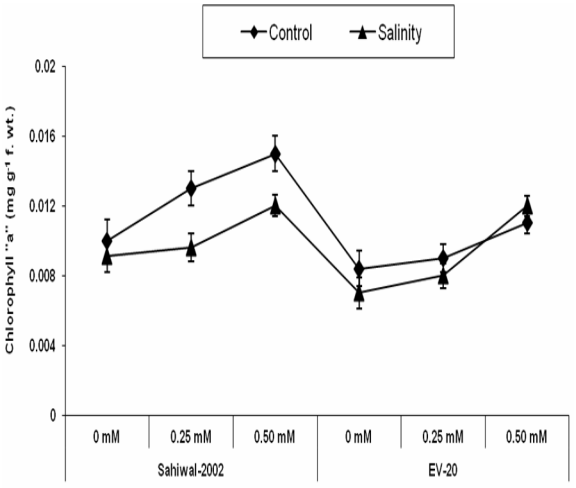

Fig. 1. Effect of salicylic acid on the chlorophyll "a" content of two maize genotypes grown in absence and presence of salt.

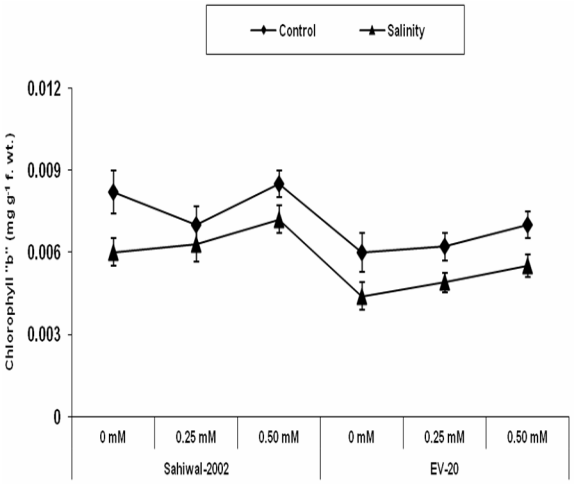

Fig. 2. Effect of salicylic acid on the chlorophyll "b" content of two maize genotypes grown in absence and presence of salt.

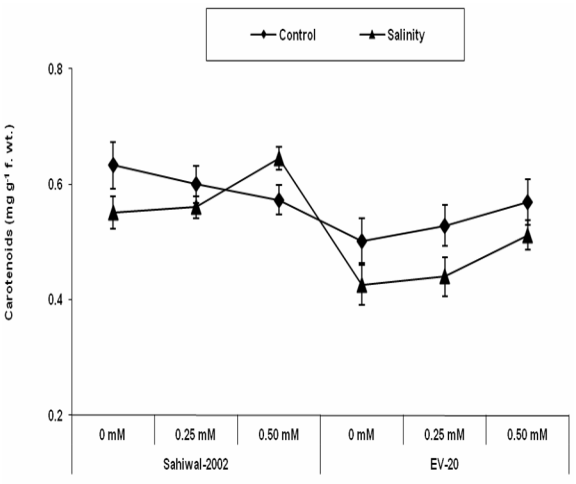

Fig. 3. Effect of salicylic acid on the caroteniod content of two maize genotypes grown in absence and presence of salt.

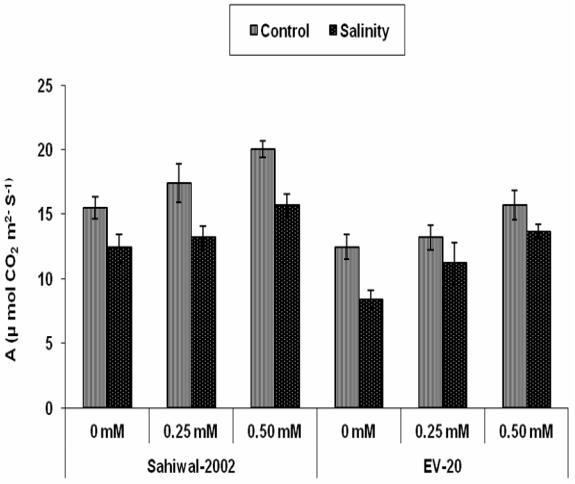

Fig. 4. Effect of salicylic acid on CO_2 assimilation rate (*A*) of two maize genotypes grown in absence and presence of salt.

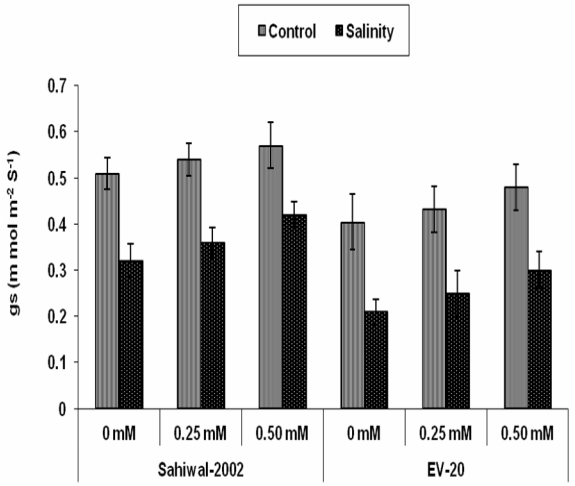

Fig. 5. Effect of salicylic acid on Stomatal conductance (*gs*) of two maize genotypes grown in absence and presence of salt.

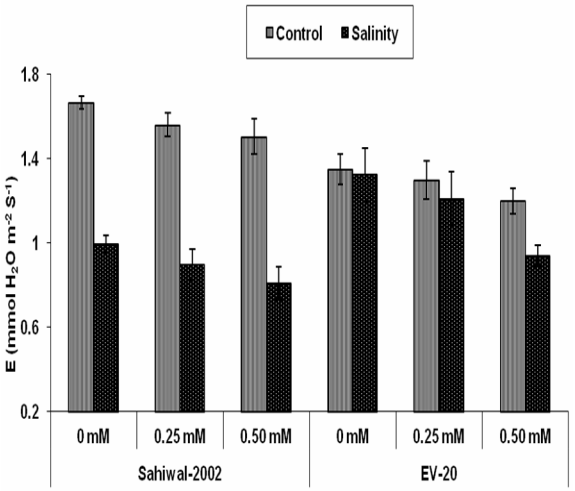

Fig. 6. Effect of salicylic acid on transpiration rate (*E)* of two maize genotypes grown in absence and presence of salt.

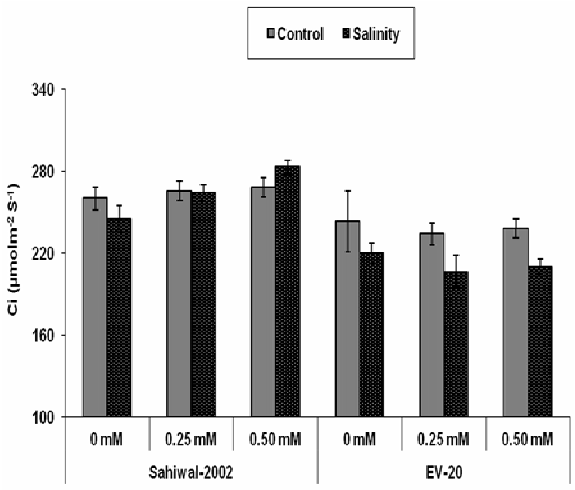

Fig. 7. Effect of salicylic acid on sub-stomatal conductance (*Ci*) of two maize genotypes grown in absence and presence of salt.

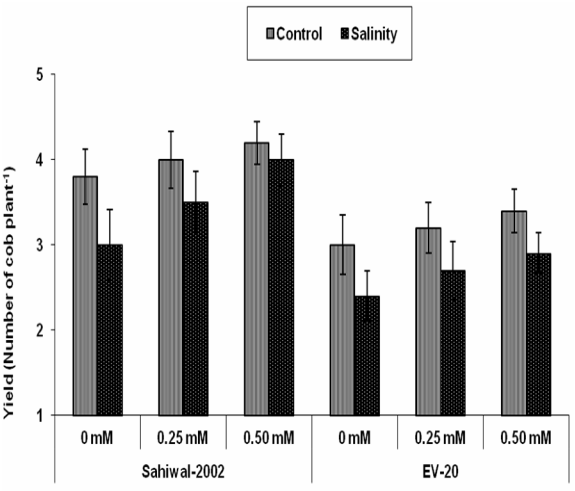

Fig. 8. Effect of salicylic acid on yield (Number of cobs plant^{-1}) of two maize genotypes grown in absence and presence of salt.

Discussion

Present experiment was executed to enhance the salinity tolerance of maize by inducing salicylic acid as rooting medium. Application of higher level of SA (0.50 m*M*) had ameliorative effect on shoot and root dry biomass as well as shoot length in both genotypes; while lower level of applied SA was only significant in EV-20 under both non-saline and saline conditions (Tables 1 & 2). Enhancement in salt tolerance by exogenous application of SA was already reported in sunflower (Noreen & Ashraf, 2008) in wheat (Khan *et al*., 2012) barley (El-Tayed, 2005) and in mungbean (Khan *et al*., 2010).

In the present study, application of higher level of SA (0.50 m*M*) caused a significant reduction in Na^+ concentration in both maize genotypes (Table 3) which was associated with the beneficial effect on plant dry matter accumulation. In addition, Na^+ concentration from root to shoot was also reduced by the application of SA. Present results showed that this treatment increased K^+ as well as Ca^{2+} concentrations in both genotypes (Tables 4 & 5). Application of lower level of SA (0.25 m*M*) ameliorate the adverse effect of salinity by reducing Na^+ and enhancing K^+ and Ca^{2+} transport in maize genotype EV-20 under salt stress. It was reported that Na^+ influence the transport of K^+ within the plant cells because of chemical resemblance (Rodriguez, 2000). Khan *et al*., (2010) explained that application of 0.50 m*M* SA enhanced salinity tolerance of mungbean by reducing Na^+ and increased N, P, K^+, Ca^{2+} and antioxidant enzymes activity. It may be advised that exogenously applied 0.50 m*M* SA induced salinity tolerance in maize by accumulating higher K^+ and less Na^+ concentration in cytosol by modifying the expression and activity of Na^+ and K^+ accumulation which create driving power for transport. Our results also showed that applied SA increased Ca^{2+} accumulation; that might be reduced Na+ transport and also supports to preserve membrane integrity. Because Ca^{2+} can play a role as secondary messenger; it increases salt tolerance by opens the stress signal transduction. It was reported that exogenous application of Ca^{2+} ameliorates the adverse effect of salinity by enhancing K^+: Na^+ selectivity (Liu & Zhu, 1998). Present results indicates that exogenous applications of SA increased K^+/Na^+ and Ca^{2+}/Na^+ ratios in both maize; however higher values were attained in Sahiwal-2002. Significance of important role of K^+/Na^+ and Ca^{2+}/Na^+ ratios in salinity tolerance of plants has already well documented by earlier reports (Gorham, 1993; Sharma, 1994).

Induced salt stress decreased chlorophyll a, b and caroteniod contents in both maize genotypes; while exogenous application of SA alleviates the adverse effect of salinity by increasing chlorophyll *a*, *b* as well as caroteniod contents (Figs. 1, 2 & 3). Reduction in chlorophyll content is supposed with salinity, due to excessive concentration of Na^+ and Cl^- that disturb membrane stability (Ashraf *et al*., 2005). Reduction in chlorophyll *a* and *b* contents under saline conditions is also reported by Gurmani *et al*., (2007); Ashraf *et al*., (2005). Present results are in agreement with that of Sweify & Abdel-Wahid (2008) who reported that exogenously applied SA increased Chlorophyll "*a*", "*b*" and caroteniod contents in *Syngonium podphyllum* plants.

It was reported that salinity stress diminished plant growth by disturbance in physiological and biochemical processes inside the plant. It is therefore proposed that salinity tolerance in plants by exogenously applied SA might be due to alteration in biochemical and physiological processes (Ashraf, 2004). Present results showed that salt stress decline photosynthesis, which was overcome by the exogenously applied 0.50 m*M* SA. The increase in photosynthetic rate by exogenous application of SA was also reported in some crop species like mungbean (Khan *et al*., 2010), rice (Masood *et al*., 2004), wheat (Sing & Usha, 2003) and Soya bean (Khan *et al*., 2003). The decrease in stomatal conductance, transpiration rate and sub-stomatal CO_2 concentration (*Ci*) under saline conditions are in agreement with Khan *et al*., (2010). Our results suggested that higher level of SA (0.50 m*M*) was affective to enhance stomatal conductance and decreased transpiration rate; however increase in sub-stomatal conductance was not affected in both maize

genotypes under salt stress. These finding are also supported with Noreen & Ashraf (2008); that foliar application of SA increased stomatal conductance and photosynthesis in salt stressed sunflower plants.

Salt stress decreased the number of cobs plant^{-1} which was alleviated by inducing 0.50 m*M* SA as rooting medium (Fig. 8). The increase in yield of maize is might be due to higher dry matter accumulation, better selectivity of ions, chlorophyll and photosynthesis by the application of 0.50 m*M* SA). Salicylic acid induce salinity tolerance by increasing yield was already reported in wheat (Arfan *et al*., 2007).

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