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EXOGENOUS POTASSIUM DIFFERENTIALLY MITIGATES SALT STRESS IN TOLERANT AND SENSITIVE MAIZE HYBRIDS

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Abstract

A hydroponic experiment was conducted to investigate the role of potassium (K) in extenuating the injurious effect of salt stress on maize hybrids differing in salt tolerance. Two salt-sensitive viz., 33H25 and 8441 and two salt-tolerant viz. 26204 and Hysun-33 maize hybrids were grown for four weeks in half strength Hoagland's solution. The nutrient solution was salinized by three salinity (0, 70 and 140 mM L^{-1} NaCl) levels and supplied with three levels of potassium (3, 6 and 9 mM L^{-1}). Salt stress significantly reduced the plant growth as reflected by a decrease in the plant height, leaf area, shoot length, shoot fresh and dry weight, relative water content (RWC), membrane stability index (MSI), chlorophyll contents (chl), transpiration rate (E), photosynthetic rate (A), internal CO_2 concentration (C_i), stomatal conductance (g_s), K^+/Na^+ ratio and increased the activities of anti-oxidative enzymes superoxide dismutase (SOD), peroxidase (POD) and catalase (CAT) at 70 mM NaCl, but activities of SOD, POD and CAT declined at 140 mM NaCl for all four maize hybrids. Salinity induced diminution in all these attributes was significantly greater in salt sensitive maize hybrids as compared to salt tolerant maize hybrids. However, application of potassium counteracted the unsympathetic effects of salinity on the growth of salt tolerant maize hybrids, particularly at 9 mM L^{-1} level. Potassium enhanced growth of salt-stressed maize hybrids 26204 and Hysun-33 was associated with increased CAT activity, higher photosynthetic capacity, and accumulation of K^+ in the leaves. These results suggested that potassium application counteracted the unfavorable effects of salinity on growth of maize by civilizing photosynthetic capacity of maize plants against salinity-induced oxidative stress and maintaining ion homeostasis, however, these alleviating effects were cultivar specific.

Introduction

Salinity is a major abiotic stress which affects the growth and productivity of a variety of crops all over the world (Ali *et al*., 2011a, Tester & Davenport, 2003; Ashraf & Foolad, 2007; Abbasi *et al*., 2012). About 100 million hectares of arable land world wide is adversely affected by high salinity which ultimately decreases crop production (Ghassemi *et al*., 1995). The ceiling in growth and yield of plants due to salt stress is particularly rigorous in arid and semi-arid regions of the world (Kuznetsov & Shevyakova, 1997).

Salt stress is acknowledged to hinder numerous morpho-physiological attributes like root and shoot fresh and dry weights and photosynthetic rate by reducing chlorophyll content (Ali *et al*., 2011b; Abbasi *et al*., 2012) and inducing the stomatal closure, in this manner reduces partial CO_2 strain within the leaf (Bethke & Drew, 1992). Salt stress disturbs plant water status by decreasing relative water contents and membrane stability index (Sairam *et al*., 2002). Plants responses towards salinity stress depend upon many factors like degree (concentration of salt and time of revelation) of the stress, variety, growth stage and environmental conditions (Sultana *et al*., 1999; Jaleel *et al*., 2007).

Salinity induced osmotic stress, ionic imbalance, ion toxicity and nutrient deficiency regarding plant growth (Parida & Das, 2005). Ionic imbalance and ion toxicity is due to substitution of potassium with sodium ions in a chemical reaction and due to protein (Zhu, 2002). Consequently, the capability of plants to sustain high echelon of K^+/Na^+ ratio is a most important attribute of crop plants regarding salt tolerance mechanism (Maathuis & Amtmann, 1999; Chen *et al*., 2005, 2007; Akram *et al*., 2010; Abbasi *et al*., 2012).

Besides the water/osmotic stress and ionic imbalance, salinity stress is also involved in an oxidative stress that result in formation of ROS (reactive oxygen species) like superoxide, hydroxyl radical, hydrogen peroxide, and singlet oxygen that involved in promoting membrane lipid peroxidation as well as membrane leakage (Ashraf, 2004; Gunes *et al*., 2007). These reactive oxygen species finally scratch chloroplast and mitochondria by distracting their cellular structures (Mittler, 2002). Naturally, plants stimulate many protective mechanisms to neutralize harmful possessions of reactive oxygen species. Along with these protective mechanisms, plants bodies also have proficient antioxidant enzymes system to hunt these reactive oxygen species. Those plants which contained high level of antioxidant enzymes also have more resistance against oxidative stress caused by reactive oxygen species (Khan *et al*., 2009; Gapinska *et al*., 2008).

Status of mineral nutrient in plant body play an important role in improving the confrontation to any environmental hazardous like water stress, salt stress and heavy metal stress etc. Along with other mineral nutrients, potassium has an important task regarding plants endurance under salt stress condition (Marschner, 1995; Mengel & Kirkby, 2001). It is very important for maintaining turgor and membrane potential, balancing osmotic potential, controlling stomatal movement and activating enzymes (Cherel, 2004). An appropriate K^+/Na^+ proportion is imperative for maintaining turgor, and cell osmoregulation, stomata opening and closing, synthesis of protein and photosynthesis (Shabala *et al*., 2003; Abbasi *et al*., 2012). Nevertheless, high production of reactive oxygen species due to salt stress lead to membrane damage and result in potassium leak from cell due to activating K^+ efflux channels (Demidchik *et al*., 2003; Cuin & Shabala, 2007). Addition of potassium in growing medium involved in improving salinity tolerance in rice (Bohra & Doerffling, 1993), wheat (Shirazi *et al*., 2001) and corn (Bar-Tal *et al.,* 2004*).* Results of previous research clearly depicted that high concentration of potassium in plant body greatly reduced the production of reactive oxygen species (Cakmak, 2005).

The application of potassium humate enhanced the activities of different antioxidant enzymes like superoxide dismutase, catalase and peroxidase on ginger roots (Liang *et al*., 2007). In another experiment, KNO_3 application alleviated the effects of salinity in winter wheat by enhancing activities of antioxidant enzymes (Zheng *et al*., 2008). The scavenging of ROS especially SOD, CAT and GPX by the scavenging system can be improved by exogenous potassium application (Soleimanzadeh *et al*., 2010).

Keeping in view the favorable possessions of potassium on the growth of crops as reported in earlier studies, experiment was deliberated to scrutinize the alleviating task of potassium regarding the salinity induced morphological, metabolic, physiological and antioxidant activity changes in maize hybrids differing in salinity tolerance.

Materials and Methods

Plant material, growth and treatment conditions: The solution culture experiment was conducted in the rain-protected wire house of Saline Agriculture Research Centre (SARC), University of Agriculture, Faisalabad. Seeds of four different maize hybrid (*Zea mays* L.) 8441 and 33H25 identified as salt-sensitive and 26204 and Hysun-33 recognized as salt-tolerant in previous study experiment of screening. Seed of these hybrids were sown in trays containing sand. Water was speckled daily above these trays for maintaining optimal humidity for the germination seed. After germination, when plants reach at two leaf stage, plants were transplanted into thermopol sheet floating in 200 liters tubs having half strength Hoagland's solution (Hoagland & Arnon, 1950). Air was provided by using aeration pumps. The culture solution was distorted twice a week. Complete randomized design (CRD) with factorial arrangement was used with five replicates. After one week of transplanting, salinity levels (control, 70 and 140 mM) were developed with NaCl salt in three increments, whereas in control no salt were added. Three mM K in half strength Hoagland's solution was considered as control and other two K levels: 6 mM K (moderate) and 9 mM K (adequate) were developed by adding KCl. The pH of solution was maintained about 6.5±0.5 with 1 M NaOH or HCl, as required.Plant harvest: Two harvests were made 10 and 20 days after the onset of salt stress. Plants were washed thoroughly with distilled water and were dried using blotting paper. The youngest fully expanded leaves were separated at harvesting time and stored at freezing temperature to determine K^+ and Na^+. The rest of plant samples were dried at 65±2°C for 24 hours in oven to determine shoot dry weight.

Photosynthetic pigments: The chlorophyll a and b were measured by the following the method of Arnon (1949) through calculating the absorbance of supernatant at 645 and 663 nm using a spectrophotometer (Hitachi-220, Japan).

Relative water contents (RWC) and membrane stability index (MSI): Relative water contents and membrane stability index were measured according to method proposed by Turner (1986) and Sairam *et al*., (2002) respectively.

Measurements of gas exchange characteristics and leaf area: Measurements of gas exchange attributes (transpiration rate (E), photosynthetic rates (A), sub-stomatal CO_2 concentration (C_i) and stomatal conductance (g_s)) were completed by using LCA-4 ADC infrared gas analyzer while leaf area meter was used for determining leaf area (cm^2 $plant^{-1}$) of plants.

Determination of Na^+ and K^+ concentration: Na^+ and K^+ concentration from leaf sap was determined by using Sherwood 410 Flame photometer.

Antioxidant enzyme assay: The concentration of protein in fresh leaf sap after centrifugation was measured by Bradford (1976) method. Giannopolitis & Ries (1977) method was followed for determination of superoxide dismutase (SOD) activity while Chance & Maehly (1955) method was used for determination of catalase (CAT) and peroxidase (POD) activities from fresh leaf sample of plants.

Statistical analysis: All data presented in this study are mean of five replicates and statistical package, SPSS version 16.0 (SPSS, Chicago, IL) was apply to check the data statistically.

Results

Effect of salinity and potassium application on plant growth parameters: Effect of salinity and potassium on plant height, leaf area, shoot length, shoot fresh weight and shoot dry weight in two salt tolerant maize hybrids 26204 and Hysun-33 and two salt sensitive maize hybrids 33H25 and 8441 are listed in Tables 1 and 2. NaCl addition caused significant decrease in plant height, leaf area, shoot length, shoot fresh weight and shoot dry weight as compared to control in all four maize hybrids irrespective of time interval and salinity level. The higher reduction in these parameters was observed in salt sensitive maize hybrids as evaluated with salt tolerant maize hybrids. Maximum plant height at 10 and 20 days intervals (63.3, 90.2 cm), leaf area (275, 542 cm^2), shoot length (45.2, 65.3 cm), shoot fresh weight (19.1, 27.1g) and shoot dry weight (3.47, 4.26 g) was observed in maize hybrids 26204 while minimum plant height (44.8, 64.01 cm), leaf area (183, 243 cm^2), shoot length (32.5, 44.3 cm), shoot fresh weight (9.9, 13.8g) and shoot dry weight (1.51, 3.62 g) was observed in maize hybrids 8441 at 140 mM NaCl level. However, potassium application significantly alleviated the effects of salinity in these plant growth parameters in both salt tolerant maize hybrids especially at higher 9 mM K level but addition of potassium had no significant effect on plant growth parameters in both salt sensitive maize hybrids at both intervals except leaf area of both salt sensitive hybrids at 20 days was significantly improved under salt stressed conditions.

Effect of salinity and potassium application on relative water contents and membrane stability index: Data regarding RWC and MSI are presented in Table 3. Higher salinity (140 mM NaCl) level, significantly decreased RWC and MSI in all four genotypes but mild salt stress (70 mM NaCl) showed no significant effect on these parameters in salt tolerant maize hybrids at both intervals. In salt sensitive 33H25 and 8441, RWC and MSI significantly decreased at both salinity levels. Addition of potassium improved RWC and MSI more effectively at adequate level (9 mM K) in salt tolerant maize hybrids as compared to salt sensitive maize hybrids.

Table 1. Effect of salt treatment and potassium application on plant height (cm) and leaf area (cm^2).

		Plant height (cm)		Leaf area (cm^2)	
Hybrids	**Treatments**	**10 days**	**20 days**	**10 days**	**20 days**
26204	Control	102 a	150.0 a	490 a	911.7 a
	70 mM NaCl	80.0 fgh	118.7de	380.2 g	716.5 g
	140 mM NaCl	63.3 mno	90.2 ij	275 op	542.0 no
	70 mM NaCl + 6 mM K	85.1 ef	125.0 cd	402.2 ef	753.5 e
	70 mM NaCl + 9 mM K	92.7cde	133.7 b	439 b	810.0 c
	140 mM NaCl + 6 mM K	66.8 k-o	95.1 f-i	292 mn	576.0 k
	140 mM NaCl + 9 mM K	72.4h-l	102.0 fg	309.5 kl	621.5 i
Hysun-33	Control	101.1ab	149.1 a	480.8 a	899.5 b
	70 mM NaCl	76.3 ghi	113.8 e	370.1 g	704.1 h
	140 mM NaCl	59.3 op	85.3 j	265.4 p	528.9 pq
	70 mM NaCl + 6 mM K	81.2 fg	119.9 cde	393.1 f	740.7 f
	70 mM NaCl + 9 mM K	86.1 def	126.8 c	429.6 bc	791.6 d
	140 mM NaCl + 6 mM K	62.6 no	90.6 ij	279.7 no	562.7 l
	140 mM NaCl + 9 mM K	65.9 k-o	95.2 f-i	297.6 lm	599.8 j
33H25	Control	96abc	140.5 b	419.5 cd	789.8 d
	70 mM NaCl	67.6 j-o	94.4 ghi	310 jkl	519.6 qr
	140 mM NaCl	47.7 qr	68.2 kl	190.7 r	250.7 vw
	70 mM NaCl + 6 mM K	71.6 h-m	99.6 fgh	320.2 ij	540.5 no
	70 mM NaCl + 9 mM K	75.9 g-j	102.5 f	337.7 h	553.7 lm
	140 mM NaCl + 6 mM K	51.4pqr	72.9 k	197.2 qr	261.2 tu
	140 mM NaCl + 9 mM K	54.4 pq	74.8 k	209.5 q	280.5 s
8441	Control	93.7 bcd	136.6 b	413.0 de	782.7 d
	70 mM NaCl	64.7 l-o	91.9 hij	303.7 klm	512.7 r
	140 mM NaCl	44.8 r	64.0 l	183.9 r	243.5 w
	70 mM NaCl + 6 mM K	70.5 i-n	94.9 f-i	313.6 jk	534.6 op
	70 mM NaCl + 9 mM K	74.5 g-k	97.3 f-i	327.5 hi	548.3 mn
	140 mM NaCl + 6 mM K	48.9 qr	67.7 kl	191.2 r	255.9 uv
	140 mM NaCl + 9 mM K	51.2 pqr	69.0 kl	196.7 qr	266.8 t

Table 2. Effect of salt treatment and potassium application on shoot length (cm), shoot fresh and dry weight (g plant^{-1}).

		Shoot length (cm)		Shoot fresh weight (g)		Shoot dry weight (g)	
Hybrids	**Treatments**	**10 days**	**20 days**	**10 days**	**20 days**	**10 days**	**20 days**
26204	Control	78.1 a	110.4 a	33.1 a	49.9 a	5.85 a	7.36 a
	70 mM NaCl	62.7 de	85.4 fg	25.6 c-g	35.2 ef	4.57 bcd	5.72 bcd
	140 mM NaCl	45.2 hi	65.3 jk	19.1 i-l	27.1 h-k	3.47 d-i	4.26 e-h
	70 mM NaCl + 6 mM K	66.3 cd	90.5 ef	27.6 bcd	37.8 de	4.97 abc	6.05 bc
	70 mM NaCl + 9 mM K	69.7 c	93.3 de	29.4 abc	40.1 cd	5.32 ab	6.51 ab
	140 mM NaCl + 6 mM K	48.0 gh	68.7 hij	20.5 h-l	29.5 g-j	3.70 d-h	4.54 def
	140 mM NaCl + 9 mM K	51.5 fg	72.8 hi	22.0 f-j	30.9 fgh	3.90 c-g	4.75 de
Hysun-33	Control	74.7 ab	106.4 ab	30.4 ab	45.9 ab	5.19 ab	6.05 bc
	70 mM NaCl	58.8 e	81.2 g	23.0 e-i	30.9 fgh	3.86 c-g	4.46 ef
	140 mM NaCl	41.9 ij	61.5 k	16.1 lm	23.4 k	2.81 ghi	3.19 ghi
	70 mM NaCl + 6 mM K	63.0 de	86.3 fg	24.5 d-h	33.1 fg	4.12 b-f	4.77 de
	70 mM NaCl + 9 mM K	66.5 cd	90.9 ef	25.8 c-f	35.0 ef	4.35 b-e	4.96 cde
	140 mM NaCl + 6 mM K	44.7 hi	65.8 jk	17.2 kl	25.0 jk	3.05 f-i	3.40 f-i
	140 mM NaCl + 9 mM K	47.8 gh	69.7 hij	17.9 jkl	26.8 h-k	3.13 e-i	3.49 f-i
33H25	Control	70.7 bc	102.8 bc	29.5 abc	43.3 bc	4.64 bcd	6.34 ab
	70 mM NaCl	51.0 fg	70.8 hij	19.8 i-l	29.2 g-j	3.22 e-i	4.17 e-h
	140 mM NaCl	36.4 kl	49.0 lm	11.9 mn	17.3 l	2.36 ij	3.07 hi
	70 mM NaCl + 6 mM K	52.6 fg	72.7 hi	20.7 h-l	30.1 ghi	3.38 d-i	4.34 efg
	70 mM NaCl + 9 mM K	53.9 f	74.2 h	21.3 g-k	31.3 fgh	3.55 d-i	4.50 def
	140 mM NaCl + 6 mM K	37.5 jkl	50.5 l	12.6 mn	17.8 l	2.50 hij	3.18 ghi
	140 mM NaCl + 9 mM K	39.0 jk	51.6 l	13.0 mn	18.4 l	2.55 hij	3.38 f-i
8441	Control	66.6 cd	98.2 cd	27.0 b-e	40.1 cd	4.17 b-f	5.13 cde
	70 mM NaCl	47.4 gh	66.0 jk	17.2 kl	26.0 ijk	2.52 hij	2.59 ij
	140 mM NaCl	32.5 l	44.3 m	9.9n	13.8 l	1.51 j	1.62 j
	70 mM NaCl + 6 mM K	49.2 fgh	67.1 ijk	18.0 jkl	27.0 h-k	2.56 hij	2.65 ij
	70 mM NaCl + 9 mM K	49.8 fgh	69.0 hij	18.3 jkl	27.6 h-k	2.68 g-j	2.71 ij
	140 mM NaCl + 6 mM K	33.8 l	45.7 lm	10.2 n	14.5 l	1.55 j	1.65 j
	140 mM NaCl + 9 mM K	35.0 kl	47.0 lm	10.4 n	15.0 l	1.57 j	1.69 j

Effect of salinity and potassium application on K^+ and Na^+ concentration and K^+/Na^+ ratio: Considerable differences were observed for concentrations of Na^+, K^+, and K^+/ Na^+ ratio in the cell sap (Table 4). Concentration of Na^+ differed significantly between control and 70 mM NaCl. By increasing salinity, a significant increase in Na^+ content was observed in each maize hybrid at both intervals. The lowest Na^+ concentrations were observed in maize hybrids 26204 and the highest in maize hybrids 33H25 at all salinity levels. The trend in case of potassium was almost reverse, showing decreased K^+ contents in all four maize hybrids. However, this decrease in potassium was more prominent in salt sensitive genotypes as compared to salt tolerant maize hybrids. Maize hybrid 26204 was better in maintaining high level of K^+ at all the salinity levels in comparison to the other three hybrids. The increasing uptake of Na^+ with increase in the salinity levels resulted in a decrease of K^+/Na^+ ratio (Table 4). The highest potassium concentration at high salinity level resulted in maintaining higher K^+/Na^+ ratio in maize hybrid 26204, showing better performance under saline culture conditions. Addition of potassium in solution significantly improves K^+/Na^+ ratio in salt tolerant maize hybrids but no significant effect of potassium on K^+/Na^+ ratio in salt sensitive maize hybrids were observed at both intervals.

Effect of salinity and potassium application on gas exchange parameters: Compared to control, significant reduction in gas exchange parameters Photosynthetic rate (A), Transpiration rate (E), Stomatal conductance (g_s), and Internal CO_2 concentration (C_i) was observed at two salinity stress levels at both intervals in all four maize hybrids (Table 5). Significant improvement in g_s and C_i at both salinity levels was observed in salt tolerant maize hybrids (26204, Hysun-33) at 10 and 20 days while in salt sensitive maize hybrids (33H25, 8441) g_s and C_i significantly improved only at high potassium level with mild salinity stress. Addition of potassium in solution medium improved A and E in salt tolerant maize hybrids more predominantly at both salinity levels while it had no significant effect on these parameters in salt sensitive maize hybrids.

Table 3. Effect of salt treatment and potassium application on relative water content (%) and membrane stability index (%).

		Relative water contents (%)		Membrane stability index (%)	
Hybrids	**Treatments**	**10 days**	**20 days**	**10 days**	**20 days**
26204	Control	90.2 a	92.0 a	84.1 a	86.1 a
	70 mM NaCl	84.2 abc	85.3 a-d	79.1 a-d	79.2 a-d
	140 mM NaCl	75.7 ef	76.4 efg	71.7 d-g	71.9 d-h
	70 mM NaCl + 6 mM K	86.9 a	87.7 abc	82.4 ab	82.1 abc
	70 mM NaCl + 9 mM K	89.4 a	90.0 ab	83.6 a	82.7 ab
	140 mM NaCl + 6 mM K	77.8 c-f	78.7 def	73.5 c-g	73.5 c-g
	140 mM NaCl + 9 mM K	79.0 b-e	79.5 def	74.9 b-g	73.7 c-g
Hysun-33	Control	89.9 a	91.3 a	83.3 a	85.1 a
	70 mM NaCl	83.3 a-d	81.6 c-f	75.0 b-g	76.2 b-f
	140 mM NaCl	71.3 f	68.4 hij	68.0 g	64.5 hij
	70 mM NaCl + 6 mM K	85.2 ab	83.3 b-e	77.2 a-f	78.1 a-e
	70 mM NaCl + 9 mM K	86.6 a	84.5 a-d	77.8 a-e	78.6 a-e
	140 mM NaCl + 6 mM K	72.7 ef	70.0 ghi	69.1 fg	65.7 ghi
	140 mM NaCl + 9 mM K	73.8 ef	70.4 gh	69.9 efg	66.8 gh
33H25	Control	89.7 a	91.5 a	82.0 ab	83.0 ab
	70 mM NaCl	75.2 ef	76.0 e-h	69.0 g	70.2 e-h
	140 mM NaCl	62.2 g	60.5 k	57.8 h	56.5 jk
	70 mM NaCl + 6 mM K	76.7 def	78.5 def	70.2 efg	71.3 d-h
	70 mM NaCl + 9 mM K	79.1 b-e	80.0 c-f	70.9 efg	71.6 d-h
	140 mM NaCl + 6 mM K	63.1 g	61.6 jk	58.9 h	57.2 jk
	140 mM NaCl + 9 mM K	64.4 g	62.8 ijk	59.5 h	57.8 ijk
8441	Control	89.4 a	90.2 ab	81.1 abc	82.2 abc
	70 mM NaCl	74.4 ef	74.8 fgh	68.1 g	67.9 fgh
	140 mM NaCl	61.2 g	58.3 k	55.6 h	53.1 k
	70 mM NaCl + 6 mM K	75.9 ef	76.3 efg	69.2 fg	68.9 fgh
	70 mM NaCl + 9 mM K	76.8 def	77.5 d-g	70.1 efg	69.1 fgh
	140 mM NaCl + 6 mM K	62.2 g	59.9 k	56.0 h	53.4 k
	140 mM NaCl + 9 mM K	63.4 g	60.5 k	56.6 h	54.2 k

Effect of salinity and potassium application on photosynthetic pigments: Effect of NaCl and potassium application on chl a, chl b and total chlorophyll contents in four maize hybrids are depicted in Table 6. Salinity treatment caused significant decrease in chl a, chl b and total chlorophyll contents as compared to control of all four maize hybrids, except chl b in 10 days at both salinity levels and in 20 days only at mild salt stress (70 mM NaCl) of both salt tolerant maize hybrids (26204, Hysun-33) and in 10 days only at mild salinity stress of both salt sensitive maize hybrids (33H25, 8441). Potassium application improved chl a, chl b and total chlorophyll contents in all four maize hybrids but statically its effect was not significant ($p>0.05$?).

Effect of salinity and potassium application on antioxidant enzymes activity: The activity of SOD was significantly increased in salt tolerant maize hybrids (26204, Hysun-33) but no significant improvement was observed in salt sensitive maize hybrids (33H25, 8441) at 70 mM NaCl (Table 7). At high salinity level, SOD activity decrease in all four maize hybrids as compared to control. POD and CAT activities were markedly improved at mild salinity stress but significantly decreased at high salinity stress level as compared to control in all four maize hybrids. At mild salinity stress, improvement in CAT and POD activities was high but reduction at high salinity level was less in salt tolerant maize hybrids as compared to salt sensitive maize hybrids. Addition of K significantly improved CAT activity at both salinity and potassium levels in salt tolerant maize hybrids. Marked increase in SOD and POD activities were observed in salt tolerant maize hybrids at mild salinity level with high potassium level (9 mM K). No significant effect of K on SOD, POD and CAT activities were observed in salt sensitive maize hybrids.

Table 4. Effect of salt treatment and potassium application on K^+, Na^+ (mol m^{-3}) and K^+/Na^+ ratio.

		K^+ concentration (mol m^{-3})		Na^+ concentration (mol m^{-3})		K^+/Na^+ ratio	
Hybrids	**Treatments**	**10 days**	**20 days**	**10 days**	**20 days**	**10 days**	**20 days**
26204	Control	167.8 a	171.4 a	48.0 n	50.3 k	3.50 a	3.42 a
	70 mM NaCl	136.1 de	135.8 cd	78.9 ij	84.6 g	1.73 g	1.60 e
	140 mM NaCl	99.4 hij	94.6 ef	104.8 def	113.7 e	0.95 ij	0.82 fg
	70 mM NaCl + 6 mM K	149.1 bcd	144.8 bc	68.6 jk	72.8 hi	2.17 ef	2.00 d
	70 mM NaCl + 9 mM K	153.5 abc	152.5 b	62.6 klm	66.6 ij	2.45 d	2.32 c
	140 mM NaCl + 6 mM K	108.1 ghi	104.1 ef	94.8 fg	103.5 ef	1.14 hi	1.01 fg
	140 mM NaCl + 9 mM K	114.8 fgh	109.5 e	91.4 gh	99.1 f	1.25 h	1.10 f
Hysun-33	Control	166.5 a	171.0 a	51.9 mn	50.3 k	3.22 b	3.41 a
	70 mM NaCl	128.8 ef	128.3 d	82.0 hi	81.0 gh	1.57 g	1.58 e
	140 mM NaCl	95.7 ijk	90.5 f	112.3 cd	112.0 e	0.85 ij	0.81 fg
	70 mM NaCl + 6 mM K	142.3 cde	138.1 cd	72.4 ijk	71.6 hi	1.98 f	1.97 d
	70 mM NaCl + 9 mM K	146.2 bcd	146.3 bc	64.0 kl	65.6 ij	2.30 de	2.29 c
	140 mM NaCl + 6 mM K	104.0 ghi	97.9 ef	105.9 def	103.7 ef	0.98 hij	0.94 fg
	140 mM NaCl + 9 mM K	108.4 ghi	102.4 ef	98.0 efg	99.2 f	1.10 hij	1.03 fg
33H25	Control	160.6 ab	157.2 b	55.0 lmn	57.5 jk	2.92 c	2.73 b
	70 mM NaCl	105.4 ghi	100.6 ef	123.4 c	140.8 c	0.85 ij	0.71 ghi
	140 mM NaCl	75.7 lmn	70.2 gh	171.9 a	180.6 a	0.44 k	0.38 j
	70 mM NaCl + 6 mM K	113.0 gh	103.8 ef	110.0 d	134.6 cd	1.02 hij	0.77 g
	70 mM NaCl + 9 mM K	116.7 fg	107.5 e	107.8 de	130.6 cd	1.08 hij	0.82 fg
	140 mM NaCl + 6 mM K	80.7 klm	73.2 g	161.2 ab	172.7 ab	0.50 k	0.42 ij
	140 mM NaCl + 9 mM K	84.5jkl	74.0 g	158.1 b	168.9 b	0.53 k	0.44 hij
8441	Control	158.2 abc	156.6 b	53.1 lmn	55.6 jk	3.00 bc	2.85 b
	70 mM NaCl	102.8 ghi	97.3 ef	123.6 c	132.3 cd	0.83 j	0.73 gh
	140 mM NaCl	64.3 n	57.1 h	165.0 ab	177.3 ab	0.38 k	0.32 j
	70 mM NaCl + 6 mM K	106.9 ghi	100.6 ef	115.9 cd	128.6 d	0.92 ij	0.78 fg
	70 mM NaCl + 9 mM K	109.1 ghi	102.9 ef	111.2 d	124.7 d	0.98 hij	0.82 fg
	140 mM NaCl + 6 mM K	66.1 mn	58.0 h	157.9 b	173.0 ab	0.41 k	0.33 j
	140 mM NaCl + 9 mM K	67.9 mn	59.5 h	156.2 b	170.5 ab	0.43 k	0.34 j

Discussion

Crop production by artificial irrigation with saline water in many arid and semiarid regions of the world is causing problem of salinity. Screening of germplasm of various crops for salinity tolerance, transfer of genes for salt tolerance into adapted cultivars, and adequate regulation of mineral nutrients are needed to supplement the chemical and engineering approaches to sustain crop productivity of salt affected soils (Akhtar *et al*., 2001; Mahar *et al*., 2003).

The present study showed that salinity markedly reduced plant growth and plant biomass, confirming many previous findings that salinity reduced plant height (Agong *et al*., 2004; Hajer *et al*., 2006; Abbasi *et al*., 2012) and leaf area (Mulholland *et al*., 2002; Agong *et al*., 2004), fresh weight (Hajer *et al*., 2006; Abbasi *et al*., 2012) as well as dry weight (Yurtseven *et al*., 2003; Abbasi *et al*., 2012; Akca & Samsunlu, 2012). Reduction in shoot fresh and dry weight of four maize hybrids in the presence of NaCl was attributed to ion toxicity as excess Na^+ resulted in nutritional and metabolic imbalances. Zhu (2002) reported that higher accumulation of Na^+ damaged plant metabolism and reduced plant growth. The four maize hybrids under study responded directly to salt stress depending upon their capabilities to selectively absorb K^+ over Na^+. Better growth of salt-tolerant genotypes under salt stress was related to their higher accumulation of K^+ than salt-sensitive genotypes, which is also evident by earlier studies in barley (Chen *et al*., 2005, 2007; Abbasi *et al*., 2012). In another study, Munns & James (2003) confirmed that genotype with lowest Na^+ concentration produced greatest biomass. Application of K significantly reduced the toxic effects of NaCl and improved plant growth in maize hybrids. This was certified to antagonistic effect of K^+ with Na^+ (Lynch & Lauchli, 1984). Similarly, enhancement in growth and dry matter yield was reported in rice by the addition of K in saline soil (Bohra & Doerffing, 1993).

Table 5. Effect of salt treatment and potassium application on photosynthetic rate (A) (µmol CO_2 m^{-2} s^{-1}), transpiration rate (E) (mmol H_2O m^{-2} s^{-1}), stomatal conductance (g_s) (mmol m^{-2} s^{-1}), internal CO_2 concentration (C_i) (µmol mol^{-1}).

Hybrids	Treatments	Photosynthetic rate (A)		Transpiration rate (E)		Stomatal conductance (g_s)		Internal CO_2 concentration (C_i)	
		10 days	20 days	10 days	20 days	10 days	20 days	10 days	20 days
	Control	16.4 a	23.0 a	2.82 a	4.02 a	251.6 a	320.8 a	200.5 a	245.4 a
	70 mM NaCl	13.0 b-g	17.2 c-f	2.12 b-f	3.0 c-f	217.9 d	268.5 ef	160.9 ef	195.6 f
	140 mM NaCl	10.0 e-h	13.0 fgh	1.57 e-i	2.07 hij	166.5 ij	201.1 i	125.3 kl	150.6 jk
26204	70 mM NaCl + 6 mM K	14.0 a-e	18.8 a-d	2.30 abc	3.27 bcd	238.2 b	294.1 cd	177.4 d	214.7 de
	70 mM NaCl + 9 mM K	15.3 ab	20.2 abc	2.55 abc	3.52 abc	253.5 a	313.0 ab	189.6 bc	228.9 bc
	140 mM NaCl + 6 mM K	10.7 f-i	13.7 e-h	1.70 d-h	2.25 hi	182.1 gh	217.4 h	136.9 ij	159.6 ij
	140 mM NaCl + 9 mM K	12.0 e-h	14.7 d-h	1.98 c-g	2.52 f-i	195.6 ef	236.2 g	144.5 hi	168.3 hi
	Control	15.6 ab	21.9 ab	2.67 ab	3.70 ab	248.7 a	318.9 a	195.2 ab	237.2 ab
	70 mM NaCl	12.2 c-h	16.3 c-g	1.99 c-g	2.67 e-h	205.6 e	255.7 f	155.6 fg	183.3 g
	140 mM NaCl	9.18 h-k	11.8 hij	1.39 g-k	1.92 ijk	144.6 k	166.7 k	110.4 mn	127.3 mn
Hysun-33	70 mM NaCl + 6 mM K	13.1 b-f	17.7 b-e	2.16 b-e	2.91 d-g	225.9 cd	276.0 e	165.5 e	196.9 f
	70 mM NaCl + 9 mM K	14.4 abc	19.3 abc	2.40 abc	3.17 b-e	237.9 b	283.3 de	177.3 d	209.0 e
	140 mM NaCl + 6 mM K	9.90 g-j	12.7 ghi	1.50 ghi	2.05 hij	158.0 j	182.5 j	117.0 lm	136.0 lm
	140 mM NaCl + 9 mM K	10.9 e-h	13.2 fgh	1.72 d-h	2.36 ghi	163.0 j	187.0 ij	127.3 k	144.1 kl
	Control	14.2 a-d	20.0 abc	2.25 bcd	3.52 abc	231.0 bc	300.7 bc	190.2 bc	231.0 bc
	70 mM NaCl	10.0 g-j	11.2 hij	1.55 f-i	1.93 ijk	180.7 gh	220.7 gh	139.9 hij	160.9 ij
	140 mM NaCl	6.75 kl	7.50 jk	1.07 ijk	1.38 kl	115.7 mn	140.9 lm	98.3 op	114.9 o
33H25	70 mM NaCl + 6 mM K	10.6 f-i	11.7 hij	1.65 e-i	2.08 hij	185.6 fgh	228.1 gh	146.7 gh	169.3 hi
	70 mM NaCl + 9 mM K	11.3 d-h	12.2 ghi	1.69 d-h	2.14 hi	194.0 f	231.6 gh	154.1 fg	177.3 gh
	140 mM NaCl + 6 mM K	7.17 jkl	7.80 jk	1.15 h-k	1.49 jkl	122.3 lm	145.8 l	103.5 no	120.3 no
	140 mM NaCl + 9 mM K	7.71 i-l	8.36 ijk	1.16 h-k	1.48 jkl	128.1 l	150.4 l	110.0 mn	127.7 mn
	Control	13.4 a-f	18.9 a-d	1.99 c-g	3.35 bcd	225.6 cd	293.2 cd	183.7 cd	223.3 cd
	70 mM NaCl	9.18 h-k	11.3 hij	1.34 h-k	1.98 ijk	175.0 hi	217.9 h	133.0 jk	153.0 jk
	140 mM NaCl	5.02 l	5.82 k	0.86 k	1.28 l	110.2 n	123.2 n	91.3 p	97.7 p
8441	70 mM NaCl + 6 mM K	9.47 h-k	11.7 hij	1.40 g-k	2.07 hij	180.1 gh	225.5 gh	137.3 hij	157.3 ij
	70 mM NaCl + 9 mM K	9.71 h-k	11.9 hij	1.46 g-j	2.12 hi	188.4 fg	231.4 gh	143.4 hi	163.5 ij
	140 mM NaCl + 6 mM K	5.19 l	6.36 k	0.90 jk	1.38 kl	116.9 mn	127.0 mn	94.5 op	100.0 p
	140 mM NaCl + 9 mM K	5.39 l	6.46 k	0.90 jk	1.42 kl	117.0 mn	130.0 n	95.6 op	101.5 p

Table 6. Effect of salt treatment and potassium application on chlorophyll a, chlorophyll b and total chlorophyll contents (mg g^{-1} F.W).

		chl a (mg g^{-1} f. wt.)		chl b (mg g^{-1} f. wt.)		chl a+b (mg g^{-1} f. wt.)	
Hybrids	**Treatments**	**10 days**	**20 days**	**10 days**	**20 days**	**10 days**	**20 days**
26204	Control	3.50 a	4.08 ab	1.87 a	2.38 a	5.37 a	6.47 ab
	70 mM NaCl	2.40 d-g	2.73 d-g	1.50 a-d	1.89 a-e	3.90 c-f	4.62 de
	140 mM NaCl	1.69 h-l	1.93 ghi	1.09 a-d	1.30 d-g	2.79 g-j	3.23 f
	70 mM NaCl + 6 mM K	2.63 cde	2.97 def	1.65 ab	2.05 abc	4.28 bcd	5.03 d
	70 mM NaCl + 9 mM K	2.80 bcd	3.05 cde	1.75 ab	2.15 ab	4.56 abc	5.20 cd
	140 mM NaCl + 6 mM K	1.85 g-j	2.07 fg	1.17 a-d	1.39 c-g	3.03 fgh	3.46 f
	140 mM NaCl + 9 mM K	1.95 f-j	2.21 efg	1.28 a-d	1.49 b-f	3.23 fgh	3.71 ef
Hysun-33	Control	3.16 abc	4.80 a	1.85 ab	2.28 a	5.01 ab	7.08 a
	70 mM NaCl	2.22 d-h	3.35 bcd	1.45 a-d	1.72 a-e	3.67 d-g	5.08 d
	140 mM NaCl	1.49 j-n	2.19 efg	1.06 bcd	1.12 efg	2.56 h-l	3.32 f
	70 mM NaCl + 6 mM K	2.37 d-g	3.52 bcd	1.56 abc	1.82 a-e	3.93 c-f	5.34 bcd
	70 mM NaCl + 9 mM K	2.50 def	3.57 bcd	1.67 ab	1.93 a-d	4.17 b-e	5.51 bcd
	140 mM NaCl + 6 mM K	1.59 h-m	2.33 efg	1.16 a-d	1.20 d-g	2.75 g-k	3.53 ef
	140 mM NaCl + 9 mM K	1.70 h-k	2.37 efg	1.22 a-d	1.28 d-g	2.92 ghi	3.65 ef
33H25	Control	3.31 ab	3.95 abc	1.82 ab	2.34 a	5.13 a	6.29 abc
	70 mM NaCl	2.05 e-j	1.96 gh	1.24 a-d	1.21 d-g	3.29 e-h	3.18 f
	140 mM NaCl	1.10 lmn	1.00 j	0.80 cd	0.73 fg	1.90 kl	1.73 g
	70 mM NaCl + 6 mM K	2.13 e-i	2.01 gh	1.31 a-d	1.27 d-g	3.44 d-h	3.29 f
	70 mM NaCl + 9 mM K	2.22 d-h	2.13 efg	1.33 a-d	1.29 d-g	3.55 d-g	3.43 f
	140 mM NaCl + 6 mM K	1.16 k-n	1.05 ij	0.85 cd	0.76 fg	2.01 jkl	1.81 g
	140 mM NaCl + 9 mM K	1.22 k-n	1.11 hij	0.86 cd	0.80 fg	2.09 i-l	1.91 g
8441	Control	3.38 a	4.02 ab	1.82 ab	2.36 a	5.20 a	6.38 ab
	70 mM NaCl	2.01 e-j	1.92 ghi	1.26 a-d	1.22 d-g	3.27 e-h	3.14 f
	140 mM NaCl	0.94 n	0.91 j	0.76 d	0.69 g	1.71 l	1.60 g
	70 mM NaCl + 6 mM K	2.06 e-j	1.98 gh	1.30 a-d	1.27 d-g	3.37 d-h	3.26 f
	70 mM NaCl + 9 mM K	2.17 e-i	2.07 fg	1.34 a-d	1.30 d-g	3.52 d-g	3.38 f
	140 mM NaCl + 6 mM K	0.98 n	1.00 j	0.80 cd	0.72 fg	1.78 l	1.72 g
	140 mM NaCl + 9 mM K	1.06 mn	0.98 j	0.82 cd	0.74 fg	1.89 kl	1.72 g

Tolerant maize hybrids showed higher RWC contents at all salinity levels and at both intervals as compared to sensitive ones. The decrease in RWC contents under salinity stress in all maize hybrids is in confirmation of already reported results (Sairam *et al*., 2002; Gadallah, 1999). Potassium played an important role in maize hybrids water relation under salinity stress and helped the plants to absorb more water to attain turgidity. Subbarao *et al*., (2000) reported that RWC and osmotic potential were significantly reduced at low potassium level in red beat. The results of present study can be related to the findings of some previous studies in which it was concluded that increase in leaf K due to supplemental K increased the leaf turgor and RWC under water stressed conditions, e.g., in maize (Premachandra *et al*., 1990) and *Vigna radiata* (Nandwal *et al*., 1998). Higher salinity level resulted in marked production of ROS which significantly decreased MSI in all four maize hybrids at both intervals. But, ROS levels were lower and MSI higher relatively in salt tolerant maize hybrids than salt sensitive maize hybrids. MSI have been suggested as indices of salt injury/tolerance in *Amaranthus* (Bhattacharjee & Mukherjee, 1996). In the present study, salinity significantly decreased MSI, but application of potassium had no significant effect in improving MSI. These results are not in conformity with Kaya *et al*., (2001) in which it was concluded that potassium application reduced the ion leakage in spinach grown under saline conditions.

Table 7. Effect of salt treatment and potassium application on SOD, POD and CAT (unit mg^{-1} of protein).

		SOD unit mg^{-1} of protein		POD unit mg^{-1} of protein		CAT unit mg^{-1} of protein	
Hybrids	**Treatments**	**10 days**	**20 days**	**10 days**	**20 days**	**10 days**	**20 days**
26204	Control	29.8 cd	32.6 cd	59.0 de	62.2 cde	86.5 cd	91.3 cde
	70 mM NaCl	38.1 ab	42.1 ab	64.2 bcd	71.0 abc	93.8 bc	96.9 c
	140 mM NaCl	26.0 de	26.7 d-i	46.8 f-i	50.2 f-j	74.5 ef	77.1 f-j
	70 mM NaCl + 6 mM K	42.4 a	45.6 ab	72.2 ab	77.8 a	104.2 a	110.9 ab
	70 mM NaCl + 9 mM K	44.1 a	47.4 a	76.0 a	79.4 a	108.5 a	118.2 a
	140 mM NaCl + 6 mM K	28.1 d	29.5 d-g	54.3 d-g	57.5 d-g	80.2 de	83.8 d-h
	140 mM NaCl + 9 mM K	29.5 cd	31.2 def	55.2 def	58.7 def	85.1 cd	87.0 def
Hysun-33	Control	28.0 d	32.0 cde	57.3 de	59.3 def	87.2 cd	88.7 cde
	70 mM NaCl	35.6 bc	38.7 bc	60.2 cde	66.6 bcd	92.1 bc	92.6 cd
	140 mM NaCl	23.4 d-h	24.8 e-j	42.5 hij	45.8 h-k	72.8 efg	72.8 ijk
	70 mM NaCl + 6 mM K	37.5 ab	41.2 ab	68.8 abc	73.6 ab	99.7 ab	106.6 b
	70 mM NaCl + 9 mM K	40.7 ab	43.7 ab	74.5 a	77.6 a	104.1 a	115.7 ab
	140 mM NaCl + 6 mM K	25.4 def	27.4 d-h	50.3 e-h	53.0 e-i	76.0 ef	81.4 e-i
	140 mM NaCl + 9 mM K	26.2 de	29.6 d-g	51.0 e-h	54.4 e-h	80.7 de	85.0 d-g
33H25	Control	20.8 e-i	24.1 f-k	37.9 i-l	39.9 j-n	61.2 ij	63.0 lm
	70 mM NaCl	26.6 de	29.3 d-g	41.2 hij	44.3 h-l	65.1 g-j	69.1 j-m
	140 mM NaCl	16.4 i	18.6 jk	29.9 kl	31.2 n	46.2 l	46.6 n
	70 mM NaCl + 6 mM K	28.0 d	31.1 def	44.3 ghi	46.7 g-k	70.5 fgh	74.9 h-k
	70 mM NaCl + 9 mM K	29.1 d	32.4 cde	45.1 f-i	47.5 g-j	72.6 efg	77.5 f-j
	140 mM NaCl + 6 mM K	18.3 ghi	20.8 h-k	32.1 jkl	33.7 l-n	49.7 kl	49.3 n
	140 mM NaCl + 9 mM K	18.5 ghi	21.5 h-k	33.3 jkl	35.1 k-n	50.2 kl	50.0 n
8441	Control	18.8 f-i	23.3 g-k	37.4 i-l	40.4 j-n	56.9 jk	61.1 m
	70 mM NaCl	24.0 d-g	27.5 d-h	39.5 ijk	42.7 i-m	63.3 hij	67.0 klm
	140 mM NaCl	15.8 i	16.9 k	28.4 l	29.8 n	44.5 l	44.5 n
	70 mM NaCl + 6 mM K	25.2 d-g	29.6 d-g	41.6 hij	44.3 h-l	68.6 f-i	72.0 i-l
	70 mM NaCl + 9 mM K	25.9 de	29.9 d-g	41.9 hij	45.5 h-k	70.8 fgh	75.1 g-k
	140 mM NaCl + 6 mM K	16.6 hi	18.4 jk	29.7 kl	31.1 n	48.1 kl	47.0 n
	140 mM NaCl + 9 mM K	18.3 ghi	19.5 ijk	30.0 kl	33.0 lmn	50.0 kl	48.2 n

High sodium accumulation under salinity stress in maize hybrids (33H25 and 8441) could be one of the reasons of its sensitivity to salt stress, while more potassium content in the case of maize hybrids (26204 and Hysun-33) must have contributed towards its discriminating tolerance to salinity stress. The higher K^+ uptake of salt-tolerant genotypes may be related to their selectivity of K^+ over Na^+. Carden *et al*., (2003) also demonstrated that salt-tolerant barley plants accumulated higher K^+ due to selective absorption of K^+ and by a preferential loading of K^+ rather than Na^+ into the xylem. However, salt-tolerant maize hybrids exhibited strong affinity for K^+ over Na^+ by maintaining higher K^+/Na^+ ratio as compared to salt-sensitive maize hybrids. Numerous studies had shown that addition of K mitigated the undesirable effects of Na^+ and improved K^+ uptake of cucumber and pepper (Kaya *et al*., 2001), olive (Chartzoulakis *et al*., 2006) and juvenile mulloway (Doroudi *et al*., 2006) and improved K^+/Na^+ ratio under salt stress (Marschner 1995; Carden *et al*., 2003). K^+/Na^+ ratio was higher in salt tolerant maize hybrids. It was suggested that the plant's tolerance response is characterized by distinctly higher K^+/Na^+ ratio, which may be used as indicator of tolerance or sensitivity in crop varieties (Joshi *et al*., 1979; Abbasi *et al*., 2012; Akram *et al*., 2012; Shah & Bano, 2012).

It is generally known as that lower photosynthetic rate leads to decreased plant growth in many crop plants. The decrease in plant photosynthesis under salt stress occurs due to closing of stomata that result in reduced in leaf transpiration rate and leaf internal CO_2 concentration. Results of present study revealed that addition of salt in growth medium significantly decreased photosynthetic rate (*A*), transpiration rate (*E*) stomatal conductance (g_s), and internal CO_2 concentration (C_i) in all four maize hybrids. However, addition of potassium enhanced these photosynthetic characteristics in salt tolerant maize hybrids especially at 9 mM potassium level. It is well known that photosynthetic ability in crop plants is very important for dry matter production. Current experiment depicted that diverse concentrations of potassium have significant impact on stomatal conductance and internal CO_2 concentration predominantly in salt-tolerant maize hybrids. Opening and closing of stomata have strong impact on water balance and photosynthesis process of plants grow under salt stress condition (Athar & Ashraf, 2005; Dubey, 2005). This will be due to major responsibility of potassium in the vacuole as an osmoticum for sustaining high moisture contents in plants tissues under salt stress (Marschner, 1995). Earlier results clearly depicted that opening and closing of stomata depends on potassium distribution in guard cell apoplast and epidermal cell (Shabala *et al*., 2002). During experiment on cotton, Bednarz *et al*., (1998) concluded that under gentle deficiency of potassium, disturbance in stomata regulation are the main factor that influenced photosynthesis process in plants while high level of potassium deficiency results in distortion of metabolic activities in plant body. Basile *et al*., (2003) reported that low level of potassium in soil result in low leaf potassium concentration.

Superoxide radicals are produced during photosynthesis process due to transfer of electron to oxygen which results in H_2O_2 production (Mittler, 2002). The level of H_2O_2 inside the cell is maintained by different type of antioxidant enzymes like POD (Foyer & Noctor, 2003) and CAT (Willekens *et al*., 1995). On the other hand, the concentration of metabolites and antioxidant enzymes can increase or decreased during different environmental conditions (Hernandez *et al*., 1995; Yu & Rengel, 1999). Results of present study showed that salinity stress enhanced the concentration of SOD, CAT, and POD in all four maize hybrids at mild salinity stress but activities of all these enzymes declined at high salinity stress in all four maize hybrids, indicating that genes encoding SOD, CAT, and POD antioxidative system were up-regulated so as to scavenge ROS in the maize hybrids. However, addition of potassium enhanced the CAT activities in salt tolerant maize hybrids under both salinity levels. Results of current experiment imply that productions of reactive oxygen species have take place during imposition of salinity stress and harmful effects of these ROS were mitigated by increasing CAT activity. These finding are also parallel to the argument that antioxidant activities in plants under salinity stress are improved by potassium application (Zheng *et al*., 2008; Soleimanzadeh *et al*., 2010). This vision is auxiliary supported by the urging that detoxification of reactive oxygen species in photosynthesis process is mediated by CAT enzymes (Noctor *et al*., 2002; Foyer & Noctor, 2003).

Conclusion

Reduction in growth of maize hybrids under salt stress was due to toxicity of Na^+ and its imbalances with K^+. The salt-tolerant maize hybrids exhibited a strong affinity for K^+ over Na^+ and showed relatively less reduction in plant height, leaf area, shoot length; shoot fresh and dry weight and K^+/Na^+ ratios. It is obvious that salt sensitive genotypes due to decreased plant growth, low K^+/Na^+ ratios, poor antioxidant enzyme and photosynthetic activities, was poorly- prepared to face salt stress as it fails to respond in a way similar to salt-tolerant maize hybrids, resulting in lower RWC, increased ROS contents and consequently lower MSI and chlorophyll content under salt stress. Addition of K increased CAT which had a protective effect on growth and photosynthetic capacity of maize hybrids against salt induced oxidative stress. Application of potassium enhanced the stomatal conductance thereby favoring higher assimilation of CO_2 but this effect was cultivar specific. Overall, addition of potassium created marked difference in the activity of CAT, stomatal conductance and K^+/Na^+ ratios, leaf area, shoot length and shoot fresh weight in tolerant maize hybrids as compared to susceptible maize hybrids suggesting that maize hybrids from different pedigrees differed in some specific mechanisms of salinity tolerance.

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