COMPETITIVE SEEDLING GROWTH AND K$^+$/Na$^+$ RATIO IN DIFFERENT MAIZE (*ZEA MAYS* L.) HYBRIDS UNDER SALINITY STRESS

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Abstract

Genetic variation for salt tolerance was assessed in maize (*Zea mays* L.) hybrids using solution-culture technique. The study was conducted in gravel culture exposed to three salinity levels (0, 50 and 100 m*M* NaCl). Seven days old maize seedlings were transplanted in gravel containing ½ strength Hoagland nutrient solutions and salinized with common salt (NaCl). The experiment was conducted in the rain protected wire house of Plant Stress Physiology Laboratory of NIAB Faisalabad, Pakistan. Ten maize hybrids were used for mass screening against three salinity levels. Substantial variations were observed in the root, shoot length and biomass of different cultivars at different salinity levels. The leaf sample analysed for inorganic osmolytes (sodium and potassium) showed that hybrid Pioneer 32B33 and Pioneer 30Y87 have high K$^+$/Na$^+$ ratio. From this study it was concluded that hybrids with high biomass, root shoot fresh weight and K$^+$/Na$^+$ ratio are salt tolerant.

Introduction

Salinity is ever-present threat to crop productivity, especially in countries where irrigation is essential for aid to agriculture. Most of the water of this planet is salty, containing 30 g of Sodium chloride per liter, which is continuously affecting the land on which crops are or might be grown (Flower, 2004). Currently, there is about 275 million hectares of irrigated land of which about 20% is salt affected (Ghassemi *et al.*, 1995). In addition, the greater pressure on arable land to produce more food for ever growing population, especially in the developing and under-developing world, is on marginal lands now being brought in to cultivation, but previously not cropped because of their high degree of natural salinity (Flowers & Yeo, 1995).

Salinity has three potential effects on plants: lowering of water potential, specific ion toxicity (sodium and chloride) and interference with the uptake of essential nutrients. The latter might not be expected to have an immediate effect as the plants have reserve of nutrients that can mobilize (Flowers & Flowers, 2005). The response of plant to growth reduction due to salinity is two phase process (Munns, 1993). The first phase is a lowering of external water potential due to salt present outside the root. This effect is same for cultivars differing in salt tolerance. The second phase is the senescence of leaves due to the accumulation of ion in the older leaves and there is a true difference in salt tolerance appearance. Sensitive cultivars accumulate ions more quickly than tolerant cultivars and this ion accumulation leads to leaf death and progressively death of plant (Munns, 2002).

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The adaptation required to survive in saline conditions are the same in all the plants. However, adaptations are at their extreme in halophytes, but can be found to different degrees in glycophytes also (Flowers & Flowers, 2005). Variation in salt tolerance of glycophytes occurs between and within species and has been quantified for many crops (Mass & Hoffman, 1976; Francois & Mass, 1994; Flowers & Yeo, 1981). Quick screening procedure has been adopted by many researchers for different crops in the early growth phase (Ashraf *et al*., 2002; Munns *et al*., 2002; Eker *et al*., 2006; Khan, *et al*., 2006).

Maize (*Zea mays* L.) is the third most important cereal crop after wheat and rice and is grown all over the world in a wide range of climatic condition. Being highly cross pollinated, maize has become highly polymorphic through the course of natural and domesticated evolution and thus contains enormous variability (Paterniani, 1990) in which salinity tolerance may exist.

Maize (*Zea mays* L.) is moderately sensitive to salinity and considered as salt sensitive of cereals (Mass & Hofffman, 1977). Despite its position, as one of the leading food crops of the world, few findings have been done to improve salt tolerance in this crop. Because of great sensitivity of this crop, improvement for salt tolerance would be of considerable value. Effective and accelerated improvement through screening would be required in order to assess the potential to produce superior salt tolerant cultivars. With this aim in mind, the present work was carried out to assess the extent of variability in salt tolerance in 10 maize hybrids and to provide an estimate of narrow-sense heritability of this tolerance.

Materials and Methods

The solution culture studies were conducted in the rain protected wire house of Plant Stress Physiology and Biochemistry Laboratory, Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan. Seeds of 10 maize (*Zea mays* L.) hybrids i.e., Pioneer 3062, Pioneer 32B33, Pioneer 30Y87, Pioneer 31R88, Dekalb 919, Dekalb 979, Dekalb 922, Hycorn 984, Hycorn 11 plus and Hycorn 993 were collected from three different seed companies i.e. Pioneer, Monsanto and ICI. Healthy seed of these hybrids were sown in trays containing pre-washed sand. Separate trays were used for the germination of each hybrid. Water was sprinkled daily over these trays to maintain optimum moisture contents for seed germination.

Seven days after sowing uniform sized seedlings were transplanted in gravel containing Hoagland's solution (Hoagland & Arnon, 1950) and salinized with 0 (T_0), 50 (T_1) and 100 (T_2) mM NaCl. The salinity was applied in splits i.e., 50 mM five days after transplantation and 50 mM seven days after transplantation. Experiment was carried out in factorial CRD and each treatment was replicated three times. The culture solution was changed twice a week. The pH of nutrient solution was monitored daily. The EC of treatment solutions was maintained at desired levels by topping up with culture-solution during the entire period of study. Plants were harvested 28 days after transplantation. Harvested plants were washed with tap water once and twice with distilled water and plants were blotted dry using blotting paper and their roots and shoots were separated. Root , shoot length and fresh weight were determined. All the plant samples were dried at 65 $\pm 2^0$C for 2 days in a forced air-driven oven to a constant weight. After drying shoot were ground data on root and shoot dry weight (g plant^{-1}), Na$^+$, K$^+$ and K$^+$/Na$^+$ were recorded. Na$^+$ and K$^+$ concentration (mg g^{-1} dry weight) of shoot was determined from a 0.5 g dried digested sample using a flame photometer (Jenway PFP-7).

Data were subjected to statistical analysis according to standard procedure (Steel *et al*., 1997) using 'MSTAT-C' (Russell & Eisensmith, 1983), and the methods described

by Gomez & Gomez (1984). Completely randomized factorial design (factorial CRD) was employed for analysis of variance (ANOVA).

Results

While comparing the growth performance of these hybrids it was found that there is linear decrease in all the parameters with increasing salinity of the medium. When seedling were exposed to 50 mM NaCl salinity maximum root length (22.23 cm) was attained by hybrid Pioneer 32B33 and minimum was observed (18.00 and 19.33 cm, respectively) in Dekalb 979 followed by Pioneer 3062 at 50 mM (Table 1). In T_2, the hybrid Pioneer 332B33 exhibited the top most value (19.67 cm) while the lowest was recorded in Pioneer 3062. The hybrid means indicated maximum root length (21.86 cm) in hybrid Pioneer 332B33 followed by hybrid Hycorn 993 having a value of 20.53 cm. From statistical analysis, it was evident that root length was significantly restrained by a progressive increase in salinity in all the hybrids. At lower level (i.e. 50 mM) of salt treatment comparatively less reduction in root length was observed. The higher salinity (100 mM) exhibited a significant reduction in seedling growth when compared with control. In T_2, maximum decrease in root length was recorded in hybrid Dekalb 979 showing about 45% decrease while least reduction (17%) was noted in hybrid Pioneer 32B33.

Maximum root fresh weight under T_1 (15.27g) was observed in hybrid Pioneer 32B33 while minimum (9.03, 9.17 and 9.52, respectively) was recorded in hybrids: Dekalb 979, Hycorn11plus and Dekalb 919, respectively. Similarly, in T_2 hybrid Pioneer 32B33 proved to be salt tolerant having a value of 11.93 g followed by hybrid Pioneer 30Y87 (Table 1). From the hybrid means, it is obvious that maximum fresh weight of root (15.14 g) was recorded in hybrid Pioneer 32B33 and minimum (10.88, 10.95 and 11.13 g, respectively) was noted in hybrid Dekalb 979, Hycorn 984 and Dekalb 922, respectively. The fresh weight of roots of all these hybrids decreased significantly as the levels of salinity increased from 50-100 mM NaCl (Table 1). Maximum root fresh weight was observed in control, while, it was minimum at highest salinity level.

Root dry weight of all hybrids showed a decline towards increase in salinity level. Hybrids Pioneer 32B33, Pioneer 30Y87 and Hycorn 993 exhibited maximum root dry weight values i.e., 1.51, 1.39 and 1.36 g, respectively, while minimum (0.82 g) was recorded in Hycorn11plus followed by Dekalb 979 (0.95g) at lower salinity level (Table 1). In T_2, maximum (0.94 g) was recorded in hybrid Pioneer 32B33 while minimum (0.4 g) was observed in hybrid Dekalb 979. Hybrids means indicated that hybrid Pioneer 32B33 out yielded the others by producing 1.60 g dry weight of root followed by hybrid Pioneer 30Y87 and Hycorn 993, respectively. From the data it is evident that hybrid Pioneer 32B33 was salt tolerant showing a decrease of 60% over control at high salinity level (100 mM).

Data regarding the shoot length of maize hybrids (Table 2) at different salinity levels revealed that shoot length of plants is inversely related to increase in salinity. Difference in shoot length at different salinity levels was highly significant. Treatment means indicated that maximum shoot length (79.04 cm) was recorded in T_0 (control) while minimum (44.34 cm) in T_2, thus indicating a decrease with progressive increase in salinity levels. Salinity x hybrid interaction indicated that in T_1, Pioneer 32B33 exhibited the maximum root length followed by hybrid Pioneer 30Y87 while 47.70 cm shoot length was noted in hybrid Dekalb 979. In T_2, hybrid Pioneer 32B33 attains greater shoot length as compared to others and proved more tolerant due to less decrease of value 46% over control.

Table 1. Effect of salinity on length, fresh and dry biomass of root of different maize hybrids at seedling stage.

Maize hybrids	Root length (cm)				Root fresh biomass (g plant⁻¹)				Root dry biomass (g plant⁻¹)			
	Treatments NaCl (mM)			Mean	Treatments NaCl (mM)			Mean	Treatments NaCl (mM)			Mean
	0	50	100		0	50	100		0	50	100	
Hycorn 984	23.17	19.00 (18)	15.00 (35)	19.06 bcd	15.51	10.32 (33)	7.56 (51)	11.13 cd	2.29	1.10 (52)	0.58 (75)	1.32 b
Dekalb 979	24.83	18.00 (28)	13.67 (45)	18.83 cd	16.92	9.03 (47)	6.70 (60)	10.88 cd	2.01	0.95 (53)	0.40 (80)	1.12 c
Dekalb 922	22.03	19.17 (13)	16.00 (27)	19.07 bcd	13.90	10.57 (24)	8.37 (40)	10.95 cd	2.18	1.29 (41)	0.59 (73)	1.35 b
Pioneer 32B33	23.67	22.23 (6)	19.67 (17)	21.86 a	18.23	15.27 (16)	11.93 (35)	15.14 a	2.36	1.51 (36)	0.94 (60)	1.60 a
Pioneer 3062	22.33	19.33 (13)	13.00 (42)	18.22 d	15.28	11.41 (25)	9.07 (41)	11.92 c	2.17	1.00 (54)	0.75 (65)	1.31 b
Pioneer 31R88	23.50	18.46 (21)	15.33 (35)	19.10 bcd	16.43	10.00 (39)	7.67 (53)	11.37 c	2.30	1.02 (55)	0.82 (64)	1.38 b
Pioneer 30Y87	21.83	20.00 (8)	17.67 (19)	19.83 bc	17.32	12.86 (26)	10.05 (42)	13.41 b	2.65	1.39 (48)	0.72 (73)	1.59 a
Hycorn 993	25.00	19.60 (22)	17.00 (32)	20.53 ab	15.35	11.03 (28)	8.70 (43)	11.69 c	2.58	1.36 (47)	0.71 (73)	1.55 a
Hycorn 11 plus	23.33	17.67 (24)	13.50 (42)	18.17 d	12.23	9.17 (25)	7.80 (36)	9.74 e	1.90	0.82 (57)	0.60 (69)	1.10 c
Dekalb 919	23.33	18.67 (20)	15.00 (36)	19.00 bcd	13.46	9.52 (29)	7.59 (44)	10.19 de	2.12	1.13 (47)	0.59 (72)	1.28 b
Mean	23.30 a	19.21 b	15.58 c		15.46 a	10.92 b	8.55 c		2.26 a	1.16 b	0.67 c	
LSD for hybrids (p≤ 0.05) = 1.367					LSD for hybrids (p≤ 0.05) = 1.01				LSD for hybrids (p≤ 0.05) = 0.116			

Means sharing same letters do not differ significantly at the 5% level of significance.
Values in parenthesis indicate % reduction over control.

Table 2. Effect of salinity on length, fresh and dry biomass of shoot of different maize hybrids at seedling stage.

Maize hybrids	Shoot length (cm)				Shoot fresh biomass (g plant⁻¹)				Shoot dry biomass (g plant⁻¹)			
	Treatments NaCl (m*M*)			Mean	Treatments NaCl (m*M*)			Mean	Treatments NaCl (m*M*)			Mean
	0	50	100		0	50	100		0	50	100	
Hycorn 984	79.53	56.20 (29)	42.00 (47)	59.24 def	32.73	28.71 (12)	13.67 (58)	25.04 d	3.45	2.99 (13)	1.37 (60)	2.60 d
Dekalb 979	72.67	47.70 (34)	35.33 (51)	51.90 g	30.73	22.07 (28)	11.16 (64)	21.32 e	3.23	2.30 (29)	1.12 (65)	2.22 e
Dekalb 922	82.03	58.13 (29)	44.30 (46)	61.49 bcd	30.90	27.49 (11)	15.75 (49)	24.72 d	3.25	2.83 (13)	1.57 (52)	2.55 d
Pioneer 32B33	84.10	67.23 (20)	59.93 (29)	70.42 a	37.26	34.57 (7)	23.56 (37)	31.80 a	3.92	3.61 (18)	2.36 (40)	3.30 a
Pioneer 3062	82.83	60.90 (26)	43.07 (48)	62.27 bc	32.99	29.28 (11)	14.18 (57)	25.49 d	3.48	3.06 (12)	1.42 (59)	2.65 d
Pioneer 31R88	78.73	57.37 (27)	43.53 (45)	59.88 cdef	34.51	30.84 (11)	17.27 (50)	27.54 bc	3.60	2.84 (21)	1.73 (52)	2.72 cd
Pioneer 30Y87	81.73	62.93 (23)	47.93 (41)	64.20 b	35.87	31.54 (12)	18.61 (48)	28.68 b	3.78	3.33 (12)	1.86 (51)	2.99 b
Hycorn 993	77.57	59.50 (23)	45.07 (42)	60.71 cde	34.56	30.94 (10)	17.37 (50)	27.62 bc	3.64	3.20 (12)	1.74 (52)	2.86 bc
Hycorn 11 plus	76.17	58.37 (23)	39.57 (48)	58.03 ef	32.47	29.08 (10)	14.26 (56)	25.27 d	3.42	2.96 (13)	1.43 (58)	2.60 d
Dekalb 919	75.00	53.70 (28)	42.70 (43)	57.13 f	32.40	29.06 (10)	15.98 (51)	25.81 cd	3.45	2.99 (13)	1.60 (54)	2.68 d
Mean	79.04 a	58.20 b	44.34 c		23.44 a	29.36 b	16.18 c		3.52 a	3.01 b	1.62 c	
LSD for hybrids (p≤ 0.05) = 2.64					LSD for hybrids (p≤ 0.05) = 1.854				LSD for hybrids (p≤ 0.05) = 0.158			

Means sharing same letters do not differ significantly at the 5% level of significance.
Values in parenthesis indicate % reduction over control.

Table 3. Effect of salinity on sodium and potassium concentration of shoot dry weight of different maize hybrids at seedling stage.

Maize hybrids	Na^+ (mg g^{-1} shoot dry weight)				K^+ (mg g^{-1} shoot dry weight)			
	Treatments NaCl (mM)			Mean	Treatments NaCl (mM)			Mean
	0	50	100		0	50	100	
Hycorn 984	3.38	14.17 (320)	20.58 (510)	12.71 b	17.17	12.50 (-27)	10.50 (-39)	13.39 cd
Dekalb 979	3.92	16.67 (326)	27.08 (591)	15.89 a	17.25	11.67 (-32)	8.30 (-52)	12.41 d
Dekalb 922	3.33	14.58 (338)	21.67 (550)	13.19 b	17.40	13.00 (-25)	10.00 (-43)	13.47 cd
Pioneer 32B33	2.92	10.08 (246)	16.83 (477)	9.94 d	18.67	17.67 (-5)	13.22 (-29)	16.52 a
Pioneer 3062	3.75	12.50 (233)	24.17 (544)	13.47 b	16.83	14.50 (-14)	8.50 (-50)	13.28 cd
Pioneer 31R88	3.58	12.92 (260)	22.92 (540)	13.14 b	16.33	13.00 (-20)	9.67 (-41)	13.00 cd
Pioneer 30Y87	2.92	11.83 (306)	18.08 (520)	10.95 c	18.57	16.67 (-10)	11.17 (-40)	15.47 b
Hycorn 993	3.08	11.58 (276)	19.92 (546)	11.53 c	16.67	14.67 (-12)	10.67 (-36)	14.00 c
Hycorn 11 plus	3.75	13.50 (260)	23.75 (533)	13.67 b	15.50	13.67 (-12)	9.17 (-41)	12.78 d
Dekalb 919	2.92	10.83 (271)	20.08 (589)	11.28 c	17.00	14.67 (-14)	10.67 (-37)	14.11 c
Mean	3.36 c	12.87 b	21.51 a		17.14 a	14.20 b	10.19 c	
LSD for hybrids (p≤ 0.05) = 0.486					LSD for hybrids (p≤ 0.05) = 0.557			

Means sharing same letters do not differ significantly at the 5% level of significance

Values in parenthesis indicate % reduction (-) or increase (+) over control

At lower salinity level Pioneer 32B33 showed better performance among all and possessed maximum shoot fresh weight and dry weight (34.57, 3.61g respectively) under T_1 was attained by hybrid Pioneer 32B33 (Table 2). At higher salinity levels (100 mM) minimum shoot fresh weight (11.16 g) was observed in hybrid Dekalb 979 and a maximum (23.56 g) in hybrid Pioneer 32B33. All others were in between these two peaks. The average shoot dry weights were 3.52, 3.01 and 1.62 g in 0, 50 and 100mM respectively. These differences were statistically highly significant.

The data for Sodium contents is presented in Table 3. There was an increase in Sodium uptake with increasing salinity levels. The better performing hybrid had comparatively less Sodium uptake than the sensitive ones. The hybrids means revealed that highest Na^+ uptake was recorded in hybrid Dekalb 979 and lowest concentration of Na^+ was found in hybrid Pioneer 32B33 which was closely followed by Pioneer 30Y87. Average Na^+ concentration was 3.36, 12.87 and 21.51 mg g^{-1} shoot dry weight in control, 50 and 100 mM respectively.

The trend of K^+ accumulation was reverse to that of Sodium, it decreases with the increase in the salinity (Table 3). Minimum reduction (29%) in K^+ uptake at highest level of salinity was noted in hybrid Pioneer 32B33 while on the other hand higher reduction in K^+ uptake over control was renowned in hybrid Dekalb 979 (52%) followed by hybrid Pioneer 3062 (50%). The increasing uptake of Sodium resulted in a decrease of K^+/Na^+ ratio in the plant leaves. The highest Potassium contents at 100 mM salinity level had resulted in higher K^+/Na^+ ratio in hybrid Pioneer 32B33 followed by hybrid Pioneer 30Y87, showing better performance under saline conditions.

Table 4. Effect of salinity on K$^+$/ Na$^+$ ratio of different maize hybrids at seedling stage.

Maize hybrid	K$^+$/ Na$^+$ ratio			Mean
	Treatments NaCl (m*M*)			
	0	**50**	**100**	
Hycorn 984	5.14	0.89 (83)	0.51 (90)	2.18 bcd
Dekalb 979	4.48	0.70 (84)	0.31 (93)	1.83 d
Dekalb 922	5.47	0.89 (84)	0.46 (92)	2.28 bcd
Pioneer 32B33	6.71	1.76 (74)	0.79 (88)	3.08 a
Pioneer 3062	4.67	1.16 (75)	0.35 (92)	2.06 cd
Pioneer 31R88	4.62	1.01 (78)	0.42 (91)	2.02 cd
Pioneer 30Y87	6.58	1.42 (78)	0.62 (91)	2.87 ab
Hycorn 993	5.58	1.27 (77)	0.54 (90)	2.46 abcd
Hycorn 11 plus	4.18	1.01 (76)	0.39 (91)	1.86 cd
Dekalb 919	5.93	1.36 (77)	0.53 (91)	2.60 abc
Mean	5.34 a	1.15 b	0.49 c	

LSD for hybrids (p≤ 0.05) = 0.362
Means sharing same letters do not differ significantly at the 5% level of significance
Values in parenthesis indicate % reduction over control

Discussion

Crop species showed wide range of genetic variation for salt tolerance (Flowers *et al.,* 2000; Ashraf *et al.,* 2002). Therefore it is necessary to find genetic variation in different plant species, which is useful for breeding programs for evaluating salt tolerance in different crops (Ashraf *et al.,* 1999). Plant roots are the first organ to be exposed to salinity, and root growth is particularly sensitive to increase in salt concentration of medium, that's why roots are rapidly reduced or prevented by salinity (Cramer *et al.,* 1988). Under saline conditions, depletion of O$_2$ deprives the plants of its primary energy source and accumulation of high levels of internal ethylene cause the inhibition of root elongation (Koning & Jakson, 1979) by reducing root growth.

High salt concentration in nutrient medium cause stunted growth in plants (Hernandez *et al.,* 1995; Cherian *et al.,* 1999; Takemura *et al.,* 2000). The immediate response of salt stress is reduction in rate of leaf surface expansion (Wang & Nil, 2000) and decrease in the fresh and dry weights of leaves, stem and roots (Hernandez *et al.,* 1995; Ali Denar *et al.,* 1999; Chartzoulakis & Klapaki, 2000). Salinity reduced plant growth either by increasing plant osmotic potential or specific ion toxicity (Dionisio-Sese & Tobita, 2000). In the present study, a significant decrease in shoot length, fresh and dry weights of shoot of all the hybrids was noted with the increase in salt concentration of medium. Reduction in plant growth as a result of salt stress has also been reported in several other plant species (Ashraf and McNeilly, 1990; Mishra *et al.,* 1991; Ashraf & O'leary, 1997).

NaCl stress significantly reduced total dry matter yield of all the hybrids but Pioneer 32B33 was the least affected at both salinity levels. The degree of reduction in dry matter increased with increasing salt stress. Reduction in dry matter has also been reported in number of crops by other investigators (Pessarakli & Huber, 1991; Al-Rawahy *et al.,* 1992). The negative response of dry weight of increasing salinity stress may be attributed to decreased leaf area expansion, smaller amount of radiation intercepted, and hence decreased photosynthesis. These results are in accordance with Ashraf *et al.,* (1991), Ullah *et al.,* (1993) and Cachorro *et al.,* (1994).

Increasing salinity is accompanied by significant reductions in shoot fresh and dry weight, plant height and root length in tomato (Mohammad *et al.,* 1998). In the present study, almost all the maize hybrids responded varyingly to imposition of different salinity levels. Maize hybrid Pioneer 32B33 showed better performance in terms of shoot and root growth and proved to be tolerant to lower as well as high level of salinity. Similar results were reported by Khan & Ashraf (1988) for Sorghum Meloni *et al.,* (2001) for cotton, Ashraf & Sarwar (2002) for Brassica and Sarwar & Ashraf (2003) for wheat.

Sensitivity of some crops to salinity has been attributed to the inability to keep Na^+ and Cl^- out of transpiration stream (Flowers & Hjibagheri, 2001). Plants limiting the uptake of toxic ions or maintaining normal nutrient ion contents could show greater tolerance.

Potassium nutrition is known to be disturbed under salt stress. Due to change in transcript level of several K^+ transporter genes (Su *et al.*, 2002); the reduction in deposition rate in growing cells (Bernstein *et al*., 1995); the decline in K^+ contents of the xylem (Munns, 1985), shoot (Jaschke & Wolf, 1985) and the expanding leaf tissue (Bernstein *et al*., 1995; Lazof & Bernstein, 1999b) and increased K^+ efflux from the root (Shabala *et al.,* 2003). Another reason for reduced K^+ uptakes is its competition with Na^+ uptakes through Na^+-K^+ co-transporters, which may also block K^+ specific transporters of root cell under salinity (Zhu, 2002). In the present study of K^+ uptake was reduced in all maize hybrids under salinity stress. The decrease in K^+ contents was due to presence of excessive Na^+ in growth medium because high external Na^+ content is known to have an antagonistic effect on K^+ uptake in plants (Jesche, 1984; Khan & Ashraf, 1992; Sarwar & Ashraf, 2003). It is also reported that salt tolerance is associated with higher K^+ contents (Ashraf & Sarwar, 2002) because of involvement in osmotic regulation and competitive effect with Na^+ (Ashraf *et al*., 2005).

Regulation of K^+ uptake and are prevention of Na^+ entry, efflux of Na^+ from the cell are the strategies commonly used by plants to maintain desirable K^+/ Na^+ ratios in the cytosole. In the present study, the tolerant hybrids are also expressing the same trend. K^+/ Na^+ ratio in the tolerant hybrids (Pioneer 32B33 and Pioneer 30Y87), was comparatively higher than the sensitive ones.

Conclusion

It was concluded that hybrids with higher K^+/ Na^+ ratio were more salt tolerance than those with low K^+/ Na^+ ratio. As a consequence, preliminary selection at the seedling stage would seem likely to be effective in improving salinity tolerance in *Zea mays* L., particularly because Rao (1997) showed that 10-days old seedling, classed as non-tolerant, also showed no salinity tolerance when grown in a sand culture experiment.

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