Soil Environ. 31(1):83-90, 2012
www.se.org.pk
Online ISSN: 2075-1141
Print ISSN: 2074-9546

Screening of maize hybrids for salt tolerance at seedling stage under hydroponic condition

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Abstract

Selection of salt-tolerant genotypes is important to grow crop plants on salt-affected areas to fulfill the increasing demand of food. Present study was conducted to screen the maize hybrids for salt tolerance under hydroponic condition using physiological and agronomical criteria. Maize seedlings at two leaf stage were transplanted and three different levels of salinity (control, 50 mM and 100 mM NaCl) were developed by using NaCl salt. A half strength Hoagland solution was used for nutrition during experiment. Significant variations were observed in all morpho-physiological attributes and ionic contents. The maize hybrid 26204 had higher plant growth, shoot dry weight, root dry weight, chlorophyll contents, leaf area, gas exchange characteristics, K^+/Na^+ ratio and found more salt tolerance at all salinity levels. While maize hybrid 8441 had lower plant growth, shoot dry weight, root dry weight, chlorophyll contents, leaf area, gas exchange characteristics, K^+/Na^+ ratio as compared to all other maize hybrids and was considered as salt sensitive genotype. The results show that salt tolerant genotypes could be a better source for breeders for further evaluation on salt affected soils.

Keywords: *Zea mays*, salinity, potassium, sodium, chlorophyll contents, gas exchange

Introduction

Crop productivity is seriously affected by soil salinity throughout the world. The deleterious effects of salt stress are obvious in soil under arid and semiarid climate owing to poor soil and water management activities (Azevedo *et al*., 2006). In salt affected soils, deleterious effects of soluble salts on plant development are due to decrease of osmotic potential in plants that ultimately decreases water availability to plants, ionic imbalance and specific ion toxicity (Ashraf and Harris, 2004). Salt stress not only affects the plant morphological attributes, but also disturbs the plant metabolic activities. The level of disturbance depends upon duration of stress, type of genotypes and concentration of stress (Munns and James, 2003). Salt stress is known to hamper numerous physiological processes like photosynthesis by decreasing the chlorophyll contents (Soussi *et al*., 1998) and closing stomata that ultimately decreases the partial pressure of CO_2 (Bethke and Drew, 1992) in leaf. The degree of salinity-caused reduction in photosynthetic capability depends on photosynthetic pigments, amount of photosynthesizing tissue, stomatal and non stomatal conductance (gas exchange attributes) (Dubey, 2005).

Screening of germplasm of particular crop plants is prerequisite to categorize salt tolerant genotypes for any breeding program. It was observed that tendency of salinity tolerance was different at different growth stages (Ashraf *et al*., 1997). However, better seedling growth has positive effects on lateral plant developmental stages and ultimately gives high yield (Grieve *et al*., 2001; Willenborg *et al*., 2005). For the development of salt tolerant genotypes, many studies have been conducted to understand the effects of salinity at different growth stages in maize (Khan *et al*., 2003a), wheat (Ali *et al*., 2002) and soybean (Kamal *et al*., 2003).

The capability of plants to sustain optimum level of K^+/Na^+ ratio in the cytosol determines its ability to survive under saline conditions (Tester and Davenport, 2003) and K^+/Na^+ ratio in leaf sap has been recommended as a reliable and quick technique for plant breeders to develop salt tolerant genotypes (Akram *et al*., 2010). Previous studies showed that K^+ retaining ability of cells is necessary for determining salinity tolerance of plants as its capability to eliminate lethal Na^+ ions concentration (Shabala *et al*., 2003). At seeding stage, measurement of K^+ concentration in plant leaf sap could be a reliable and quick screening technique that will contribute in saving time and field space.

Keeping in view all above discussion, a hydroponic experiment was conducted using nine maize hybrids at three levels of salinity (control, 50 and 100 mM NaCl) to find out best salt tolerant maize hybrid that could be further used to evaluate its potential on natural salt affected soil.

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Materials and Methods

A hydroponic study was performed at SARC, University of Agriculture, Faisalabad. Seeds were collected from various seed companies like Pioneer, Soni Dharti, ICI and Syngenta. Seeds of 9 maize hybrids (*Zea mays* L.) i.e., 26204, Hysun-33, 32B33, 6142, 32F10, 6525, 3335, 33H25, 8441, were sown in iron trays having washed sand. Single iron tray was used for each maize hybrid during germination. Water was spread daily over these iron trays to sustain optimum humidity.

When seedling growth reached at two leaf stage (after 8 days of sowing), the seedlings of each maize hybrid were transplanted in holes of thermo pole sheet with the help of foam wrapped at shoot root junction, suspended on 100 L iron tub, having ½ strength Hoagland's nutrient solution and air was provided with the help of air pumps. The culture solution was renewed once a week. Complete randomize design (CRD) with factorial arrangement was used with five replicates. After four days of transplanting, three levels of salinity (control (2), 50 and 100 mM) were developed by using sodium chloride salt in three increments. The solution pH was adjusted to 6.5±0.5 throughout the experiment with 1 M NaOH or HCl, as required.

Plants were harvested after four weeks of onset of salinity stress and washed thoroughly with distilled water. The youngest fully expanded leaves were separated at harvesting time and stored at freezing temperature to determine K^+ and Na^+ concentration in leaf sap. Plant samples were placed in oven at 65 ±5°C for 48 hours to determine dry weight of root and shoot (g plant^{-1}).

Determination of chlorophyll content, leaf area, Na^+ and K^+ contents

SPAD value (Soil-plant analyses development) of the leaves was determined by suing SPAD instrument (model SPAD-502; Minolta Corp., Ramsey, N.J.), while leaf area was determined by using leaf area meter (Delta MK-2). Na^+ and K^+ concentration was determined in leaf sap by using Sherwood 410 Flame photometer.

Measurements of gas exchange characteristics

Measurements of net photosynthetic rate (A), transpiration rate (E), stomatal conductance (Gs), and internal CO_2 concentration (Ci) were made on a fully expanded youngest leaf by using an open system LCA-4 ADC portable infrared gas analyzer.

Statistical Analysis

All data presented in this experiment are means of five replicates and standard deviation (SD). Analysis of variance (ANOVA) was performed by using a statistical package, SPSS version 16.0.

Results

Data regarding root length and shoot length (Table 1) showed that salinity stress exerted strong negative impact on shoot length and root length of maize hybrids. However, the impact of salinity differed significantly between maize hybrids. Minimum effects of salinity on root and shoot length were observed in maize hybrid 26204 where 86 and 65% root length at 50 and 100 mM NaCl level and 79 and 64% of control shoot length at low and high salt level, respectively, was observed when compared with unstressed control. While maize hybrid 8441, on the other hand,

Table 1: Root and shoot length of nine maize hybrids after 4 weeks exposure to NaCl

Maize Hybrid	Root length (cm)			Shoot length (cm)		
	Control	50mM	100mM	Control	50mM	100mM
26204	44.6±10.0	38.4±2.7	29.4±1.3	108.2±7.3	85.8±4.2	70.0±4.6
Hysun-33	43.0±7.7	36.6±3.4	27.6±2.0	110.6±6.4	78.4±5.9	64.8±4.0
32B33	48.6±3.6	36.4±3.3	25.8±8.0	107.8±7.4	74.4±6.5	57.2±14.9
6142	45.0±8.7	33.6±3.0	25.0±2.0	115.8±12.7	72.6±6.3	54.6±6.2
32F10	41.4±11.5	32.6±2.4	23.8±3.8	106.2±4.2	69.8±6.4	50.0±7.1
6525	38.4±5.2	31.2±2.3	23.4±4.9	106.6±8.2	68.6±5.3	49.2±12.3
3335	40.8±5.1	30.6±5.3	22.2±4.3	102.6±11.3	67.2±6.2	48.8±9.9
33H25	36.8±3.7	29.6±2.0	20.6±2.8	104.2±9.4	67.0±9.0	47.6±10.9
8441	38±3.9	26.4±2.4	18.6±5.3	104.8±8.0	64.6±6.3	33.6±9.1

Each value is an average of 5 replicates ± S.D showed much larger sensitivity to sodium chloride application (on an average 69 and 48% of control of root length and 61 and 32% of control shoot length at low and high salt stress, respectively).

Plant biomass was severely affected due to increase in salinity level therefore; dry and fresh weights of plants were significantly decreased. Fresh weight of root and shoot of maize hybrids under control and various levels of salinization (Table 2) showed that minimum reduction in root and shoot fresh weight was exhibited by maize hybrid 26204. However, at 50 and 100 mM NaCl stress, reduction was up to 79, 66% in root and 70, 52% relative to control in shoot fresh weight, respectively, at low and high salinity. At maximum level of salinization (100mM), maize hybrid 8441 proved to be salt sensitive and shoot fresh weight and root fresh weight was decreased up to 44 and 40%, respectively, relative to control. Maize hybrid Hysun-33 and maize hybrid 6142 effectively grew at high level of salinization (100 mM NaCl) and showed less than 50% reduction in root fresh weight.

The data regarding mean root dry weight and shoot dry weight of different maize hybrids under control, 50 and 100 mM of sodium chloride stress are depicted in (Table 3). Plant root and shoot dry weight reduced to varying degree among these maize hybrids and all maize hybrids followed the same pattern of dry weight reduction as in case of fresh weight. The highest reduction in root and shoot dry weight was noted in maize hybrid 8441 where level of decline was 27 and 26% at 100 mM of NaCl. At 100 mM NaCl, maize hybrid (26204) showed 55 and 52% reduction in root dry weight and shoot dry weight, respectively, while all other 8 maize hybrids showed reduction in between these two maize hybrids. The highest reduction in shoot dry weight was observed in maize hybrid 8441 and lowest in maize hybrid 26204.

Application of sodium chloride resulted in a significant decrease in leaf area and SPAD chlorophyll value (Table 4). The highest reduction in leaf area was observed in maize hybrid 8441 at all salinity levels (50 and 100 mM NaCl) and lowest reduction in leaf area was observed in maize hybrid 26204. No clear tendency was noted in effects of elevated sodium chloride level at 50 mM concentration on chlorophyll content. But at higher level of salinity stress (100 mM NaCl), chlorophyll contents were significantly

Table 2: Root and shoot fresh weight of nine maize hybrids after 4 weeks exposure to NaCl

Maize Hybrid	Root fresh weight(g plant^{-1})			Shoot fresh weight(g plant^{-1})		
	Control	50mM	100mM	Control	50mM	100mM
26204	8.9±0.2	7.1±0.4	5.9±0.5	55.8±13.0	39.3±4.5	29.4±3.3
Hysun-33	8.0±0.9	6.2±0.8	5.0±0.9	50.5±6.8	34.8±1.9	24.6±3.5
32B33	9.0±0.7	6.2±0.8	4.1±0.5	56.3±7.1	35.4±3.8	23.9±2.1
6142	7.6±1.4	5.9±0.3	4.3±1.0	47.1±7.0	31.8±5.5	20.3±7.0
32F10	7.0±0.7	5.2±0.9	3.6±0.6	46.6±4.8	32.0±3.6	20.1±3.5
6525	6.6±0.8	5.1±0.5	3.1±0.6	44.4±7.1	30.4±2.7	19.6±2.8
3335	6.3±1.0	4.7±0.4	3.0±0.4	44.5±7.7	29.2±3.3	19.1±2.7
33H25	6.5±2.2	4.7±0.6	2.9±0.3	42.2±7.2	27.5±2.4	19.1±2.3
8441	6.1±0.5	4.0±0.6	2.7±1.4l	43.9±7.6	26.6±1.7	17.8±2.2

Each value is an average of 5 replicates± S.D

Table 3: Root and shoot dry weight of nine maize hybrids after 4 weeks exposure to NaCl

Maize Hybrid	Root dry weight(g plant^{-1})			Shoot dry weight(g plant^{-1})		
	Control	50mM	100mM	Control	50mM	100mM
26204	2.18±0.21	1.53±0.17	1.20±0.29	8.8±0.1	6.3±0.3	4.6±0.3
Hysun-33	2.20±0.20	1.35±0.26	1.08±0.36	7.6±1.4	5.2±0.2	3.8±0.6
32B33	1.74±0.42	1.01±0.29	0.87±0.38	7.7±0.2	5.0±0.4	3.5±0.3
6142	1.86±0.30	0.99±0.15	0.86±0.36	7.0±0.4	4.7±0.6	2.4±0.3
32F10	1.58±0.25	0.98±0.47	0.69±0.14	6.6±0.8	4.3±0.2	2.1±0.3
6525	1.60±0.28	0.92±0.28	0.63±0.22	6.1±0.5	4.0±0.1	2.0±0.2l
3335	1.35±0.35	0.79±0.22	0.60±0.45	6.5±2.2	4.1±0.4	2.1±0.4l
33H25	1.36±0.36	0.76±0.41	0.49±0.12	6.0±0.4	3.4±0.3	1.8±0.5l
8441	1.50±0.38	0.75±0.15	0.41±0.16	5.9±0.4	3.1±0.1	1.6±0.3l

Each value is an average of 5 replicates± S.D reduced in all maize hybrids with maximum reduction in chlorophyll contents was observed in maize hybrid 8441 while minimum reduction was noted in maize hybrid 26204 at highest level of salinity stress.

Effect of salinity on photosynthetic rate (A) and transpiration rate (E) of nine maize hybrids are listed in Table 5. Compared to control, NaCl addition caused significant reduction in photosynthetic rate and transpiration rate in all maize hybrids at both levels of salinity. The higher reduction in photosynthetic rate and transpiration rate was observed in maize hybrid 8441 (30%, 29%, respectively) followed by maize hybrid 33H25 (32%, 30%, respectively) while minimum reduction was observed in maize hybrid 26204 (59%, 58%, respectively) followed by maize hybrid 33H25 (51%, 54%, respectively) at high level of salinity (100 mM NaCl). All other maize hybrids showed reduction in between these maize hybrids at both levels of salinity.

NaCl), maize hybrids exhibited different responses. Stomatal conductance and internal CO_2 concentration of maize hybrid 8441 were most affected due to salinity stress, producing132 mmol $m^{-2}s^{-1}$ and 105 µmol mol^{-1}, respectively. In contrast, stomatal conductance and internal CO_2 concentration of maize hybrid 26204 were 220 mmol $m^{-2}s^{-1}$ and 169 µmol mol^{-1}, respectively, at high level of salinity and appeared to be the most salt tolerant.

Salt stress caused dramatic increases in Na^+ concentration and exhibited significant reduction in K^+ concentration in leaf sap of maize hybrids (Table 7). At maximum level of salinization (100 mM NaCl), highest Na^+ concentration was observed in maize hybrid 8441 followed by maize hybrid 33H25 and maize hybrid 3335 while lowest Na^+ concentration was observed in maize hybrid 26204. The tendency in case of K^+ uptake was opposite by showing minimum K^+ concentration at maximum level of salinization and highest K^+ concentration was observed in control treatments in all the hybrids. Maize hybrid 26204 was efficient in keeping maximum K^+ concentration at all levels of salt stress. The increasing uptake of Na^+ concentration and decreasing K^+ concentration with

Table 4: Chlorophyll content and leaf area of nine maize hybrids after 4 weeks exposure to various NaCl levels

Maize Hybrid	Chlorophyll content (SPAD value)			Leaf area (cm^2)		
	Control	50mM	100mM	Control	50mM	100mM
26204	34.2±2.9	33.7±2.7	29.5±2.2	902.8±98.9	670.0±94.9	530.4±31.2
Hysun-33	34.9±3.9	32.0±2.	29.2±3.5	910.6±75.7	621.2±35.5	493.6±57.6
32B33	35.8±1.3	31.6±2.7	28.9±2.6	827.2±85.3	596.6±63.8	430.2±50.6
6142	33.4±4.9	31.2±4.1	28.3±3.3	870.8±92.5	591.0±41.8	411.2±82.3
32F10	34.0±2.3	31.0±2.4	28.2±5.5	913.0±55.5	605.6±34.9	403.6±29.5
6525	33.7±2.8	30.8±4.5	27.5±3.0	837.6±91.1	555.0±26.4	363.0±24.8
3335	31.9±1.3	30.1±2.8	27.1±2.8	792.2±68.8	548.8±27.3	330.6±93.7
33H25	31.5±3.7	29.3±2.4	27.1±3.7	810.4±35.9	540.6±34.4	318.6±59.6
8441	31.9±4.5	28.6±5.8	25.5±2.0	771.8±64.9	503.4±44.0	304.2±48.0

Each value is an average of 5 replicates± S.D

Table 5: Photosynthetic rate and transpiration rate of nine maize hybrids after 4 weeks exposure to NaCl

Maize Hybrid	Photosynthetic rate (A) (µmol CO_2 m^{-2} s^{-1})			Transpiration rate(E) (mmol H_2O m^{-2} s^{-1})		
	Control	50mM	100mM	Control	50mM	100mM
26204	25.0±1.9	18.7±2.1	14.8±1.7	5.04±0.5	4.0±0.2	2.9±0.5
Hysun-33	24.2±2.1	16.9±1.2	12.3±2.0	5.0±0.4	3.8±0.3	2.7±0.6
32B33	23.3±1.2	17.2±1.1	10.9±1.4	4.8±0.6	3.6±0.4	2.4±0.4
6142	24.9±1.8	15.4±2.2	11.1±2.3	4.6±0.7	3.5±0.5	2.1±0.2
32F10	25.4±2.2	14.2±1.9	9.4±1.4	4.5±0.4	2.9±0.2	1.8±0.3
6525	22.2±1.0	14.8±1.3	8.2±2.1	4.8±0.3	2.5±0.3	1.6±0.2
3335	23.6±1.3	13.8±1.4	8.0±1.4	4.7±0.4	2.1±0.2	1.5±0.1
33H25	22.2±1.6	13.2±2.1	7.1±2.0	4.3±0.3	1.9±0.2	1.3±0.2
8441	21.5±1.8	12.1±1.6	6.4±1.2	4.1±0.5	1.8±0.3	1.2±0.1

Each value is an average of 5 replicates± S.D

The mean values of stomatal conductance (Gs) and internal CO_2 concentration (Ci) of nine maize hybrids in control and two NaCl levels of 50 and 100 mM are given in Table 6. At both levels of salinization (50 and100 mM increasing salinization resulted in a reduction of K^+/Na^+ ratio (Table 8). The highest potassium concentration at higher level of salinity (100 mM NaCl) resulted in maintaining highest K^+/Na^+ ratio in maize hybrid 26204, showing better growth under salt stress environment.

Discussion

Variation exists in plants for salt tolerance at 100 mM NaCl during early growth stages. The existence of such kind of genotypic variation for NaCl tolerance could be useful for the development of high-yielding salt-tolerant genotypes (Ashraf *et al*., 1997; Munns *et al*., 2000). Results of present study revealed that salt stress significantly reduced the growth of all maize hybrids by affecting plant moropho-physiological characteristics like plant biomass, shoot length, root length, gas exchange attributes and K^+/Na^+ ratio confirming the previous findings that salinity caused negative impact on plant by reducing its growth (Khan, 2001; Akram *et al*., 2010; Ahmad, 2010).

Like other workers, results of our study also depicted that salinity caused reduction in plant height, fresh weight as well as dry weight of maize hybrid (Yurtseven *et al*., 2003; Agong *et al*., 2004; Hajer *et al*., 2006). Reduction in shoot fresh and dry weight of all maize hybrids in the presence of NaCl was attributed to ion toxicity as excess

Table 6: Stomatal conductance and internal CO_2 concentration of nine maize hybrids after 4 weeks exposure to NaCl

Maize Hybrid	Stomatal conductance (Gs) (mmol m^{-2} s^{-1})			Internal CO_2 concentration(Ci) (µmol mol^{-1})		
	Control	50mM	100mM	Control	50mM	100mM
26204	340±29	290±27	220±19	256±17	201±15	169±19
Hysun-33	335±22	282±26	210±17	252±22	193±17	140±13
32B33	332±32	271±30	191±18	249±21	185±16	132±12
6142	325±27	259±21	177±21	240±15	177±14	127±11
±32F10	333±29	251±19	165±16	244±13	172±18	121±15
6525	324±35	255±22	160±14	239±19	169±13	118±17
3335	321±25	241±18	148±17	235±24	165±19	114±12
33H25	320±21	231±15	140±13	232±21	167±12	117±13
8441	318±26	220±14	132±11	228±16	160±14	105±11

Each value is an average of 5 replicates± S.D

Table 7: K^+ and Na^+ concentration in leaf sap of nine maize hybrids after 4 weeks exposure to NaCl

Maize Hybrid	K^+ contents in leaf sap ($molm^{-3}$)			Na^+ contents in leaf sap ($molm^{-3}$)		
	Control	50mM	100mM	Control	50mM	100mM
26204	156.8±8.4	115.6±5.8	86.0±7.7	50.0±8.9	82.8±4.6	105.0±4.1
Hysun-33	162.6±7.1	110.6±7.6	79.4±7.4	49.0±5.3	86.6±6.9	120.2±3.9
32B33	166.6±9.4	103.4±7.6	76.8±5.0	46.0±4.3	90.6±4.4	127.2±3.9
6142	155.0±6.2	102.4±5.4	75.6±7.0	51.6±7.1	103.2±11.6	143.8±15.8
32F10	152.8±6.3	102.2±10.4	74.8±5.8	55.8±8.7	105.4±11.6	147.4±14.5
6525	150.6±7.1	101.6±7.1	73.0±5.3	53.2±7.4	113.0±9.5	148.0±6.8
3335	149.4±9.0	100.8±7.2	71.4±6.0	57.4±6.0	116.4±8.3	157.0±10.6
33H25	141.4±5.0	96.2±8.1	65.6±5.7	55.2±4.1	117.4±7.5	157.2±11.6
8441	147.4±7.1	92.8±6.5	63.2±7.2	56.6±8.2	122.8±5.4	170.4±6.8

Each value is an average of 5 replicates± S.D

Table 8: K^+/ Na^+ concentration in leaf sap of nine maize hybrids after 4 weeks exposure to NaCl

Maize Hybrid	K^+/ Na^+ ratio		
	Control	50mM	100mM
26204	3.21±0.58	1.39±0.07	0.82±0.10
Hysun-33	3.35±0.42	1.28±0.13	0.66±0.05
32B33	3.63±0.26	1.14±0.04	0.60±0.04
6142	3.05±0.45	1.00±0.18	0.53±0.07
32F10	2.79±0.45	0.97±0.10	0.51±0.08
6525	2.87±0.43	0.90±0.09	0.49±0.03
3335	2.63±0.44	0.87±0.11	0.45±0.04
33H25	2.57±0.22	0.81±0.04	0.42±0.06
8441	2.64±0.37	0.75±0.07	0.37±0.03

Each value is an average of 5 replicates± S.D

Na^+ resulted in nutritional and metabolic imbalances (Zhu, 2002). Among all, maize hybrid 26204 showed high root and shoot dry weight that indicates its tolerance to different salinity levels. It might be due to different mechanism of ion uptake and the results were in line of those obtained in previous studies (Ahmad, 2010; Akram *et al*., 2010).

Exposure of plants against salinity stress leads to decreased plant growth by reducing photosynthetic activities and high salt stress (100 mM NaCl) significantly reduced the chlorophyll contents and leaf area in all genotypes which ultimately reduced plant growth as it was evident from the previous research (Agong *et al*., 2004; Hayat *et al*., 2010). Reduction in photosynthesis under salinity stress occurs due to stomatal closure that ultimately leads not only to reduced leaf internal CO_2 concentration and leaf transpiration rate but also to non-stomatal factors such as reduction in leaf area and green pigments (Misra *et al*., 1997). In the present study, although imposition of salt stress significantly reduced the photosynthetic rate (A), transpiration rate (E), stomatal conductance (Gs) and internal CO_2 concentration (Ci) in all maize hybrids, however, the extent of reduction in these gas exchange attributes was more in maize hybrid 8441and 33H25 as compared to other hybrids. It might be due to the reason that salinity reduced the availability of water in growth medium (Liu *et al*., 2005) and plants sensed the water availability around the roots and responded by sending chemical signals to the shoot to extract adaptive responses, by closing stomata (Warren and Dreyer, 2006). The maize hybrid 26204 performed better by maintaining higher photosynthetic rate, transpiration rate, stomatal conductance and internal CO_2 concentration at both levels of salinity. These results are similar to those of Zheng *et al*., (2009) who reported that salt tolerant wheat genotypes maintain better gas exchange attributes as compared to salt sensitive wheat genotypes at high level of salinity.

Sodium transport from growth medium to cytoplasm of plant cells depends upon electrochemical potential gradient of Na^+ and presence of Na^+ transport channels in the plasma membranes, which permit Na^+ penetration (Jacoby, 1999). This selective uptake of Na^+ ions in plasma membrane may be a key factor in sensitivity or tolerance of maize hybrids. High salinity induces an increase in the Na^+ ions concentration which competes with the uptake of other important nutrients ions like K^+ and ultimately leads to K^+ scarcity in plant cells (Khan, 2001; Khan *et al*., 2000). Results of current study depicted that high level of Na^+ ions in leaf sap of salt sensitive maize hybrids negatively affects their growth. Our results are in line with previous studies in which the concentration of Na^+ ions increased with increasing salinization (Munns *et al*., 1995) that leads to salt injury to plants (Serrano *et al*., 1999).

On the other hand, potassium retaining capability of plant cells is a key factor for salinity tolerance, High retention of K^+ and higher K^+/Na^+ ratio are two major factors that help the salt-tolerant genotypes to perform well under salt stress condition (Zhu *et al*., 1998; Santa- Cruz *et al*., 1999). The salt tolerance ability of maize hybrid 26204 was also due to maintaining high K^+ ion concentration in the cell sap that resulted in high K^+/Na^+ ratio. Ahmad (2010) also found more root and shoot fresh weight and higher K^+/Na^+ ratio in salt tolerance genotype. Present study revealed that maize hybrids have variable response to salinity from highly sensitive to highly tolerant ones. This variation in salinity tolerant was due to their ability to maintain high K^+/Na^+ ratio and related attributes.

Conclusion

Present study revealed that at seedling growth stage, shoot/root length, shoot/root dry weight, chlorophyll contents, leaf area, photosynthetic rate, transpiration rate, stomatal conductance, internal CO_2 concentration and K^+/Na^+ ratio can be a good parameters for screening genotypes against salinity. These results can be a good source for the plant breeders and plant physiologists engaged in the development of salt tolerant maize genotypes. These salinity tolerant genotypes could be exploited in the breeding program for the development of elite genotypes having high salinity tolerance and have the potential to grow effectively on natural salt affected soil. Therefore further work is needed to evaluate the performance of this screened material in soil culture.

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