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Exploitation of variability for salinity tolerance in maize hybrids (*Zea mays* L.) at early growth stage

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Salinity is extremely serious problem that has a drastic effect on maize crop, environment and causes economic losses of country. An advance technique to overcome salinity is to develop salt tolerant genotypes which require screening of huge germplasm to start a breeding program. Therefore, present study was undertaken to screen out 25 maize hybrids of different origin for salinity tolerance at seedling stage under three levels of salt stress 250 and 300 mM NaCl including one control. The existence of variation for tolerance to enhanced NaCl salinity levels at seedling stage in maize proved that hybrids had differing ability to grow under saline environment and potential variability within specie. Almost all the twenty five maize hybrids behaved varyingly in response to different salinity levels. However, the maize hybrids H_6, H_{13}, H_{21}, H_{23} and H_{24} expressed better performance under salt stress in terms of all six characters and proved to be as highly tolerant while H_{22}, H_{17} H_{20}, H_{18}, H_4, H_9, and H_8 were identified as moderately tolerant. Hybrids H_{14}, H_5, H_{11} and H_3 H_{12}, H_2, were expressed as most sensitive to salinity suggesting that screening is an effective tool to exploit genetic variation among maize hybrids and salt tolerance in maize can be enhanced through selection and breeding procedure.

Key words: Salinity, hybrids, maize, variation.

INTRODUCTION

Salinity is one of the most important abiotic factor limiting plant growth and productivity. In fact, it is the accumulation of water soluble salts in the growth medium to such an extent that has a drastic effect on crops, surrounding atmosphere and makes losses economically to the country (Rengasamy, 2006). Salinity in the soil is mainly result of reduced rainfall and high evapotranspiration. It not only adversely affects crop lifecycle but also ground water that becomes brackish (Rhoades and Loveday, 1990; Evans, 1998). Worldwidely, about one quarter of irrigated land (60 million hectares) is salt affected that extremely damaging to crop plants (Lewis, 2002). High concentrations of soluble salts in the root medium results in reduced flowering and yield (Gill, 1979), reduction in photosynthesis (Yeo, 1998), plant nutrient uptake

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(Grattan and Grieve, 1999), plant growth rates and causes physiological drought (Mahajan and Tuteja, 2005). Salinity reduces fresh and dry weights of maize shoot (Raptan et al., 2001). According to Rabie (2005) who also found that salinity decreases the growth of mungbean. Similarly, Ghoulam et al. (2002) stated that salinity affects all growth parameters such as leaves fresh and dry weights.

Maize is one of the major food grain crops in Pakistan and occupies a significant position in agricultural economy of the country. It is third most important cereal crop in the world after wheat and rice but its production is affected negatively owing to high salt concentrations (Ashraf and McNeilly, 1989).

Salinity is tolerated by several crops including maize to a threshold level and above that yield reduces (Khan et al., 2006). To overcome salinity, plant breeders have been adopted many strategies, among them the most important one is exploitation of genetic variability in germplasm for identification of salinity tolerant genotypes pertaining yield potential even in presence of salinity in the soil (Ashraf et al., 2006).

To start a breeding programme, screening of huge germplasm is first and extremely important step in evolving high yielding and salt tolerant maize genotypes. This approach requires complete understanding about mechanism of plant response to different salinity levels at various plant growth stages as reported in several crops such as sorghum (Azhar and Khan, 1997), rice (Shannon et al., 1998), cotton (Azhar and Ahmad, 2000), wheat (Ali et al., 2002; Khan et al., 2003b), maize (Khan et al., 2003a), soybean (Kamal et al., 2003). Rao and McNeilly (1999) studied the genetic components of variation for salt tolerance in maize and concluded that salinity tolerance is high heritable and governing by additive and non additive genetic effects. Similarly, Akram et al. (2010) studied the screening of salt tolerance in maize (*Zea mays* L.) hybrids at an early seedling stage and found that overall salt tolerance performance was best at all salinity levels.

To use variation that already exists in plant material is crucial to develop salt tolerant genotypes within short time span (Flowers and Yeo, 1995). But, heterogeneity of soil physico-chemical properties and rainfall fluctuations are two main factors which cause difficulties for screening of salt tolerant genotypes in maize crop under field conditions. However, maize is basically cross pollinated crop which is highly polymorphic in nature that is why its cultivated species have great genetic variation; hence salinity tolerance exists in it (Paterniani, 1990). Therefore, present study was planned to screen out 25 maize hybrids for salinity tolerance under different levels of salinity stress.

MATERIALS AND METHODS

The present study on salinity tolerance in maize hybrids (Table 1) was carried out in the Department of Plant Breeding and Genetics, University College of Agriculture, Bahauddin Zakariya University, Multan during 2009-10. Three levels of NaCl salinity including a control were developed. Three seeds of each hybrid were sown in plastic bags filled with 0.5 kg of soil under proper moisture conditions. The pH, EC and saturation percentage of the soil medium was 7.6, 0.79 and 25.6, respectively. Twenty five hybrids were randomized in three replications following Two-Factor Factorial Completely Randomized Design. The desired levels of salinity were developed using anhydrous NaCl. Two desired levels of 250 and 300 mM NaCl were applied following three steps, that is, after five days of germination first dose of 250 and 300 mM NaCl was applied. After 4 days of first application, second dose of 250 and 300 mM NaCl was applied. After three days of second application, third dose of 250 and 300 mM NaCl was applied to growing seedlings. To measure the salt tolerance, the data on root length, shoot length, root fresh weight, shoot fresh weight, root dry weight and shoot dry weight were recorded after 16 days of sowing from three seedlings of each hybrid grown under each treatment.

To measure the significance, the data of 25 hybrids were subjected to analysis of variance (Steel et al., 1997). The means of treatments were separated by LSD (Least Significant Difference) test at 5% level of significance to establish difference between the genotypes, salinity levels and their interaction.

RESULTS

Tukey's LSD at 5% separated hybrids, salinity levels and their interaction into several groups, with no significant difference between the means within the groups, while great significant difference was found among groups. Results showed that hybrids, salinity levels and their interaction had a significant effect on root length, shoot length, root fresh weight, shoot fresh weight, root dry weight and shoot dry weight. According to mean values of the data, hybrid H_{21} gained maximum root length 40.56 cm followed by H_{22}, H_{17} obtaining 37.92 and 36.22 cm, respectively as compared to the others. However, minimum root lengths 26.21, 27.21, 27.18 and 26.99 cm were recorded by hybrids H_{24}, H_{14}, H_{13} and H_{11} (Table 2). Similarly, hybrids H_{21}, H_{23} and H_{13} obtained highest shoot lengths 31.63, 31.22 and 30.44 cm followed by H_{20}, H_{18}, H_4, H_6 and H_9 obtaining 27.18, 27.02, 26.89, 26.75 and 26.53 cm, respectively (Table 5). Whereas, hybrid H_{24} showed minimum shoot length 19.77 cm. Among the salinity levels, highest level S_2 (300 mM NaCl) produced minimum root and shoot lengths which were 57.20 and 66.21% less than that of the control (0 NaCl), respectively. Highest root and soot lengths 54.64 and 51.36 cm were recorded by H_{15} and H_{21} hybrids, respectively at 0 NaCl level. Whereas, H_{11} and H_3 hybrids produced minimum root and shoot lengths 13.96 and 7.84 cm, respectively at 300 mM NaCl salinity level.

Data regarding mean root and shoot fresh weights of twenty five maize hybrids at different levels of salinity are presented in (Tables 3 and 6). Hybrids H_6 and H_{24} recorded maximum root and shoot fresh weights 3.73 and 3.9 g followed by H_8 and H_{23} those gained 3.59 and 3.69 g, respectively. Whereas, minimum root and shoot fresh weights 2.84 and 2.01 g were observed by hybrids

Table 1. Name of maize CIMMYT Hybrids, Tropical and High Land Yellow.

Hybrids	Parentage
H_1	(cl02725/clrcy015)//cl02450
H_2	(clrcy034/clg2502)//cl02450
H_3	(clrcy038/clg2502)//cl02450
H_4	(clrcy040/clg2502)//cl02450
H_5	(clrcy040/clrcy038)//cl02450
H_6	(clrcy040/clrcy039)//cl02450
H_7	(clrcy040/cl02450)//cml451
H_8	(clrcy044/clg2502)//cl02450
H_9	(clrcy044/clrcy038)//cl02450
H_{10}	(clrcy044/clrcy039)//cl02450
H_{11}	(clrcy044/clrcy040)//cl02450
H_{12}	cml451*cl02450
H_{13}	(clqg2508/clqrcyq47)//cml165
H_{14}	(clqrcyq49/clrcyq47)//cml165
H_{15}	(clqrcyq49/clrcyq66)//cml165
H_{16}	(clqrcyq49/clrcyq67)//cml165
H_{17}	(clqrcyq59/((cml165*cl02450)-b*cl02450)-62-1-2*cl02450)-28-1-b-))//cml161
H_{18}	(clqrcyq59/cml165)//cml161
H_{19}	(clqrcyq60/clqrcyq62)//cml161
H_{20}	(clqrcyq60/clqrcyq63)//cml161
H_{21}	(cml462/cml461)//cml245*p86c4f13-3-1-2-1-3-1-1-1)b-4tl-2-1-b-b-b
H_{22}	(cml462/cml461)//cml245*p86c4f13-3-1-2-1-3-1-1-1)b-4tl-2-1-b-b-b
H_{23}	(cml462/cml461)//p88c5f6-6-1-2-1-2-1-b*s.morado tardio tl93a-5-b-1tl-1-1-1-b)-b-22tl-1-1b
H_{24}	(cml462/cml461)//p88c5f6-6-1-2-1-2-1-b*s.morado tardio tl93a-5-b-1tl-1-1-1-b)-b-22tl-1-1b
H_{25}	(cml460/cml461)//p86asdpc1f90-1-2-1-b-1-b-4-b-b-b-b-b-b-b

H_{24} and H_{12}, respectively. Fresh root and shoot biomass was also affected by salinity. Maximum root fresh weight 4.73 g was recorded in control but minimum 1.92 g in S_2 when salt was applied at the rate of 300 mM. Same pattern was studied for shoot fresh weight. Hybrids H_{12} and H_{19} obtained maximum root and shoot fresh weights 5.53 and 5.53 g at control followed 5.40 and 5.52 g by H_6 and H_{21}, respectively.

Different maize hybrids had significant effect on the root and shoot dry weights (Tables 4 and 7). Maize hybrid H_6 recorded maximum root dry weight 0.198 g followed by H_8 that gained 0.193 g whereas, minimum 0.151 g was observed by hybrid H_{24}. Hybrid H_{24} recorded maximum shoot dry weight 0.19 g followed by H_{23} that gained 0.18 g, respectively whereas, minimum 0.10 g was observed by hybrid H_{12}. Salinity also had significant effect on root and shoot dry weights. Maximum root and shoot dry weights 0.252 and 0.20 g were recorded in control but minimum 0.102 and 0.08 g, respectively were observed in S_2 when salt was applied at the rate of 300 mM. The interactive effect of both sources of variation (hybrids and salinity levels) had a significant effect on the root and shoot dry weight. Hybrid H_{12} recorded maximum root dry weight 0.293 g at control followed by H_6 that obtained 0.286 g. Minimum root dry weight 0.213 g was recorded by hybrids H_5 and H_{24}. Hybrids H_{19} and H_{21} recorded maximum shoot dry weight 0.28 g followed by H_{18} that obtained 0.26 g. Minimum shoot dry weight 0.11 g was observed by H_{11}, H_2, H_4 at control.

DISCUSSION

Salinity tolerance is entirely important for whole plant life cycle from germination till harvesting for production of seed in grain producing crops like maize. It has been revealed from a lot of studies that in crop plants salinity tolerance at early seedling stage also reflects great tolerance at adult stage (Akram et al., 2010). In accordance with that, the present investigation expressed the existence of variation for tolerance to enhanced NaCl salinity levels at seedling stage in maize. Our findings were supported by several scientists like, Ashraf et al. (1986) investigated that variation exists in several forage grass species, Ashraf and McNeilly (1990) exploited variation for improved salinity tolerance in maize, Al-Khatib et al. (1993) studied salinity tolerance in lucerne, Kebebew and McNeilly (1994) studied variation for salinity tolerance in pearl millet, Maiti et al. (1996) found that in maize, variation for salinity tolerance that is

Table 2. Effect of salinity and maize hybrids on root length (cm).

Hybrids	S_0 (Control)	S_1 (250 mM)	S_2 (300 mM)	Means
H_1	48.45 ^{cd}	29.46 $^{p-t}$	20.75 z-^{d}	32.89 $^{h-k}$
H_2	41.50 ^{ij}	34.19 ^{mn}	24.70 $^{w-y}$	33.46 $^{g-j}$
H_3	52.18 ^{ab}	27.95 $^{r-u}$	14.66 ^{fg}	31.59 $^{k-m}$
H_4	47.30 $^{d-f}$	30.76 $^{o-q}$	22.75 $^{w-a}$	33.60 $^{f-j}$
H_5	42.03 ^{ij}	34.08 ^{mn}	29.06 $^{p-t}$	35.06 $^{c-g}$
H_6	52.24 ^{ab}	31.54 $^{n-p}$	22.15 $^{y-a}$	35.31 $^{c-e}$
H_7	43.85 $^{g-i}$	36.78 $^{k-m}$	24.87 $^{v-y}$	35.16 $^{c-f}$
H_8	47.54 $^{d-f}$	30.26 $^{o-s}$	18.47 $^{b-d}$	32.09 $^{j-m}$
H_9	45.65 $^{e-g}$	31.47 $^{n-p}$	16.30 $^{d-g}$	31.14 ^{lm}
H_{10}	49.26 ^{cd}	29.52 $^{p-t}$	18.18 $^{b-e}$	31.32 $^{i-m}$
H_{11}	41.76 ^{ij}	25.24 $^{q-x}$	13.96 ^{g}	26.99 ^{n}
H_{12}	50.55 ^{bc}	36.55 ^{lm}	22.76 $^{x-a}$	36.62 ^{bc}
H_{13}	42.26 h^{i}	24.72 $^{w-y}$	14.56 ^{g}	27.18 ^{n}
H_{14}	37.82 ^{kl}	28.35 $^{q-t}$	15.46 $^{e-g}$	27.21 ^{n}
H_{15}	54.64 ^{a}	34.13 ^{mn}	18.32 $^{b-d}$	35.69 ^{cd}
H_{16}	46.83 $^{d-f}$	36.11 ^{lm}	20.34 $^{a-c}$	34.43 $^{b-h}$
H_{17}	52.15 ^{ab}	32.75 no	23.76 ^{xy}	36.22 ^{c}
H_{18}	42.06 ^{ij}	31.52 n-p	24.38 $^{w-y}$	32.65 $^{i-l}$
H_{19}	47.85 $^{c-e}$	30.50 o-r	13.98 ^{g}	30.77 ^{m}
H_{20}	44.92 $^{f-h}$	39.38 ^{jk}	1741 $^{d-f}$	33.90 $^{e-i}$
H_{21}	52.97 ^{ab}	41.10 ^{ij}	27.60 $^{s-v}$	40.56 ^{a}
H_{22}	52.06 ^{ab}	38.30 ^{kl}	23.41 $^{x-z}$	37.92 ^{b}
H_{23}	46.93 $^{d-f}$	28.84 p-t	20.45 $^{a-c}$	32.07 $^{j-m}$
H_{24}	37.59 ^{kl}	26.90 $^{t-w}$	14.13 ^{g}	26.21 ^{n}
H_{25}	48.54 ^{cd}	30.97 $^{o-q}$	17.85 $^{c-e}$	32.45 $^{i-l}$
Mean	46.76 ^{a}	32.05 ^{b}	20.01 ^{c}	

Table 3. Effect of salinity and maize hybrids on root fresh weight (g).

Hybrids	S_0(Control)	S_1(250mM)	S_2(300mM)	Means
H_1	4.39^{i-k}	2.93^{t-x}	2.07^{y-d}	3.13^{i-k}
H_2	5.12^{b-e}	3.41^{m-r}	1.99^{y-e}	3.51^{b-d}
H_3	4.55^{g-k}	3.03^{s-w}	2.21^{yz}	3.26^{f-j}
H_4	4.76^{f-h}	3.17^{q-u}	2.13^{y-b}	3.35^{d-h}
H_5	4.01^{l}	2.67^{x}	1.82^{b-h}	2.84^{m}
H_6	5.40^{ab}	3.60^{mn}	2.12^{yz}	3.73^{a}
H_7	4.90^{d-f}	3.27^{o-s}	1.99^{y-e}	3.39^{c-g}
H_8	5.14^{b-e}	3.42^{m-r}	2.21^{yz}	3.59^{ab}
H_9	4.65^{f-j}	3.10^{r-v}	2.32^{y}	3.35^{d-h}
H_{10}	5.15^{b-e}	3.44^{m-q}	1.69^{e-i}	3.43^{b-f}
H_{11}	4.30^{kl}	2.87^{u-x}	2.18^{y-a}	3.12^{i-k}
H_{12}	5.53^{a}	3.68^{m}	1.51^{hi}	3.57^{a-c}
H_{13}	5.25^{a-c}	3.50^{m-p}	1.83^{b-h}	3.53^{b-d}
H_{14}	4.77^{fg}	3.18^{p-u}	1.67^{f-i}	3.21^{g-k}
H_{15}	4.68^{f-i}	3.11^{r-v}	1.77^{d-i}	3.19^{h-k}
H_{16}	4.94^{c-f}	3.33^{n-s}	1.80^{c-i}	3.36^{d-h}
H_{17}	4.34^{jk}	3.23^{o-t}	1.88^{a-g}	3.15^{i-k}
H_{18}	4.44^{h-k}	3.23^{o-t}	2.10^{y-c}	3.26^{f-j}
H_{19}	4.31^{kl}	3.22^{o-t}	1.73^{e-i}	3.09^{j-l}
H_{20}	5.21^{a-d}	3.20^{p-t}	1.96^{z-f}	3.46^{b-e}

Table 3. Contd.

H_{21}	4.84^{e-g}	3.54^{m-o}	1.49^{i}	3.29^{e-i}
H_{22}	4.56^{g-k}	2.73^{wx}	1.82^{b-i}	3.04^{kl}
H_{23}	4.76^{f-h}	3.17^{q-u}	2.13^{y-b}	3.35^{d-h}
H_{24}	4.01l	2.67^{x}	1.82^{b-h}	2.84^{m}
H_{25}	4.31^{kl}	2.82^{v-x}	1.63^{g-i}	2.92^{lm}
Mean	4.73^{a}	3.1^{ab}	1.92^{c}	

Table 4. Effect of salinity and maize hybrids on root dry weight (g).

Hybrids	S_0(Control)	S_1(250mM)	S_2(300mM)	Means
H_1	0.233^{ij}	0.153^{r-e}	0.113^{w-z}	0.166^{h-j}
H_2	0.270^{b-f}	0.183^{m-p}	0.106^{x-a}	0.186^{b-d}
H_3	0.243^{h-j}	0.160^{q-u}	0.120^{wx}	0.174^{f-h}
H_4	0.253^{f-h}	0.170^{p-r}	0.116^{w-y}	0.180^{d-f}
H_5	0.213^{kl}	0.143^{uv}	0.096^{z-c}	0.151^{l}
H_6	0.286^{ab}	0.193^{mn}	0.116^{w-y}	0.198^{a}
H_7	0.263^{c-g}	0.173^{o-q}	0.106^{x-a}	0.181^{d-f}
H_8	0.276^{a-d}	0.183^{m-p}	0.120^{wx}	0.193^{ab}
H_9	0.250^{g-i}	0.163^{q-t}	0.126^{vw}	0.180^{d-f}
H_{10}	0.273^{b-e}	0.183^{m-p}	0.090^{a-c}	0.182^{c-f}
H_{11}	0.230^{jk}	0.153^{r-u}	0.116^{w-y}	0.166^{h-j}
H_{12}	0.293^{a}	0.200^{lm}	0.080^{c}	0.191^{a-c}
H_{13}	0.280^{a-c}	0.183^{m-p}	0.096^{z-c}	0.186^{b-d}
H_{14}	0.253^{f-h}	0.166^{p-s}	0.086^{bc}	0.168^{g-j}
H_{15}	0.250^{g-i}	0.163^{q-t}	0.093^{a-c}	0.168^{g-j}
H_{16}	0.260^{d-h}	0.173^{n-q}	0.096^{z-c}	0.177^{d-g}
H_{17}	0.233^{ij}	0.170^{p-r}	0.100^{y-b}	0.167^{h-j}
H_{18}	0.233^{ij}	0.170^{p-r}	0.116^{w-y}	0.173^{f-i}
H_{19}	0.230^{jk}	0.170^{p-r}	0.093^{a-c}	0.164^{i-k}
H_{20}	0.280^{a-c}	0.170^{p-r}	0.103^{w-b}	0.180^{b-e}
H_{21}	0.256^{e-h}	0.190^{m-o}	0.080^{c}	0.175^{e-h}
H_{22}	0.243^{h-j}	0.146^{tu}	0.096^{z-c}	0.162^{jk}
H_{23}	0.253^{f-h}	0.170^{p-r}	0.116^{w-y}	0.180^{d-f}
H_{24}	0.213^{kl}	0.143^{uv}	0.096^{z-c}	0.151^{l}
H_{25}	0.230^{jk}	0.150^{s-u}	0.086^{bc}	0.155^{kl}
Mean	0.252^{a}	0.169^{b}	0.102^{c}	

expressed at early seedling stage produces high yields at maturity. Our findings expressed that screening at seedling stage for salinity tolerance in maize is a productive method, considering that variation at the seedling stage is controlled genetically.

A lot of morphological seedling traits in maize have been employed for identification of salinity tolerance. Among them, broadly used trait is the root length of seedlings grown in control and saline solutions; root length has been reduced rapidly when the seedlings is exposed to salinity (Rao and McNeilly, 1999; Khan and McNeilly, 2005). Accordingly, our results show that root length was one of the morphological traits that suffered major losses as compared to the non-saline treatment throughout the experiment of screening (Table 2). This attitude was expectable, because root is the first important plant organ that has direct contact with the growth medium supplying all the necessary nutrients from soil to growing plant and is first to be affected, therefore roots provide the important information in context to salinity tolerance in crops like maize (Collado et al., 2010; Akram et al., 2010). Similarly, Cramer et al. (1988) and Ashraf et al. *(*2005) were of the opinion that root growth and development is extremely sensitive to high salinity

Table 5. Effect of salinity and maize hybrids on shoot length (cm).

Hybrids	S_0 (Control)	S_1 (250 mM)	S_2 (300 mM)	Means
H_1	39.84^{e-g}	$26{\cdot}67^{n-q}$	8.71^{ij}	25.07^{c-g}
H_2	32.76^{j-l}	22.40^{s-u}	11.87^{d-i}	22.34^{h-j}
H_3	39.66^{e-g}	21.99^{s-v}	7.84^{j}	23.16^{g-i}
H_4	41.3^{de}	23.40^{q-t}	15.73^{z-c}	26.89^{bc}
H_5	38.32^{e-i}	19.77^{u-y}	9.30^{h-j}	22.46^{h-j}
H_6	44.98^{bc}	21.87^{s-v}	13.40^{c-g}	26.75^{bc}
H_7	35.57^{h-j}	17.43^{w-a}	14.04^{a-e}	22.34^{h-j}
H_8	31.00^{lm}	22.58^{s-u}	11.58^{e-i}	21.72^{i-k}
H_9	46.27^{bc}	23.39^{q-t}	9.94^{h-j}	26.53^{bc}
H_{10}	32.06^{k-m}	29.01^{m-o}	14.39^{a-e}	25.15^{c-f}
H_{11}	27.03^{n-p}	21.05^{t-v}	13.92^{b-e}	20.67^{jk}
H_{12}	39.02^{e-g}	24.51^{p-s}	14.15^{a-e}	25.89^{b-e}
H_{13}	44.57^{b-d}	27.14^{n-p}	19.60^{u-y}	30.44^{a}
H_{14}	47.91^{b}	17.43^{w-a}	10.35^{f-j}	25.23^{b-e}
H_{15}	36.74^{g-i}	22.93^{r-u}	10.06^{g-j}	23.24^{f-i}
H_{16}	35.10^{i-k}	23.57^{q-t}	14.40^{a-e}	24.26^{d-h}
H_{17}	38.73^{e-h}	24.62^{p-s}	15.03^{a-d}	26.13^{b-d}
H_{18}	35.57^{h-j}	31.88^{k-m}	13.63^{c-f}	27.02^{bc}
H_{19}	31.70^{k-m}	20.70^{t-w}	11.87^{d-i}	21.42^{i-k}
H_{20}	43.93^{cd}	26.15^{o-r}	11.46^{e-i}	27.18^{b}
H_{21}	51.36^{a}	26.27^{o-r}	17.26^{x-b}	31.63^{a}
H_{22}	38.08^{f-i}	23.40^{q-t}	16.79^{y-c}	26.09^{b-d}
H_{23}	45.92^{bc}	29.13^{m-o}	18.60^{v-z}	31.22^{a}
H_{24}	29.83^{l-n}	17.31^{w-b}	12.17^{d-h}	19.77^{k}
H_{25}	40.25^{ef}	20.53^{t-x}	11.23^{e-j}	24.00^{e-h}
Mean	38.71^{a}	23.40^{b}	13.08^{c}	

Table 6. Effect of salinity and maize hybrids on shoot fresh weight (g).

Hybrids	S_0 (Control)	S_1 (250 mM)	S_2 (300 mM)	Means
H_1	2.98^{n-q}	2.22^{t-c}	1.82^{a-j}	2.34^{k-m}
H_2	2.32^{t-z}	2.89^{o-r}	1.89^{y-h}	2.37^{j-m}
H_3	4.63^{ef}	3.32^{l-o}	1.54^{g-k}	3.16^{de}
H_4	2.23^{t-b}	2.56^{q-w}	1.98^{x-g}	2.26^{l-n}
H_5	2.64^{q-u}	2.15^{u-e}	1.84^{z-i}	2.21^{mn}
H_6	4.62^{ef}	2.58^{q-v}	1.65^{f-j}	2.95^{e-g}
H_7	4.47^{fg}	2.92^{n-r}	2.17^{u-d}	3.19^{de}
H_8	4.44^{fg}	1.69^{d-j}	1.85^{y-i}	2.66^{hi}
H_9	4.12^{gh}	2.29^{t-a}	1.77^{b-j}	3.73^{f-i}
H_{10}	3.52^{j-m}	3.00^{n-q}	1.43^{h-k}	2.65^{h-j}
H_{11}	2.33^{t-z}	3.33^{l-o}	1.78^{b-j}	2.48^{i-m}
H_{12}	2.43^{r-x}	2.23^{t-b}	1.38^{i-k}	2.01^{n}
H_{13}	4.42^{fg}	2.67^{p-t}	1.66^{e-j}	2.92^{e-h}
H_{14}	5.06^{a-e}	2.06^{x-f}	1.68^{e-j}	2.93^{e-h}
H_{15}	5.03^{b-e}	2.57^{q-v}	1.45^{h-k}	3.02^{e}
H_{16}	3.87^{h-k}	2.09^{v-f}	1.74^{c-j}	2.56^{i-k}
H_{17}	4.01^{g-j}	3.04^{m-q}	1.91^{y-h}	2.99^{ef}
H_{18}	5.26^{a-c}	3.40^{k-n}	2.08^{w-f}	3.58^{bc}
H_{19}	5.53^{a}	2.64^{q-u}	1.35^{jk}	3.17^{de}

Table 6. Contd.

H_{20}	4.80^{c-f}	2.58^{q-v}	1.79^{b-j}	3.05^{e}
H_{21}	5.52^{ab}	3.13^{l-p}	1.43^{h-k}	3.36^{cd}
H_{22}	3.60^{i-l}	2.82^{p-s}	1.08^{k}	2.50^{i-l}
H_{23}	4.34^{f-h}	4.67^{d-f}	2.06^{x-f}	3.69^{ab}
H_{24}	5.15^{a-d}	4.80^{c-f}	1.74^{c-j}	3.9^{a}
H_{25}	4.05^{g-i}	2.34^{s-y}	1.64^{f-j}	2.68^{g-i}
Mean	4.05^{a}	2.80^{b}	1.71^{c}	

Table 7. Effect of Salinity and maize hybrids on shoot dry weight (g).

Hybrids	S_0(Control)	S_1(250mM)	S_2(300mM)	Means
H_1	0.16^{j-m}	0.11^{q-v}	0.09^{u-a}	0.12^{j-m}
H_2	0.11^{q-u}	0.14^{l-p}	0.09^{u-a}	0.11^{k-m}
H_3	0.23^{c-e}	0.16^{j-m}	0.08^{y-b}	0.16^{de}
H_4	0.11^{q-v}	0.12^{p-s}	0.10^{t-y}	0.11^{l-n}
H_5	0.13^{n-q}	0.11^{q-w}	0.09^{u-a}	0.11^{mn}
H_6	0.23^{c-e}	0.13^{q-r}	0.08^{w-a}	0.15^{e-g}
H_7	0.22^{d-f}	0.14^{l-p}	0.11^{q-w}	0.16^{de}
H_8	0.22^{d-f}	0.08^{w-a}	0.09^{u-a}	0.13^{g-j}
H_9	0.21^{e-g}	0.11^{q-u}	0.09^{v-a}	0.13^{f-i}
H_{10}	0.17^{i-k}	0.15^{k-o}	0.07^{z-b}	0.13^{h-j}
H_{11}	0.11^{q-v}	0.16^{j-m}	0.08^{w-a}	0.12^{j-m}
H_{12}	0.12^{p-t}	0.11^{q-v}	0.07^{ab}	0.10^{n}
H_{13}	0.22^{d-g}	0.13^{n-q}	0.08^{w-a}	0.14^{e-h}
H_{14}	0.25^{a-c}	0.10^{s-y}	0.08^{x-a}	0.14^{e-h}
H_{15}	0.25^{a-c}	0.12^{p-s}	0.07^{z-b}	0.15^{ef}
H_{16}	0.19^{g-i}	0.10^{s-y}	0.09^{b-a}	0.13^{i-k}
H_{17}	0.20^{f-h}	0.15^{k-o}	0.09^{u-z}	0.15^{ef}
H_{18}	0.26^{ab}	0.17^{j-l}	0.10^{s-y}	0.17^{bc}
H_{19}	0.28^{a}	0.13^{o-r}	0.07^{ab}	0.16^{de}
H_{20}	0.24^{b-d}	0.13^{q-r}	0.09^{u-a}	0.15^{de}
H_{21}	0.28^{a}	0.15^{k-n}	0.07^{z-b}	0.17^{cd}
H_{22}	0.18^{h-j}	0.14^{m-p}	0.05^{b}	0.12^{i-l}
H_{23}	0.22^{d-g}	0.23^{cd}	0.10^{r-x}	0.18^{ab}
H_{24}	0.25^{a-c}	0.24^{b-d}	0.08^{x-a}	0.19^{a}
H_{25}	0.20^{f-h}	0.11^{q-u}	0.08^{x-a}	0.13^{g-j}
Mean	0.20^{a}	0.14^{b}	0.08^{c}	

level in the soil that is reduced rapidly in size.

Measurement of shoot length under salt stress may be a more effective and useful parameter than root length to identify salinity tolerance (Eker et al., 2006). In accordance with that, our findings also showed an important reduction in shoot length of seedlings in salinity compared to the controls and this trait could be useful in screening salinity tolerance (Table 5). Our results were also supported by (Collado et al., 2010; Akram et al., 2010) that increasing the concentration of NaCl declines the root and shoot lengths of the maize hybrids.

Increasing salinity is accompanied by a significant reduction in shoot length, plant fresh and dry biomass in tomato Mohammad et al. (1998) and in maize Akram (2010). Accordingly, our studies revealed that salinity significantly reduced root and shoot fresh weights and dry weights (Tables 3, 4, 6 and 7). Similar findings were also reported in upland cotton (*Gossypium hirsutum* L.) by Hanif et al. (2008). This showed that the increasing levels of salinity hampered the root and shoot growth which ultimately resulted in reduced root and shoot fresh and dry weights among the 25 maize hybrids.

In the present experiment, almost all the twenty five maize hybrids behaved varyingly in response to different salinity levels. But the maize hybrids H_6, H_{13}, H_{21}, H_{23} and H_{24} expressed better performance in term of root and shoot lengths, fresh and dry weights and have proved as salt tolerant hybrids.

Conclusion

The results of our study concluded that screening is an effective tool to exploit genetic variation among maize hybrids. These variations can further be utilized in a breeding programme to develop high yielding salt tolerant genotypes of maize through selection and breeding procedures. Our findings will provide guidelines about selection of salt tolerant hybrids in maize and this information will be very necessary and relevant to plant breeders and physiologists who are indulged in improving salt tolerance of maize. This criterion is also applicable for other crops to develop high yielding salt tolerant varieties.

Conflict of Interests

The authors have not declared any conflict of interests.

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