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Full Length Research Paper

Effects of salt stress on germination of some maize (*Zea mays* L.) cultivars

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This study was conducted to investigate the effects of salt stress on germination of six maize (*Zea mays* L.) cultivars (ADA-523, Bora, C-955, PR 3394, Progen 1150 and Trebbia). The degrees of salinity tolerance among these cultivars were evaluated at seed germination stage at six different salt concentrations (0, 50, 100, 150, 200 and 250 mM NaCl). The results showed that in all cultivars as the salt concentration increased, both germination percentage and germination index decreased significantly. Responses of cultivars to salt stress indicated differences. For all salt concentrations, C-955 had the highest germination percentage and germination index. Salt concentration decreased shoot and root dry weight. Bora and C-955 had the lowest reduction of shoot and root dry weight, respectively. Progen-1550 had the highest reduction of shoot and root dry weight. On the other hand, C-955 showed better results than the other cultivars in respect of salt tolerance index. The results showed that C-955 is the cultivar to be recommended for saline soils. Progen-1550 was more sensitive to salinity in this study.

Key words: Maize, NaCl, germination percentage, stress tolerance ındex, germination ındex.

INTRODUCTION

Salinity is a major environmental constraint to crop productivity throughout the arid and semi-arid regions of the world (Foolad and Lin, 1997). Salinity has reached a level of 19.5% of all irrigated-land (230 million ha of irrigated land, 45 million ha are salt-affected soils) and 2.1% of dry-land (1500 million ha of dryland agriculture, 32 million are salt-affected soils) agriculture worldwide. According to the FAO, around 1.5 million ha of land in Turkey have both salinity and sodicity problems (FAO, 2000).

Seed germination is a major factor limiting the establishment of plants under saline conditions. Salinity may cause significant reductions in the rate and percentage of germination, which in turn may lead to uneven stand establishment and reduced crop yields (Foolad et al., 1999).

Salt tolerance at germination stage is important factor, where soil salinity is mostly dominated at surface layer. High concentration of salts have detrimental effects on germination of seeds (Kayani and Rahman, 1987; Rahman et al., 2000; Sharma et al., 2004; Saboora and Kiarostami, 2006). Plant growth is ultimately reduced by salinity stress but plant species differ in their sensitivity or tolerance to salts (Torech and Thompson, 1993; Munns and Termaat, 1986; Rogers et al., 1995).

Maize (*Zea mays* L.) is in the third rank 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 in which salinity tolerance may exist (Paterniani, 1990).

Maize, which belongs to the plants with C4 metabolism, is also classified as moderately sensitive to salinity (Mass and Hofffman, 1977; Katerji et al., 1994; Ouda et al., 2008). For maize grown under salinity, reduction in growth characters and yield were observed (Ouda et al., 2008).

This study was conducted to determine the maize cultivar(s) resistant to salt stress which can be grown on cultivated lands having salt problems.

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Table 1. Results of analysis of variance of the traits determined.

Sources	df	Germination percentage	Germination index	Shoot dry weight	Root dry weight	Stress tolerance index
Cultivars (C)	5	**	**	**	**	**
Salt(S)	5	**	**	**	**	**
C x S	25	**	**	**	**	**

** $P < 0.01$, df, degrees of freedom.

MATERIALS AND METHODS

Maize cultivars

This study was a laboratory-conducted experiment and carried out in Uludag University, Agricultural Faculty, Field Crops Departmant, Turkey in 2007. Six cultivars (Ada-523, Bora, C-955, PR 3394, Progen-1550 and Trebbia) of maize (*Zea mays* L.) were used and their seeds were obtained from the MayAgro, Monsanto, Özbuğday and Pioneer Seed Corporations and Sakarya Agricultural Research Institute. These cultivars are largely grown in Marmara Region.

To obtain homogeneous emergencies after seedlings, seeds with similiar size and weight were selected. Seeds were surface sterilized in 1.5% (v/v) sodium hypochloride for 10 min and thoroughly washed with distilled water. Thirty seeds were placed on filter papers which contained different salt concentrations and located in 15 cm diameter steril petri dishes. Salt stress was realized by subjecting the seeds to 15 ml salt solutions of 50, 100, 150, 200 and 250 mM NaCl. In addition 15 ml of distilled water without NaCl was used as control. Dishes were sealed with parafilm and kept under controlled conditios (25 ± 1℃ during the day and 80% humidity) for ten days. The filter papers were irrigated daily with 15 ml solutions of the respective treatments. The filter papers were changed with the new ones after 48 h in order to avoid salt accumulation.

Germination percentage

The emergence of plumule was taken as index of germination. Initiation and completion of germination was recorded daily. The germination percentage was recorded daily for 10 days and germination percantage was calculated with the following formula:

$$\text{Germination percantage (\%)} = \frac{\text{Number of germinated seeds}}{\text{Number of total seeds}} \times 100$$

Germination index

This parameter was calculated using the following formula:

$$\text{Germination index} = \Sigma(Gt/Tt)$$

where Gt is the number of seeds germinated on t^{th} day and Tt is the number of days up to t^{th} day (Alvarado et al., 1987; Ruan et al., 2002; Atik et al., 2007).

Growth parameters

The dry weights of the shoots and roots of the seedlings were measured immediately after 10 days. The dry weights were meausered after drying the shoot and root at 80℃ for 24 h, to standardize the weight.

Salt tolerance index

This value was calculated as the ratio of the total dry weight of plants subjected to different salt concentrations to the total dry weight of plants of control.

Salt tolerance index (%) = (TDW at S_x / TDW at S_0) × 100.

TDW = Total dry weight, S_0 = control, S_x = a given concentration out of five salt concentration.

The experiment was conducted by using randomized block desing with 4 replications. The data of germination percentage and stress tolerans index were transformed using by arcsine values prior to statistical analysis. Significant differences between treatments were determined using LSD test at the 0.05 level.

RESULTS AND DISCUSSION

The results showed that mesaured components of maize cultivars were significantly affected by salt concentrations (Table 1). At different salt concentrations, C-955 and Bora had the highest and lowest germination percentage as 98.06% and 81.94% respectively. PR 3394 had the second highest germination percentage (94.58 %). C-955 demonstrated better tolerance to salt stress than other cultivars for germination percentage. Rahman et al. (2000) reported that maize cultivars were significantly more tolerant to salt stress at germination than at later stages of growth. Seeds in the control dishes (0 mM NaCl) had the highest germination percentage (100%), and as the salt concentration increased, germination percentage decreased up to 250 mM NaCl concentration (Table 2). A higher germination percentages of cultivars at control (0 mM NaCl) were due to lack of salt in the medium. High concentration of NaCl in the salt solution increases its osmotic potential. In addition, high absorption of Na and Cl ions during seed germination can be due to cell toxicity that finally inhibits or slows the rate of germination and thus decreases germination percentage (Taiz and Zeiger, 2002). In this study, the responses of cultivars to different salt concentrations were found significantly different. This condition caused significant interactions between salt treatments and cultivars. This means that there are genetical differences among cultivars in respect of tolerance to salt stres. However, increasing salinity decreased the germination percentage in all cultivars, some of the cultivars were more tolerant than the others. As the result of this fact, the germination

Table 2. Effects of different salinity levels on germination and seedling characteristics of six maize cultivars.

Cultivar	Salt Concentrations (mM)						Means
	0	50	100	150	200	250	
Germination Percentage (%)							
Ada-523	100.00^{a}	97.50^{a-d}	95.83^{b-e}	95.00^{c-f}	85.00^{i-k}	71.67^{lm}	90.83^{c}
Bora	100.00^{a}	95.00^{b-f}	87.50^{h-k}	80.84^{j-l}	65.00^{mn}	63.33^{mn}	81.94^{d}
C-955	100.00^{a}	100.00^{a}	99.17^{ab}	98.34^{a-d}	99.17^{ab}	91.67^{f-i}	98.06^{a}
PR3394	100.00^{a}	100.00^{a}	98.33^{a-c}	96.67^{b-f}	93.33^{e-h}	79.17^{kl}	94.58^{b}
Progen-1550	100.00^{a}	100.00^{a}	96.67^{b-e}	85.84^{h-k}	81.67^{j-l}	54.17^{n}	86.39^{c}
Trebbia	100.00^{a}	99.17^{ab}	94.17^{d-g}	90.00^{g-j}	83.33^{i-k}	63.34^{mn}	88.33^{c}
Means	100.00^{a}	98.61^{a}	95.28^{b}	91.11^{c}	84.58^{d}	70.56^{e}	
Germination Index							
Ada-523	55.58^{a-c}	49.44^{e-h}	42.95^{j-l}	39.32^{lm}	30.33^{n-p}	19.90^{rs}	39.59^{d}
Bora	52.25^{c-e}	52.90^{b-e}	43.79^{i-k}	41.01^{k-m}	29.27^{op}	26.60^{pq}	40.97^{cd}
C-955	56.75^{a}	54.91^{a-c}	53.75^{a-d}	45.79^{h-j}	42.86^{j-l}	30.71^{no}	47.46^{a}
PR3394	55.71^{a-c}	52.21^{c-f}	49.80^{e-g}	41.46^{k-m}	32.51^{no}	23.45^{qr}	42.52^{b}
Progen-1550	54.62^{a-c}	50.08^{d-g}	47.58^{g-i}	38.56^{m}	31.30^{no}	19.12^{s}	40.2^{d}
Trebbia	56.43^{ab}	53.05^{a-e}	48.44^{f-h}	41.59^{k-m}	33.62^{n}	19.97^{rs}	42.18^{bc}
Means	55.22^{a}	52.10^{b}	47.72^{c}	41.29^{d}	33.32^{e}	23.29^{f}	
Shoot Dry Weight (mg plant^{-1})							
Ada-523	22.93^{cd}	21.61^{de}	16.09^{f-j}	15.86^{g-j}	10.33^{m-p}	5.12^{qr}	15.32^{b}
Bora	23.34^{b-d}	19.97^{d-f}	18.18^{e-h}	15.36^{h-k}	13.83^{i-m}	13.26^{j-m}	17.32^{a}
C-955	27.06^{b}	16.82^{f-j}	16.55^{f-j}	14.06^{i-m}	13.90^{i-m}	7.71^{o-q}	16.02^{ab}
PR3394	33.98^{a}	17.57^{f-i}	16.93^{f-j}	14.78^{h-i}	11.61^{k-n}	7.03^{p-r}	16.98^{a}
Progen-1550	25.80^{bc}	17.52^{f-i}	11.35^{l-o}	9.00^{n-q}	3.31^{rs}	1.23^{s}	11.37^{c}
Trebbia	21.56^{de}	19.45^{d-g}	19.58^{d-g}	16.17^{f-j}	14.21^{i-l}	9.27^{n-p}	16.71^{ab}
Means	25.78^{a}	18.82^{b}	16.44^{c}	14.21^{d}	11.20^{e}	7.27^{f}	
Root Dry Weight (mg plant^{-1})							
Ada-523	80.16^{a}	62.25^{b}	47.14^{ef}	45.28^{e-h}	39.16^{g-j}	28.53^{m-o}	50.42^{a}
Bora	61.77^{b}	43.97^{f-i}	38.62^{g-j}	37.38^{i-k}	31.57^{j-n}	26.91^{m-p}	40.04^{b}
C-955	46.39^{e-g}	47.77^{ef}	47.08^{ef}	45.58^{e-g}	33.63^{j-m}	24.24^{n-q}	40.78^{b}
PR3394	60.95^{b}	52.49^{c-e}	48.62^{d-f}	37.14^{i-l}	29.32^{l-o}	19.56^{pq}	41.34^{b}
Progen-1550	56.30^{b-d}	50.12^{d-f}	30.41^{k-o}	24.87^{n-q}	18.16^{q}	10.17^{r}	31.67^{c}
Trebbia	59.45^{bc}	49.79^{d-f}	44.97^{e-i}	37.63^{h-k}	29.94^{k-o}	22.81^{o-q}	40.76^{b}
Means	60.84^{a}	51.07^{b}	42.81^{c}	37.98^{d}	30.29^{e}	22.04^{f}	
Salt Tolerance Index							
Ada-523	100.00^{a}	83.71^{b-d}	60.23^{e-k}	59.50^{f-k}	48.11^{i-m}	32.87^{l-m}	64.07^{b}
Bora	100.00^{a}	77.70^{b-g}	68.92^{d-i}	64.80^{d-k}	56.00^{g-l}	48.93^{i-m}	69.39^{b}
C-955	100.00^{a}	92.75^{b}	91.39^{bc}	85.16^{b-d}	69.15^{d-i}	44.92^{j-m}	80.56^{a}
PR3394	100.00^{a}	73.86^{c-h}	69.09^{d-i}	54.88^{g-l}	43.13^{j-m}	28.00^{mn}	61.49^{bc}
Progen-1550	100.00^{a}	82.31^{b-e}	51.12^{h-m}	41.43^{k-m}	26.17^{mn}	14.13^{n}	52.53^{c}
Trebbia	100.00^{a}	85.70^{b-d}	79.93^{b-f}	67.06^{d-j}	55.08^{g-l}	40.00^{k-m}	71.29^{b}
Means	100.00^{a}	82.67^{b}	70.11^{c}	62.14^{c}	49.60^{d}	34.81^{d}	

* Different letters at the same line and coloum show significant differences at 0.05 level.

percentages of cultivars at 250 mM NaCl were arranged in gradually decreasing way as C-955 > PR3394 > Ada-523 > Trebbia, Bora > Progen-1550, when they were compared with control (Table 2). Our results were supported by many researches conducted on this subject (Rahman et al., 2000; Gill et al., 2002; Almodares et al., 2007; Blanco et al., 2007).

Cultivars had different responses in germination index at different levels of NaCl and cultivar C-955 had the highest germination index (47.46). Germination indices of all the cultivars decreased with increasing salt stress. Mean germination index of cultivars was 55.22 at control

(0 mM NaCl) while it decreased linearly to 23.29 at 250 mM NaCl (Table 2). Generally, increasing salinity levels decreased germination index in all of the cultivars, but C-955 had been less damaged and its germination index was greater than the other cultivars at 250 mM NaCl (Table 2).

Shoot dry weights of cultivars were negatively affected by increasing salt treatments. The average shoot dry weight of cultivars was 25.78 mg $plant^{-1}$ at control and this value gradually decreased throughout the increasing salt concentrations, and reached to 7.27 mg $plant^{-1}$ at 250 mM NaCl. The reduction rate in shoot dry weights of cultivars at 250 mM NaCl when compared with the control were detected in Ada-523 with 77.67%, Trebbia with 57.00%, Bora with 43.19%, C-955 with 71.51%, PR3394 with 79.31% and Progen-1550 with 95.23%. According to these values, the cultivars were arranged as following: Progen-1550 > PR 3394 > Ada-523 > C-955 > Trebbia > Bora (Table 2). Our results are in agreement with the results of other researchers. For example, Hussein et al. (2007), reported that a negative relationship was detected between vegetative growth parameters and increasing salinity. In same study, shoot dry weight was 52.01 mg $plant^{-1}$ at control while it decreased linearly to 25.26 mg $plant^{-1}$ at 4000 ppm. The same results were also obtained by other researchers (Alberico and Cramer, 1993; Cramer, 1993; Cramer et al., 1994; Mansour at al., 2005).

Root dry weight of cultivars decreased significantly as the levels of salinity increased from 0 to 250 mM NaCl. Thus, the highest root dry weight was determined at control and the lowest root dry weight at the highest salinity level. Among the cultivars, C-955 and Bora were affected least by salinity. The rate of reduction in root dry weight at 250 mM NaCl in comparison with the control was detected in Ada-523 with 64.41%, Trebbia with 61.13%, Bora with 56.44%, C-955 with 47.75%, PR3394 with 67.91% and Progen-1550 with 81.94%. According to the reduction rate in root dry weight from the highest to the lowest value the cultivars were arranged as Progen-1550 > PR 3394 > Ada-523 > Trebbia > Bora > C-955 (Table 2). Akram et al. (2007) reported that root dry weight of all corn hybrids showed a decline towards increase in salinity level. On the other hand, 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 and O'leary, 1997).

The salt tolerance index of cultivars at the early seedling stage also showed a large genotipic variation. C-955 had the highest salt tolerance index while Progen-1550 had the lowest. Therefore, C-955 demonstrated a better tolerance to salt stress than other cultivars. The effects of different salt concentrations on salt tolerance indices of cultivars were of importance. As the salt concentrations increased the salt tolerance indices of cultivars decreased. Therefore, the lowest value of salt tolerance index was determined at 250 mM NaCl (Table 2).

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