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Full Length Research Paper

Evaluation of salinity effects on germination and early growth of maize (*Zea mays* L.) hybrids

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In order to study the effect of salinity stress on germination and early growth of seedling of hybrids of maize, experiment was conducted at Seed Laboratory, Islamic Azad University, Shoushtar Branch, Iran in 2011. The principal aim of current study was to compare the hybrids of maize in relative to the stress conditions. This investigation was performed as factorial experiment under Completely Randomized Design (CRD) with three replications. There were seven hybrids of selected inbred lines and five salinity levels (0, -3, -6, -9 and -12 bar) of NaCl. Analysis of variance showed for hybrids, there were significant difference for all traits, except the length of radicle and the length of seedling. Results indicated that germination percentage, germination rate, length of radicle and plumule, length of seedling and seed vigour traits were decreased by decrease in osmotic potential, whereas the best performance was from seedlings germinated in pure water (control treatment). The mean germination time increased with decrease in the osmotic potential in NaCl solution. Hybrid K18×K47/2-2-21-2-1-1-1 was the most tolerant hybrid than other hybrids under salinity stress.

Key words: Early growth, germination, maize, Sodium Chloride, salinity stress.

INTRODUCTION

One of the most important abiotic factors limiting plant germination and early seedling stages is water stress brought about by drought and salinity (Almansouri et al., 2001), which are widespread problems around the world (Soltani et al., 2006). Water stress acts by decreasing the percentage and rate of germination and seedling growth (Delachiave and De Pinho, 2003). At low concentrations, salt suppresses plant growth and at higher concentration can cause death (Michael et al., 2004). It has also been reported that under saline conditions, germination ability of seeds differ from one crop to another and even a significant variation is observed amongst the different varieties of the same crop (Asana and Kale, 1965; Maas and Hoffman, 1977).

Among the cereal species, maize seems to be sensitive to salt stress (Maas et al., 1986), although intraspecies variability of salt resistant has been reported (Maas and Hoffman, 1977). Maize is being increasingly cultivated in Iran, with its cultivation area expanding to areas having high potential for accumulation of salts in the soil profile, such as Khuzestan. It is therefore important to develop new maize varieties with high genetic capacity to tolerate salt stress. The first important step in breeding new varieties with high salt tolerance is to have a useful and substantial genetic variation in tolerance to salinity stress.

Breeders seek to develop and identify cultivars that are more tolerant of salinity and water stress (Janmohammadi et al., 2008). Seed sowing generally considered the first critical and most sensitive stage in the live cycle of plants and seeds are frequently exposed to unfavorable environmental conditions that may compromise the establishment of seedling (Figueiredo-e-Albuquerque and Carvalho, 2003; Misra and Dwivedi, 2004). Mohammed et al. (2002) reported that by NaCl levels germination percentage decreased as mean germination time increased.

NaCl compound have been used to simulate osmotic stress effects in petri dish (*in vitro*) for plants to maintain uniform water potential throughout the experimental period (Kulkarni and Deshpande, 2007).

The present study was therefore mainly conducted to evaluate the effect of salinity on seed germination and seedling growth of seven maize hybrids under salinity conditions. The primary objective of the present study

Table 1. Pedigree/Origin of studied inbred lines of maize.

Inbred line	Pedigree sources/origin
Lancaster Sure Crop (LSC)	
K18	Derived from MO17 changes in Iran
K19	Derived from MO17 changes in Iran
Reid Yellow Dent (RYD)	
A679	A B73 back-cross derived line [(A662 × B73)(3)]
Extracted from late synthetic (Created in Iran)	
K3651/1	SYN-Late(Iran)
K3640/5	SYN-Late(Iran)
Lines extracted from CIMMYT originated materials in Iran	
K166A	
K166B	
Lines extracted from Unknown materials in Iran	
K47/2-2-21-2-1-1-1	

was to compare seven maize hybrids toward salinity stress and to select the most tolerant hybrid of maize.

MATERIALS AND METHODS

Effect of salt stress induced by different osmotic potential levels [(distilled water) 0, -3, -6, -9 and -12 bar] NaCl treatments on germination and early seedling development of maize were studied. Seven hybrids combinations of selected inbred lines (Table 1) of maize were used. This investigation was performed as factorial experiment under Completely Randomized Design (CRD) with three replications at Seed Laboratory, Islamic Azad University Shoushtar Branch in Iran in 2011. In each level of stress, twenty seeds of any hybrid were selected and sterilized in sodium hypochlorite (1%) and then washed in distilled water twice. The seeds of hybrids were germinated in petri dishes on 2 layers of filter paper in an incubator maintained at 25°C. Replacement of filter papers and addition of NaCl soluble was done as required. Germination rate was measured daily. Seeds were considered germinated when the emergent radicle reached 2 mm length. After 7 days, germination percentage was measured by ISTA (International Seed Testing Association) standard method. At end of the seventh day, the germination percentage, mean germination time (MGT) (Ellis and Robert, 1981), germination rate, the length of radicle and plumule of seeds, length of seedling and seed vigour were also measured.

$$GP = \frac{SNG}{SN0} \times 100 \qquad (1)$$

where GP is germination percentage, SNG is the number of germinated seeds, and SN0 is the number of experimental seeds with viability (Scott et al., 1984).

$$GR = \frac{\sum N}{\sum (n \times g)} \qquad (2)$$

where GR: Germination rate; N: the number of germinated seeds; n: number of germinated seed on growth day and g: Number of total germinated seeds (Ellis and Robert, 1981).

Seed vigour = Germination percentage × Seedling length (3)

For statistical analysis, the data of germinating percentage were transformed to arcsin $\sqrt{\frac{X}{100}}$. Analyses were done using the SPSS var. 16 software. Differences between means were determined by Duncan's Multiple Range Tests (DMRT) at probability level 5%. Drawings were made using Excel computer software.

RESULTS AND DISCUSSION

Analysis of variance showed that, there were significant differences between salinity stress levels. The results of this study reveal that various concentrations of NaCl had significant effect on the all measured traits. For hybrids, there were significant difference for all traits, except the length of radicle and the length of seedling. Also analysis of variance showed that, interaction effects was significant for all investigated traits (Table 2).

Germination percentage of all hybrids was adversely affected due to the application of different levels (0, -3, -6, -9 and -12 bar) of NaCl (Table 3). It was observed that, in all of hybrids there was a decrease in germination percentage due to salinity stress increment and maximum germination percentage was delayed. The study showed that all of the parameters taken were affected negatively by increase in salinity stress. Among the maize hybrids, hybrid K18×K47/2-2-21-2-1-1-1 had the highest germination percentage, and hybrid K18×K19 had the lowest germination percentage. At the highest

Table 2. Analysis of variance on mean of squares of measured traits maize hybrids under salinity stress.

Source of variance	Df	Germination (%)	Mean germination time	Germination rate	Length of radicle (cm)	Length of plumule (cm)	Length of seedling (cm)	Seed vigour
Salinity levels	4	2524**	3.3**	0.18**	44.6**	26.9**	138.9**	267736.4**
Hybrid	6	412.75**	3.5**	0.04**	0.81^{ns}	0.44*	1.5ns	12920**
Salinity levels × Hybrid	24	170.8**	3.9**	0.01**	2.3**	0.70**	3.3**	5766.9**
Error	70	39.2	0.29	0.002	0.68	0.18	1.07	2264.8

ns, *, ** indicates non significant, significant at 5 and 1% probability levels, respectively.

Table 3. Mean comparison of main effects of hybrids and salinity stress levels.

Treatment	Germination (%)	Mean germination time (day)	Germination (number in day)	Length of radicle (cm)	Length of plumule (cm)	Length of seedling (cm)
K18×A679	39.5^{bc}	2.1^{c}	0.31^{b}	1.6^{a}	1.56^{abc}	3.3^{ab}
K18× K47/2-2-21-2-1-1-1	70.2^{a}	2.9^{b}	0.36^{a}	2.1^{a}	1.59^{abc}	3.7^{ab}
K18×K19	30.8^{e}	3.6^{a}	0.29^{b}	2.2^{a}	1.3^{b}	3.5^{ab}
K18×K3651/1	43.5^{b}	3.0^{b}	0.34^{a}	1.8^{a}	1.7^{ab}	3.5^{ab}
K18×K166B	39.9^{bc}	3.4^{a}	0.30^{b}	2.0^{a}	1.6^{abc}	3.6^{ab}
K47/2-2-21-2-1-1-1×K3640/5	37.7^{cd}	2.7^{b}	0.24^{c}	2.2^{a}	1.8^{a}	4.1^{a}
K166A×K47/2-2-21-2-1-1-1	34.1^{de}	3.0^{b}	0.22^{c}	1.6^{a}	1.5^{bc}	3.1^{b}
0	70.5^{a}	2.39^{d}	0.42^{a}	4.1^{a}	3.05^{a}	7.2^{a}
-3 bar	45.1^{b}	2.8^{c}	0.36^{b}	2.7^{b}	2.4^{b}	5.1^{b}
-6 bar	42.3^{b}	3.0^{ab}	0.33^{b}	1.4^{c}	1.4^{c}	2.8^{c}
-9 bar	33.6^{c}	3.2^{ab}	0.31^{b}	0.9^{cd}	0.67^{d}	1.3^{d}
-12 bar	20.5^{d}	3.4^{a}	0.29^{c}	0.6^{d}	0.39^{e}	1.3^{d}

Means with similar letter(s) in each trait is not significantly different (P= 5%, Duncan's Multiple Range Test).

salt level -12 bar, K18×K47/2-2-21-2-1-1-1 and K18×K3651/1 produced maximum germination rate of all hybrids and they were considered as relatively tolerant. Results of means comparison showed that germination percentage and germination rate were decreased by increase in salinity concentration, while the maximum germination rate and percentage were obtained at 0 bar level (control treatment) (Table 3). Mayer and Poljakoff-Mayber (1989) obtained similar results which he attributed to absence of energy to start the germination process, as energy was obtained by increments in the respiratory pathway after the imbibitions and in low levels of water potential tax water absorption was processed slowly.

Also germination rate had the most important effect on stand establishment and plan density under laboratory and greenhouse conditions. This agreed with the results of Farsiani and Ghobadi (2009) and Khayatnezhad et al. (2010) in maize; Gholamin and Khayatnezhad (2010) in wheat and Mostafavi (2011) in safflower. Some studies revealed that stress can contribute to improved germination rate and seedling emergence in different plant species by increasing the expression of aquaporins (Gao et al., 1999), enhancement of ATPase activity, RNA and acid phosphathase synthesis (Fu et al., 1988), also by increase of amylases, proteases or lipases activity

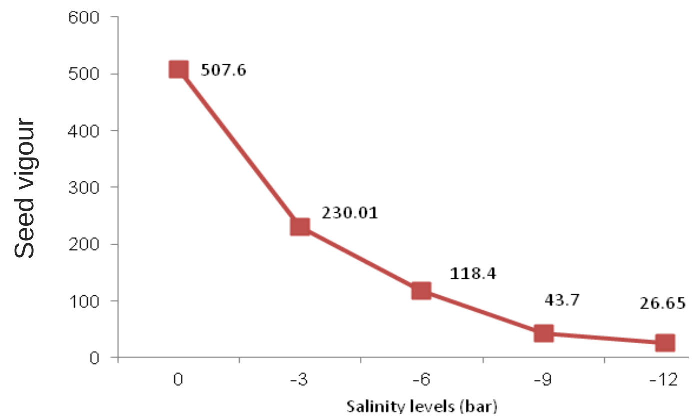

Figure 1. Seed vigour under salinity stress levels.

(Ashraf and Foolad, 2005).

Among the maize hybrids, K18×K19 and K18×K166B had the highest mean germination time. The mean germination time increased with decrease in the osmotic potential in NaCl solution (Table 3). In NaCl treatments, the mean germination time was delayed by stress conditions. Mohammed et al. (2002) reported that by NaCl levels germination percentage decreased and mean germination time increased proportionately. Alebrahim et al. (2008) reported that with a decrease in the osmotic potential in PEG and NaCl solutions, the mean germination time in lines of MO17 and B73 increased.

In his study on 6 genotypes of safflower, Mostafavi (2011) reported that the mean germination time increased with a decrease in the osmotic potential in NaCl solution.

The length of radicle is one of the most important traits for salinity stress because roots are in contact with soil and absorb water from soil. For this reason, the length of radicle provides an important clue to the response of plants to salinity stress. A marked reduction in the length of radicle, the length of plumule and the length of seedling of all hybrids of maize was attributed to salt stress. There were no significant differences in length of radical among the hybrid materials.

Among the maize hybrids, hybrid K47/2-2-21-2-1-1-1×K3640/5 had the longest plumule and seedling. Result of this study showed that, length of radical, plumule and seedling shortened with increasing salinity levels in all hybrids (Table 3). The best treatment in length of radicle, plumule and seedling was from the control treatment. Results obtained in this study is in agreement with many researches (Gholamin and Khayatnezhad, 2010; Farsiani and Ghobadi, 2009; Mohammadkhani and Heidari, 2008; Jajarmi, 2009; Khayatnezhad et al., 2010). Kramer (1974) reported that the first effect measurable due to water deficit was the growth reduction, caused by the decline in the cellular expansion. The cellular elongation process and the carbohydrates wall synthesis were very susceptible to water deficit (Wenkert et al., 1978) and the growing decrease was a consequence of the turgescence laying down of those cells (Shalhevet et al., 1995).

Seed vigour decreased with increase in concentration of NaCl solution. Best level of NaCl concentration in seed vigour was control treatment (Figure 1). A significant inter-genotype variation was observed under salt stress. Of all hybrids, K18×K47/2-2-21-2-1-1-1 produced highest seed vigour at all salt regimes (Figure 2). Mostafavi (2011) reported that seed vigour increased in osmotic potential until -3 bar but decreased in -5 bar and there were no statistical differences between measured genotypes at high salinity levels (-1.5 MPa) for seed vigour trait.

Conclusion

In the present study, salt stress adversely affected the germination percentage, germination rate, mean germination time, length of radicle, length of plumule, length of seedling and seed vigour of all 7 hybrids of maize and a significant variation in salt tolerance was observed among all the hybrids. Many researchers have reported similar results (Demir and Aril, 2003; Mauromicale and Licandro, 2002). Acceptable growth of plants in arid and semiarid lands which are under exposure of salinity stress is related to ability of seeds for best germination under unfavourable conditions, so necessity of evaluation of salinity tolerant genotypes is important at primary growth stage. To find the best tolerant genotype to such conditions, taking all traits into account in this study, we found that K18×K47/2-2-21-2-1-1-1 is the most tolerant genotype. It suggested that more experiments were carried out on the similar hybrids and further investigation be done on K18×K47/2-2-21-2-1-1-1 hybrid. Results of the current study were in agreement with other experiments in different plants including Farsiani and Ghobadi (2009) and Khayatnezhad et al.

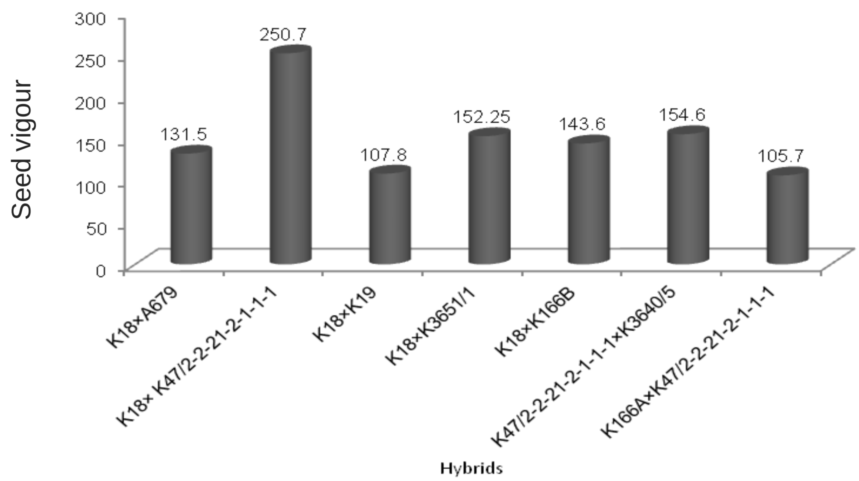

Figure 2. Seed vigour of maize hybrids under salinity stress levels.

(2010) in maize; Almansouri et al. (2001), Soltani et al. (2006) and Gholamin and Khayatnezhad (2010) in wheat; and Mostafavi (2011) in safflower.

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