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Full Length Research Paper

Evaluation of maize (*Zea mays* L.) hybrids, seed germination and seedling characters in water stress conditions

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Drought stress is one of the most important environmental factors that reduce growth, development and production of plants. Germination is one of the main growth stages, and success in this stage is dependent on moisture content of soil at time of planting. This study examined germination characteristics of four maize hybrids under four levels of osmotic potential (0, -3, -6 and -9 bar) polyethyleneglycol (PEG) 6000 using a 4 × 4 factorial experiment based on a completely randomized design (CRD) with three replications. Germination and early growth were affected by drought stress. Water potential significantly reduced germination percentage (92.8%), germination rate (69.2%), radicle length (80.3%), plumule length (85%), seedling length (83.2%) and seed vigour (98.8%). The mean germination time (70.4%) increased with decrease in the osmotic potential of PEG solution. Hybrid Simon produced the highest germination percentage, germination rate, radicle length, plumule length, seedling length and seed vigour, therefore this hybrid was the most tolerant hybrid to drought stress.

Key words: Early growth, germination, maize, polyethyleneglycol (PEG), water stress.

INTRODUCTION

Drought stress is one of the most important environmental factors that reduce growth, development and production of plants. It can be said that it is one of the most devastating environmental stresses. Iran, with an annual rainfall of 240 mm, is classified as one of the dry regions (Jajarmi, 2009).

Maize is an important cereal crop grown all over the world (Farhad et al., 2009). Also, it is a stable food and commercial crop (Tri-da et al., 2006) which is sensitive to drought (Khan et al., 2004).

Among the stages of the plant life cycle, seed germination and seedling emergence and establishment are key processes in the survival and growth of plants Hadas, 2004). Germination is regulated by duration of wetting and the amount of moisture in the growth medium (Schutz and Milberg, 1997; Gill et al., 2002).

Water stress acts by decreasing the percentage and rate of germination and seedling growth (Delachiave and De Pinho, 2003). Water stress not only affects seed germination but also increases mean germination time in maize plants (Willanborb et al., 2004). The adverse effect of water shortage on germination and seedling growth has been well reported in different crops such as corn (Mohammadkhani and Heidari, 2008; Farsiani and Ghobadi, 2009; Khayatnezhad et al., 2010; Mostafavi et al., 2011; Khodarahmpour, 2011).

Mostafavi et al. (2011) studied four maize hybrids in drought stress conditions and reported that hybrid KSC704 was tolerant, while KSC500 was sensitive to drought. Khayatnezhad et al. (2010) and Mostafavi et al. (2011) studied four maize hybrids in drought stress conditions and reported that hybrid golden west and KSC704 produced the highest radicle length, plumule length and seedling length, respectively.

Solutions of high molecular weight polyethylene glycol are often used to control water potential in seed germination studies (Hardegree and Emmerich, 1990). The polyethyleneglycol (PEG)-induced inhibition of germination has been attributed to osmotic stress (Dodd and Donovan, 1999; Sidari et al., 2008).

The aim of this study was to investigate the effects of osmotic stress generated by PEG on germination characteristics and seedling growth of maize hybrids. The primary objective of the present study was to compare the response of four maize hybrids to drought stress.

MATERIALS AND METHODS

Effect of water stress induced by different osmotic potential levels [(distilled water) 0, -3, -6, -9 and -12 bar] PEG 6000 treatments on germination and early seedling development of maize were studied. Four hybrids of maize were used. This investigation was performed as factorial experiment under completely randomized design (CRD) with three replications (for each hybrid and salinity level) at Seed Laboratory, Islamic Azad University, Shoushtar Branch, Iran in year 2012. This study was performed using Petri dishes (11 cm) containing two layered filter paper (90 mm). The selected seeds of each hybrid were first sterilized in sodium hypochlorite (1%) solution and then washed twice in deionized distilled water. Then, Petri dishes containing double layer filter paper were moistened with respective prepared PEG solutions. Thereafter, a selected number of seeds of each hybrid were soaked in these Petri dishes and then kept in an incubator (40% relative humidity) at 25°C. Daily germination rate was measured and filter papers were replaced when needed. Similarly, respective PEG solutions were added when required. Seeds were considered to have germinated when the emergent radicle reached 2 mm in length. After seven days, germination percentage was measured by International Seed Testing Association (ISTA) (1996) standard method. By the end of the 7th 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, radicle/plumule length ratio and seed vigor 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 is 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 of 1%.

RESULTS AND DISCUSSION

Analysis of variance showed that there were significant differences between drought stress levels. The results of this study reveal that various concentrations of PEG had a significant effect on all the measured traits, except radicle/plumule length ratio. For hybrids, there were significant differences for all traits, except mean germination time, germination rate and radicle/plumule length ratio. Also, analysis of variance showed that interaction effects were significant for all investigated traits except radicle/plumule length ratio (Table 1).

Germination percentage and rate

According to results of mean comparison, hybrid Simon (42.3%) had the highest germination percentage and there was no significant difference with hybrid L3 (33.9%), but hybrids Maxima (24.9%) and Bolson (17.7%) had the lowest germination percentage, respectively (Table 3). Germination percentage of all hybrids was adversely affected due to the application of different levels (-3, -6 and -9 bar) of PEG. It was observed that in all the hybrids, there was a decrease in germination percentage due to drought stress increment and maximum germination percentage was delayed. In this experiment, different hybrids had different response to the drought stress. Mean germination percentage for all hybrids was 59.2% for control (0 bar) but 4.2% at osmotic potential of -9 bar (Table 2).

Hybrids Bolson (0.30), Maxima (0.31) and Simon (0.33) had the highest germination rate. Result of means comparison showed that germination percentage (92.8%) and germination rate (69.2%) were decreased by decrease in osmotic potential, while the maximum germination rate and percentage were obtained in control treatment (Table 2). Germination rate for all hybrids was 0.65 for control but 0.20 at osmotic potential of -9 bar (Table 2). This agreed with the results of Khayatnezhad et al. (2010), Khodarahmpour (2011) and Mostafavi et al. (2011). According to Ayaz et al. (2001), decrease in seed germination under stress conditions is due to some metabolic disorders. It seems that, decrease in germination percentage and germination rate is related to reduction in water absorption into the seeds at imbibitions and seed turgescence stages (Hadas, 1977).

Mean germination time

Among the maize hybrids, L3 (4.15 days) had the highest mean germination time (Table 3). The mean germination time (70.4%) increased with increase in the concentration of PEG solution (Table 2). Mean germination time for all hybrids was 1.5 days for control but 5.6 days at osmotic potential of -9 bar (Table 2). In PEG treatments, the mean germination time was delayed by stress conditions. Water stress not only affects seed germination but also increases mean germination time in crop plants (Willanborb et al., 2004). Khodarahmpour (2011) reported that the mean germination time increased with decrease

Table 1. Analysis of variance on mean of squares of measured traits maize hybrids under drought stress.

Source of variance	Df	Germination (%)	Mean germination time (day)	Germination rate (number in day)	Radicle length (cm)	Plumule length (cm)	Seedling length (cm)	Radicle/plumule length ratio	Seed vigour
Drought levels	3	7319.39**	33.66**	0.68*	30.62**	83.85**	210.62**	2.23^{ns}	1193089.12**
Hybrid	3	1370.31**	2.95^{ns}	0.15^{ns}	28.45**	72.54**	180.31**	1.63^{ns}	548791.01**
Drought levels×Hybrid	9	96.19*	7.38**	0.19*	2.33*	1.44*	4.71*	0.96^{ns}	113369.68**
Error	32	66.10	2.32	0.20	2.69	2.21	6.29	0.83	20228.20

^{ns}, *, **, Non-significant, significant at 5 and 1% probability levels, respectively.

Table 2. Mean comparison of main effects of drought stress levels.

Drought stress	Germination (%)	Mean germination time (day)	Germination rate (number in day)	Radicle length (cm)	Plumule length (cm)	Seedling length (cm)	Radicle/plumule length ratio	Seed vigour
0	59.15^{a}	1.5^{cd}	0.65^{a}	4.47^{a}	6.87^{a}	11.34^{a}	0.82^{a}	670.76^{a}
-3	40.11^{b}	2.54^{c}	0.39^{b}	2.89^{ab}	2.53^{b}	5.42^{b}	1.51^{a}	217.40^{b}
-6	15.37^{c}	4.61^{b}	0.22^{c}	1.48^{bc}	1.64^{b}	3.12^{c}	1.34^{a}	47.95^{c}
-9	4.23^{d}	5.06^{a}	0.20^{c}	0.88^{c}	1.03^{b}	1.91^{d}	0.59^{a}	8.08^{d}
Decrease percent	-92.8	+70.4	-69.2	-80.3	-85.0	-83.2	-	-98.8

Mean with similar letter(s) in each trait is not significantly different (P = 1% Duncan's multiple range test).

Table 3. Mean comparison of main effects of maize hybrids.

Hybrid	Germination (%)	Mean germination time (day)	Germination rate (number in day)	Radicle length (cm)	Plumule length (cm)	Seedling length (cm)	Radicle/Plumule length ratio	Seed vigour
Bolson	17.72^{c}	3.36^{b}	0.30^{a}	1.86^{bc}	1.87^{b}	3.73^{bc}	0.83^{a}	66.09^{c}
L3	33.93^{ab}	4.15^{a}	0.24^{b}	2.97^{ab}	2.24^{b}	5.2^{b}	1.45^{a}	176.44^{b}
Maxima	24.92^{bc}	3.24^{b}	0.31^{a}	0.64^{c}	1.30^{b}	1.94^{c}	1.29^{a}	48.34^{c}
Simon	42.29^{a}	3.01^{b}	0.33^{a}	4.24^{a}	6.66^{a}	10.90^{a}	0.68^{a}	460.96^{a}

Mean with similar letter(s) in each trait is not significantly different (P = 1% Duncan's multiple range test).

in the osmotic potential of PEG solution. 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.

Radicle, plumule, seedling length and radicle/plumule length ratio

The radicle length provides an important clue to the response of plants to drought stress. A significant reduction in radicle length, plumule length and seedling length of all hybrids of maize was observed because of drought stress. Among the maize hybrids, hybrid Simon had the highest radicle length, plumule length and seedling length

(Table 3). Khayatnezhad et al. (2010) and Mostafavi et al. (2011) studied four maize hybrids in drought stress conditions and reported that hybrid golden west and KSC704 produced the highest radicle length, plumule length and seedling length, respectively. Results of this study show that, radicle length, plumule length and seedling length decreased with increasing drought levels in all hybrids. The most effective level in reducing radicle length and seedling length was -9 bar of PEG, but the most effective level in reducing plumule length was -3 bar of PEG (Table 2). The best level of PEG concentration in radicle length, plumule length and seedling length was the control treatment (Table 2). Between hybrids and different drought levels, there were no significant differences for radicle/plumule length ratio (Tables 2 and 3).

Water stress acts by decreasing the percent and rate of germination and seedling growth (Farsiani and Ghobadi, 2009; Khayatnezhad et al., 2010). There are reports in the literature of potential drought resistance traits like extensive viable radicle system that could explore deeper soil layers for water (Mirza, 1956; Bocev 1963). Maize plants with more radicles at seedling stage subsequently developed stronger radicle system, produce more green matter and had higher values for most characters determining seed yield (Bocev, 1963).

Seed vigour

Among the hybrids, hybrid Simon was affected the least by drought stress because it gave the lowest reduction rate for seed vigour (Table 3). Seed vigour decreased (98.8%) with increase in concentration of PEG solution. The best level of PEG concentration in seed vigour was the control treatment (Table 2). Maximum reduction in seed vigour was observed at -9 bar of PEG (Table 2). Khodarahmpour (2011) reported that seed vigour decreased with increase in concentration of PEG solution to 91.7%. Also, maximum reduction in seed vigour was observed at -9 bar of PEG. Mostafavi et al. (2011) studied four corn hybrids in drought stress conditions and reported that hybrid KSC704 produced the highest seed vigour.

Conclusion

Drought affected the morphological behavior of maize hybrids. From the present results, it can be concluded that in our experimental conditions, germination of maize hybrids was reduced by only 4.23% under an osmotic potential of -9 bar. The variation among hybrids showed that germination percentage decreased with an increase in PEG-6000 concentration in all the hybrids. Hybrid Simon produced the highest germination percentage, germination rate, radicle length, plumule length, seedling length and seed vigour. Therefore, hybrid Simon performed better than others. Many reports indicated that germination percentage and seed vigour can be utilized as screening criteria for stress tolerance. In the present study, the findings are very similar to the former case, in which germination decreased due to the increase in PEG-6000 concentration. This study strongly supports the assertion that germination indices can be utilized to screen maize hybrids for drought tolerance at germination and early seedling growth stage. There are many reports which are in agreement with the present findings indicating that drought stress severely reduces seed germination and early seedling growth, but the varieties having genetic potential to maintain the higher growth under stress conditions are drought tolerant. Emergence rate is an important criterion in breeding for high yield, especially under drought conditions because the seedlings with high emergence rate will have an edge in competition for space, light and water resources, and eventually have highest yield as compared to other. Drought reduced emergence index in most populations, and those showing high emergence rate with low susceptibility might be helpful in evolving better performing maize cultivars under drought conditions. Water stress due to drought is probably the most significant abiotic factor limiting plant and also crop growth and development (Hartmann et al., 2005). Therefore, it was necessary to identify hybrids tolerance to drought at the primary growth stage. This study shows that Simon was the most tolerant hybrid to such conditions, taking all traits into account.

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