

Studies on response of maize genotypes against PEG–6000 for various effects under drought stress

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Abstract: Drought is one of the most serious problems posing a grave threat to cereal production, including maize. The present study was conducted in the laboratory of the division of Genetics and Plant Breeding, Faculty of Agriculture, Wadura. Ten genotypes of maize were evaluated comprising of released composites in white and yellow group along with derived lines from crosses of GM-6, a drought tolerant composite. The present investigation was performed under artificially imposed drought stress by PEG-6000 at four levels of drought treatment {distilled water (0), 10, 15 and 20 per cent}. Results indicated significant differences among the genotypes and drought stress levels. Further, the results indicated that significant decrease was observed in primary root length, root biomass, seminal root number and lateral root number. Based on the results, genotypes KDM-111 followed by SMC-3 and DT-1 exhibited lesser reduction in total root length and KG-2 followed by SMC-3 and SMC-4 in root weight, GM-6 followed by KDM-111 and KG-2 in number of seminals and GM-6 followed by KDM-111 and C-15 in number of laterals. Hence, there was a progressive decline in all the parameters across all genotypes with an increase in PEG concentration from 0–20 per cent level, respectively.

Keywords: Drought · Genotype · Maize · PEG · Root

Introduction

Water stress is one among the major limiting factors in rainfed agriculture resulting in reduced crop growth and productivity (Ghassemi-Golezani *et al.*, 2009). Water is the basic requirement for all the growth stages of plant and it is also limited in some areas such as arid and semi-arid region of the world. Water is required by the plant for its growth and development. Without water the plant goes under drought condition and severally affects its growth stages and ultimately yield of crops is reduced. Maize (*Zea mays* L.) is one of the most versatile cereal crops having wider growth adaptability under varied agro-climatic conditions and also has the highest yield potential among the cereals. It is one of the important cereal crops in India after rice and wheat, grown in all the states. Also, it is a staple food and commercial crop which is sensitive to drought. The most important stage of crop is seed germination in the presence of water so, growing seeds under drought stress conditions, effects the growth of plant (Albuquerque *et al.*, 2003). The polyethylene glycol (PEG) has high molecular weight and is important for controlling germination of seed by creating osmotic stress in plants. The PEG inhibits seed germination by creating stress in plants (Sidari *et al.*, 2008). Several physiological characteristics have been reported as being reliable indicators for the selection of germplasm possessing drought tolerance. These characteristics include seed germination and seedling growth in nutrient solutions with low osmotic potential (Richards *et al.*, 1978; Blum *et al.*, 1981; Ashraf *et al.*, 1992). The success of these approaches requires evidence that the drought tolerance of cultivars tested under laboratory reflects this character under field conditions (Sammons *et al.*, 1978).

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The aim of this study was to investigate the effects of osmotic stress generated by PEG-6000 on germination stage and water stress at seedling growth of maize genotypes. The primary objective of the present study was to screen out the most tolerant and most sensitive maize genotypes under drought stress.

Materials and methods

The present study was conducted during 2017 at the green house faculty of the Division of Genetics and Plant Breeding, Faculty of Agriculture, Wadura, SKUAST-K Sopore. Ten genotypes of maize comprising of released composites in white and yellow group along with derived lines from crosses of GM-6 a drought tolerant composite were evaluated in the present study viz., composite-8 (C-8), C-15, Kishan Ganga-2 (KG-2), Gujarat Makka-6 (GM-6), SMC-3, SMC-4, DT-1, DT-2, KDM- 111 and Mahi Dhawal, respectively. In case of experiment with polyethylene glycol, PEG-6000 (HIMEDIA) was used in four concentrations viz., control (0%), 10, 15 and 20 per cent. Four seeds for each genotype were surface sterilized with 0.5 per cent NaOCl for one minute, rinsed thoroughly with distilled water and were put in petri plates containing moist filter paper with different concentrations of PEG and allowed to germinate in a germinator at 25°C and 75 per cent humidity in darkness. Radicle length, root biomass, seminal root number and lateral root number was measured after seven days. The design used was completely randomized design with four replications.

Results

In vitro response of maize genotypes to PEG mediated screening

The genotypes used in the present study were evaluated for response to PEG-6000 given in Table 1 at different levels (0, 10, 15 and 20%) and the results are given below under appropriate headings:

1. Length of radical (cm)

The data recorded under controlled conditions for length of radical under different levels of PEG-6000 are as under:

0% level: Under 0%, the length of radical had a mean value of 14.56 with the highest value recorded in DT-1 (17.50) followed by SMC-4 (17.50) and C-8 (16.75) and was lowest in KDM-111 (9.50) followed by KG-2 (12.75).

10% level: Under 10%, the length of radical had a mean value of 8.15 with highest value recorded in DT-1 (11.00) followed by GM-6 (9.50) and DT-2 (9.50) and the lowest was in SMC-3 (4.25) followed by KG-2 (7.00).

15% level: Under 15%, the length of radical had a mean value of 5.5 with highest value recorded in GM-6 (7.50) followed by SMC-4 (6.50) and DT-1 (6.00) and the lowest was in SMC-3 (3.50) followed by Mahi Dhawal (4.50).

20% level: Under 20%, the length of radical had a mean value of 3.97 with highest value recorded in DT-2 (5.00) followed by KG-2 (5.00) and GM-6 (4.50) and the lowest was in KDM-111 (2.75) followed by SMC-3 (3.00).

Table 1. Mean response of maize genotypes to PEG mediated screening

Genotype	Total root length (cm)				Root weight (g)				Number of seminals				Number of laterals			
	0%	10%	15%	20%	0%	10%	15%	20%	0%	10%	15%	20%	0%	10%	15%	20%
C 8	16.75	8.50	5.50	3.50	0.51	0.46	0.48	0.23	5.00	4.00	3.00	2.50	25.50	20.50	18.00	3.50
C 15	15.25	9.00	5.50	3.75	0.52	0.53	0.44	0.33	6.50	5.50	3.50	3.00	27.50	22.50	9.50	2.00
SMC 3	15.50	4.25	3.50	3.00	0.33	0.27	0.20	0.14	4.50	3.50	2.00	1.50	17.50	14.00	11.00	9.00
SMC 4	17.50	7.75	6.50	4.50	0.56	0.50	0.47	0.22	6.00	4.50	2.50	1.50	17.50	13.00	12.00	7.50
KG 2	12.75	7.00	5.50	5.00	0.49	0.22	0.20	0.11	3.50	2.500	1.50	1.00	22.00	20.00	12.50	4.50
DT 1	17.50	11.00	6.00	3.50	0.67	0.63	0.59	0.39	9.50	7.500	6.00	4.50	34.00	29.50	22.50	5.50
DT 2	13.50	9.50	5.50	5.00	0.63	0.48	0.54	0.36	8.50	6.500	4.50	4.00	32.00	20.50	26.500	6.50
KDM 111	9.50	7.50	5.00	2.75	0.61	0.50	0.37	0.29	4.50	2.500	1.50	1.00	31.00	27.00	25.000	1.00
GM 6	13.85	9.50	7.50	4.50	0.32	0.27	0.23	0.18	6.50	4.500	3.50	1.00	25.00	19.00	7.500	1.00
Mahi Dhawal	13.50	7.50	4.50	4.20	0.62	0.35	0.29	0.18	5.50	4.000	4.00	3.50	10.50	7.50	6.500	5.50
Mean	14.56	8.15	5.5	3.97	0.52	0.42	0.38	0.24	6.00	4.50	3.20	2.35	24.25	19.35	15.1	4.6
CD (p≤0.05)	Genotype = 1.07 PEG Levels = 0.68				Genotype = 0.04 PEG Levels = 0.03				Genotype = 0.74 PEG Levels = 0.47				Genotype = 2.14 PEG Levels = 1.35			

2. Root biomass (g)

The data recorded under controlled conditions for root biomass under different levels of PEG-6000 are as under:

0% level: Under 0%, the root biomass had a mean value of 0.52 with highest value recorded in DT-1 (0.67) followed by DT-2 (0.63) and Mahi Dhawal (0.62) and the lowest was in GM-6 (0.32) followed by SMC-3 (0.33).

10% level: Under 10%, the root biomass had a mean value of 0.42 with highest value recorded in DT-1 (0.63) followed by C-15 (0.53) and SMC-4 (0.50) and the lowest was in KG-2 (0.22) followed by GM-6 (0.27).

15% level: Under 15%, the root biomass had a mean value of 0.38 with highest value recorded in DT-1 (0.59) followed by DT-2 (0.54) and C-8 (0.48) and the lowest was in SMC-3 (0.20) followed by KG-2 (0.20).

20% level: Under 20%, the root biomass had a mean value of 0.24 with highest value recorded in DT-1 (0.39) followed by DT-2 (0.36) and C-15 (0.33) and the lowest was in SMC-3 (0.14) followed by GM-6 (0.18).

3. Number of seminals

The data recorded under controlled conditions for number

of seminals under different levels of PEG-6000 are as under:

0% level: Under 0%, the number of seminals had the highest value recorded in DT-1 (9.50) followed by DT-2 (8.50) and C-15 (6.50) and the lowest was in KG-2 (3.50) followed by SMC-3 (4.50), with a mean value of 6.00.

10% level: Under 10%, the number of seminals had a mean value of 4.50 with highest value recorded in DT-1 (7.50) followed by DT-2 (6.50) and C-15 (5.50) and the lowest was in KG-2 (2.50) followed by KDM-111 (2.50).

15% level: Under 15%, the number of seminals had a mean value of 3.20 with the highest value recorded in DT-1 (6.00) followed by DT-2 (4.50) and Mahi Dhawal (4.00) and the lowest was in KG-2 (1.50) followed by KDM-111 (1.50).

20% level: Under 20%, the number of seminals had the highest value recorded in DT-1 (4.50) followed by DT-2 (4.00) and Mahi Dhawal (3.50) and was lowest in KDM-111 (1.00) followed by GM-6 (1.00), having a mean value of 2.35.

4. Number of laterals

The data recorded under controlled conditions for number

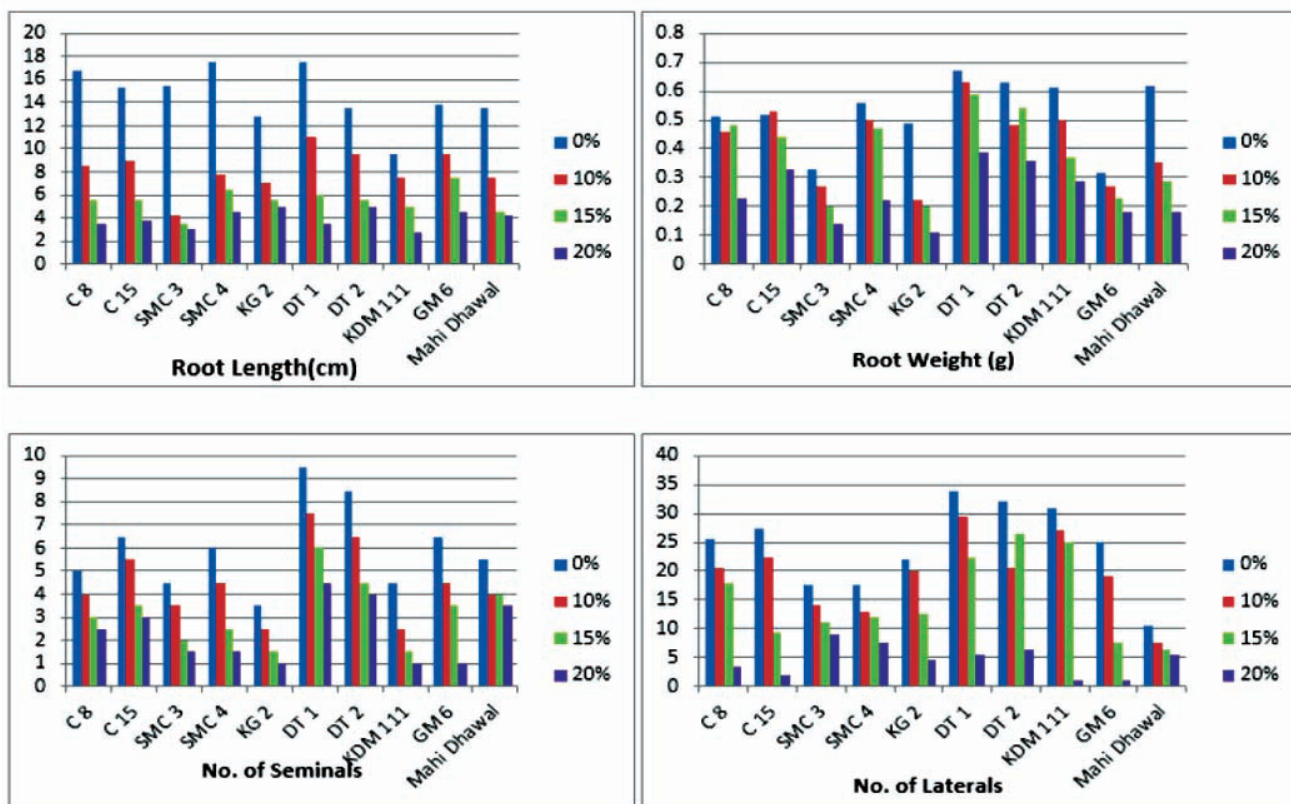
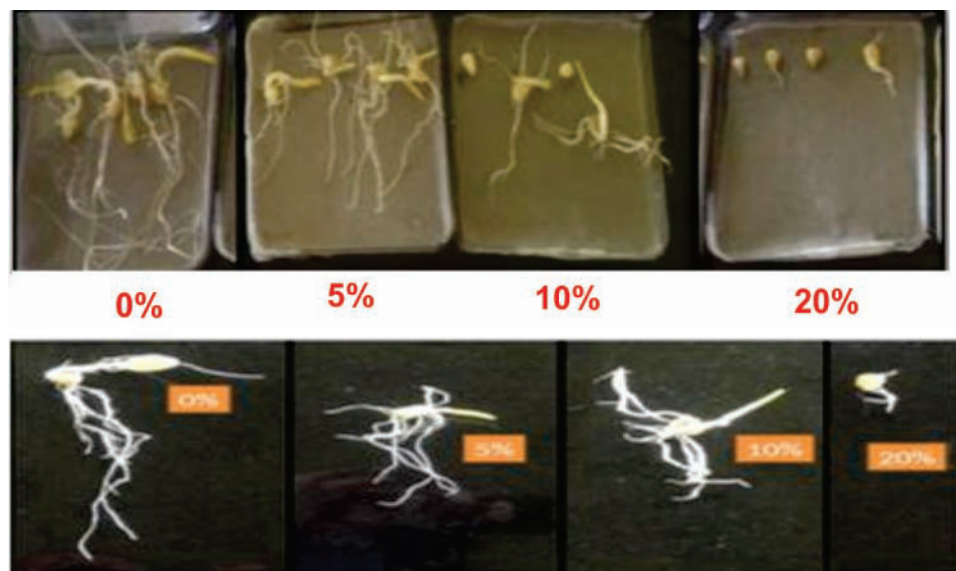


Figure 1. Response of maize genotypes to PEG-6000 mediated screening

Figure 2. PEG-6000 response of DT-1 genotype under different concentrations



of laterals under different levels of PEG-6000 are as under:

0% level: Under 0%, the number of laterals had a mean value of 26.45 with the highest value recorded in C-8 (37.50) followed by C-15 (37.50) and DT-1 (34.00) and the lowest was in SMC-3 (17.50) followed by SMC-4 (17.50).

10% level: Under 10%, the number of laterals had a mean value of 21.85 with the highest value recorded in C-8 (35.50) followed by C-15 (32.50) and DT-1 (29.50) and the lowest was in Mahi Dhawal (7.50) followed by SMC-4 (13.00).

15% level: Under 15%, the number of laterals had a mean value of 18.5 with the highest value recorded in C-8 (31.00) followed by C-15 (30.50) and DT-2 (26.50) and the lowest was in Mahi Dhawal (6.50) followed by GM-6 (7.50).

20% level: Under 20%, the number of laterals had a mean value of 9.50 with the highest value recorded in C-8 (23.50) followed by C-15 (21.00) and DT-2 (10.50) and was lowest in KDM-111 (1.00) followed by GM-6 (1.00).

Analysis of variance for root traits scored under laboratory screening

Analysis of variance for various root traits scored under laboratory conditions is presented in Table 2 which showed that mean square due to genotypes was significant for all the traits.

Discussion

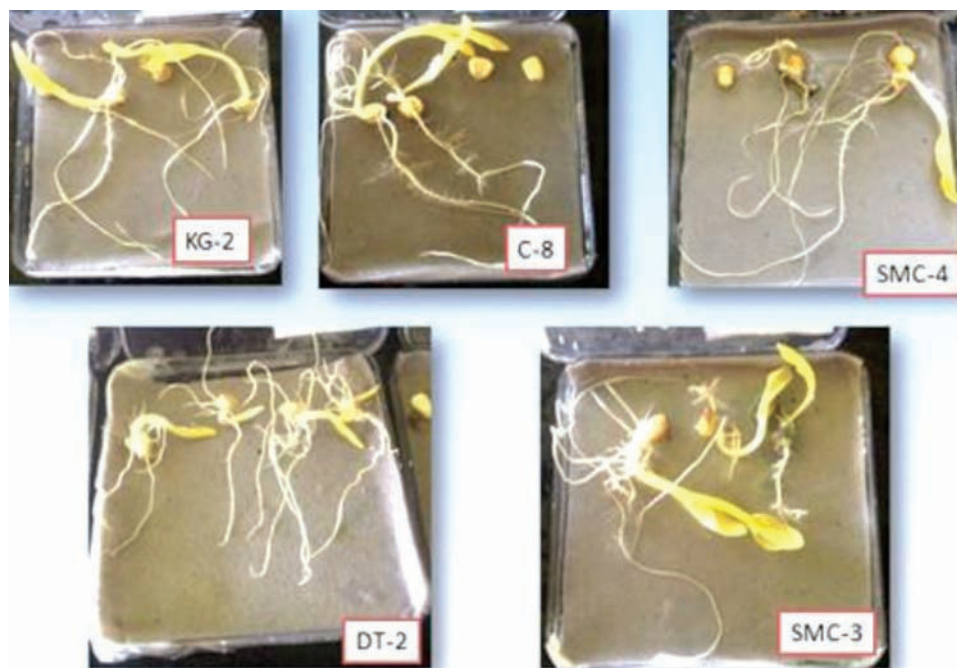
In the present study, polyethylene glycol (PEG) compounds have been used to stimulate osmotic stress effects in petri dish (*in vitro*) for plants to maintain uniform water potential throughout the experimental period. There was a progressive decline in all the parameters across all genotypes with increase in PEG concentration from 0–20 per cent level and the parameters, length of radical, root biomass, number of seminals and number of laterals had the highest value under control and had significant differences under water stress. Under 0%, length of radical had the highest value in DT-1 and lowest in KDM-111. Under 10 per cent, it had the highest value in DT-1 and the lowest in SMC-3. Under 15 per cent, it

Table 2. Analysis of variance for root traits under PEG-6000 mediated screening

Source of variation	df	Total root length (cm)	Root weight (g)	Number of seminals	Number of laterals
Genotype	9	9.361**	0.105**	17.735**	515.200**
Replication	3	422.593	0.271	50.746	1002.617
Genotype × replication	27	5.982	0.007	0.653	43.330
Error	40	1.125	0.002	0.538	4.475

**Significant at 0.05% level

Figure 3. PEG-6000 response of maize genotypes under various concentrations



had the highest value in GM-6 and lowest in SMC-3. Under 20 per cent, the highest value was recorded in DT-2 and lowest in KDM-111. However, root biomass under 0, 10 and 15 per cent had the highest value in DT-1 and the lowest in GM-6, KG-2 and SMC-3, while root biomass had the highest value in DT-2 and the lowest in SMC-3 under 20 per cent level of PEG-6000. Similarly, number of seminal roots under 0, 10, 15 and 20 per cent had the highest value in DT-1 and lowest in KG-2 and under various PEG concentrations (0, 10, 15 and 20 per cent) number of laterals had the highest value recorded in C-8 and lowest in SMC-3, Mahi Dhawal and KDM-111. Results of the current study were in agreement with other experiments in different plants including (Kalefetoglu *et al.*, 2009) in chickpea, (Almansouri *et al.*, 2001; Soltani *et al.*, 2006) in wheat.

The polyethylene glycol (PEG)-induced inhibition of germination has been attributed to osmotic stress (Dodd and Donovan, 1999; Sidari *et al.*, 2008). The solutions of high molecular weight polyethylene glycol are often used to control water potential in seed germination studies (Hardegree and Emmerich, 1990). Water stress acts by decreasing the percentage and rate of germination and seedling growth (Delachave and De Pinho, 2003). Water stress not only affects seed germination but also increases mean germination time in crop plants (Willenborb *et al.*, 2004). The adverse effect of water shortage on germination and seedling growth has been well reported in different crops such as corn (Farsiani and Ghobadi,

2009; Khayatnezhad *et al.*, 2010; Mostafavi *et al.*, 2011), wheat (Jajarmi, 2009), sorghum (Gill *et al.*, 2002), sunflower (Mohammed *et al.*, 2002). This agreed with the results of Khayatnezhad *et al.* (2010) and Mostafavi *et al.*, (2011) in corn, Jajarmi (2009) in wheat and Mostafavi (2011) in safflower. According to Ayaz *et al.* (2000) decrease of seed germination under stress conditions was due to the occurrence of some metabolic disorders. It seems that decrease of germination percentage and rate is related to reduction in water absorption into the seeds at imbibitions and seed turgescence stages (Hadas, 1977). Water deficit affects the germination of seed and the growth of seedlings negatively as germination is one of the most important traits in early stage of growth in most plants. The adverse effect of water shortage on germination and seedling growth has been well reported in different crops (Mostafavi *et al.*, 2011). An artificially created water-stress environment is used to provide the opportunity in selecting superior genotypes out of a large population. Therefore, it is necessary to identify genotypes that are tolerant to drought at the primary growth stage.

Conclusion

Keeping in view the above stated research finding it can be concluded that genotypes viz., KDM-111 followed by SMC-3 and DT-1 exhibited lesser reduction in total root length and KG-2 followed by SMC-3 and SMC-4 in root weight, GM-6 followed by KDM-111 and KG-2 in number

of seminals and GM-6 followed by KDM-111 and C-15 in number of laterals. There was a progressive decline in all the parameters across all genotypes with increase in PEG concentration from 0–20 per cent level. The genotypes had significant differences under water deficit stress and hence, those genotypes having potential genetic sources to maintain the higher growth under stress conditions are considered to be drought tolerant.

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