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RESEARCH PAPER

Seedling drought tolerance in maize genotypes

RAJESHWARI HUGAR, G. K. NAIDU, R. M. KACHAPUR AND K. N. PAWAR

Department of Genetics and Plant Breeding, College of Agriculture, Dharwad
University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
E-mail: naidug@uasd.in

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Abstract: Maize is one of the most important crops, but its production is threatened by drought stress worldwide. So improving grain yield is of great importance considering more frequent severe droughts in the climate change scenario. Hence, the present investigation was carried out at the Main Agricultural Research Station, UAS, Dharwad during 2020-21 to study the seedling drought tolerance in 28 maize genotypes by subjecting to different osmotic levels (0 %, 10 % and 20 %) induced by poly ethylene glycol in factorial completely randomized design with three replications by using slanting plate technique. Highly significant differences among genotypes, PEG levels and interaction between PEG levels and genotypes was observed for all the seedling traits. High heritability coupled with high GAM was observed for germination percentage and seedling traits except germination velocity index under 20 % PEG. The genotypes PDM 4641, DIM 204, GPM 114, PML 46 and PML 93 showed less per cent reduction in germination over control at 10 % and 20 % PEG. Hence, can be considered as potential drought tolerant genotypes at seedling level. These genotypes could be tested for their drought tolerance and yielding ability under field conditions before utilizing them in the crop improvement programme.

Key words: Drought, Heritability, Maize, Osmotic potential

Introduction

Maize (*Zea mays* L.), a versatile crop, belongs to the family Poaceae and is known as "Queen of cereals'' because of its outstanding production potential and wider range of climatic adaptability. In the World, maize occupies an area of 193.7 m ha, with the productivity of 5.75 t ha^{-1} and production of 1147.7 mt (ICAR-IIMR, 2020). In India, it is grown over an area of 9.2 m ha with the production of 27.8 mt and the productivity is 3.02 t ha^{-1} (ICAR-IIMR, 2020). In Karnataka, it is cultivated in an area of 13.4 lakh hectares with the production of 37.3 lakh tonnes and productivity of 27.77 qha^{-1}. Important maize growing districts in Karnataka are Davangere, Belagavi, Haveri, Bellary, Chitradurga, Vijayapura and Bagalkote (ICAR-IIMR, 2020).

In contemporary times, with the ever-surging realization of the fear of the catastrophic effects of global climate change, an inflated insistence on world food security and its impact at the regional stages specifically, have come to the front line of scientific community. Thus, crop growth, development, water use and yield under normal condition are majorly established by weather conditions during the growing season of the crop. Unexpectedly, with slight diversions from regular weather conditions, the proficiency of genotype performance, notable applied inputs and food production is gravely under determined. Among the various abiotic stresses, drought is an important one.

Drought is a multidimensional stress that affects plants at various levels of their organization over time and place, resulting in complicated and often unpredictable physiological responses. Moisture stress is seriously affecting the maize crop resultantly hindering the productivity like other crops (Tai *et al*., 2011). Being drought sensitive crop, maize is affected at each and every stage of growth and development by low moisture availability. Prevalence of drought at seedling stage causes poor crop stand and under extreme conditions it can result in complete failure of seedling establishment (Zeid and Nermin, 2001). The damaging effect of drought was more severe when it coincides with germination, seedling development and flowering stages (Khayatnezhad *et al.,* 2010 and Tsago *et al.,* 2014). It shows that crop sensitivity to water stress at early growth stage plays an important role in overall success of a crop. Polyethylene glycol (PEG) is metabolically inactive compound frequently used to induce uniform drought stress at early germination and seedling growth stages to study the effects of water stress in different groups of plants (Kauser *et al.,* 2006, Khodarahmpour, 2011 and Shamim *et al.,* 2014). Keeping these points in view, the current study was planned to assess the seedling drought tolerance in maize genotypes. An artificially created water stress environment using Poly Ethylene Glycol (PEG) was used to study seedling drought tolerance and select drought tolerant genotypes for emergence and early seedling traits.

Material and methods

The laboratory experiment was carried out at All India Coordinated Research Project on Maize, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad to study the effect of drought stress by subjecting to different osmotic concentrations (0 %, 10 % and 20 %) induced by PEG-6000 on germination and early seedling growth characters. The experiment was performed as Factorial Completely Randomized Design with three replications by using slanting plate technique (Babu *et al.,* 2014). Twenty-eight diverse maize genotypes were collected from AICRP on Maize and Indian Agricultural Research Institute Regional centre, Dharwad for the study. Pedigree and source details of the genotypes are given in Table 1.

Slanting plate technique methodology

Glass plates having 3 mm thickness with 25 cm length and 30 cm width were used. The glass plate length and breadth

Table 1. List of maize genotypes with their pedigree and source

Sl. No.	Genotype	Pedigree	Source
1	PDM 77-4	(Comp 85164 × Comp 8527) × 10-2-8-7-1-1-4-f	IARI Regional center, Dharwad
2	PDM 260-1	PS-28-3-1-2-2-1-1-AE	IARI Regional center, Dharwad
3	PDM 4341	(Comp8551 X Comp 8527 x Ageti 76 X MDR) -9- 4-2-8-7-1-1-2-1-L-1	IARI Regional center, Dharwad
4	PDM 4251	PS-25-1-1-1-1-1-1-1-1-R-1	IARI Regional center, Dharwad
5	PDM 4641	KDMH-176-5-1-1-R-1	IARI Regional center, Dharwad
6	PML 17	KDMH-176-5-1-1-R-2	IARI Regional center, Dharwad
7	PML 46	SAFAL-X12-9-1-1	IARI Regional center, Dharwad
8	PML 93	KDMH-176-5-1-1-R-6-1	IARI Regional center, Dharwad
9	PML 54	KDMH-755-12-1-1	IARI Regional center, Dharwad
10	PML 102	KMH-218PLUS-1-1-3-R-1	IARI Regional center, Dharwad
11	DIM 204	Advanta 7074-1-2-1-1-1	IARI Regional center, Dharwad
12	DIM 302	PHB-12-1-3-3-1-K-1	IARI Regional center, Dharwad
13	CDM 112	CA 1 45 14-1 0-8-2-8*4-8	IARI Regional center, Dharwad
14	D 2287	PMH-3-2Bulk-Bulk-1-2-1-1	IARI Regional center, Dharwad
15	D 1013	Sel-LCY3-7-1-2-2-1-1-f	IARI Regional center, Dharwad
16	CM 111	Cuba-342-2-F-#-#	AICRP on Maize, UAS, Dharwad
17	GPM 114	EC 618990	AICRP on Maize, UAS, Dharwad
18	CML 451	Hy 09R-N9251-18	AICRP on Maize, UAS, Dharwad
19	CAL 1426-2	CA-1457/P145C4MH7-1-B-1-1-B-1-1B*17	CIMMYT
20	CML 563	HY18 R-Y75-2	CIMMYT
21	IMIC 2030	VL-19008-[DTPYsyn16HG(B)]-6-2-1-2-B_1	CIMMYT
22	CML 579-1	HY 18 R-Y75-6-1	CIMMYT
23	CML 579-2	HY18R-Y75-6-2	CIMMYT
24	CML 580	HY18R-Y75-7	CIMMYT
25	CML 582	(CA-34505 × CA-00302)-B-2-1-B-1-BB(T-B3-#15-2-B-1-B*6-B2)	CIMMYT
26	IMIC 2024	VL-162283-AMDROUT1c3-B-5-1-BB-B_1	CIMMYT
27	PML 9	Polo-1-2-2-R-1-R-1-2	IARI Regional center, Dharwad
28	PML 21	DMH-119-1-1-4-K-1-K-1-21	IARI Regional center, Dharwad

depends on the number of seeds used for the germination study in the laboratory. The glass plates were covered with 560 × 570 mm blotting paper from bottom to top. Uniform sized good quality seeds were selected from each of the 28 different maize genotypes.

Maize seeds of all the genotypes were disinfected with 0.1 % $HgCl_2$. Six seeds were kept on top portion of the filter paper per glass plate at 5 cm spacing. The seeds were covered with a small strip of filter paper. Supporting wooden block was used to avoid the fall of seeds in slanting position. Initially little quantity (5 ml) of prepared PEG solution (0 %, 10 % and 20 %) were added on to the small strip of filter paper which helps in adsorption of seeds on to filter paper firmly. Glass plate was inserted in polythene cover. The plate was kept on the supporting wooden block in slanting position. Added 25 ml of corresponding concentrations of PEG osmotic solutions into the respective polyethylene cover kept in slanting plate. The PEG solution moved upward and reached to the seeds by capillary movement through filter paper. Seedlings were allowed to germinate and grow under room temperature. Fresh PEG-6000 solutions were added equally to all respective polythene covers at regular intervals of 3 days to maintain the level of PEG solution. The observations on germination per centage at 7th day, root length, shoot length, root to shoot ratio at 7th and 12th day were recorded. Germination velocity index, shoot vigourindex, root vigour index, seedling vigour index were calculated using the primary data.

The average of all seedlings used was subjected to variance analysis and test of significance as per the method of Fisher (1935) and also mean comparison between maize genotypes and various levels of PEG was performed by Indostat Software. Phenotypic and Genotypic coefficient of variation (PCV and GCV), Heritability (H) and Genetic advance as per cent of mean (GAM) were calculated.

Results and discussion

Different levels of PEG stress, genotypes and their interaction were significant for all the traits *viz*., germination percentage, germination velocity index, shoot length, root length, root to shoot ratio, shoot vigour index, root vigour index and seedling vigour index (Table 2) indicating significant differences among moisture stress levels and genotypes. Significant interaction between moisture stress and genotypes indicated differential behaviour of genotypes to different moisture stress levels. Earlier, Magar *et al*. (2019), Badr *et al.* (2020), Raj *et al.* (2020) also reported significant differences among genotypes, interaction between genotypes, PEG levels and moisture stress levels induced by PEG in maize.

Germination per cent varied from 77.7 % (2 genotypes) to 100.0 % (16 genotypes) with a mean of 95.2 % under control treatment (PEG – 0 %). In PEG -10 %, it varied from 50 (CML 451) to 100 % (2 genotypes) with a mean of 81.9 % and in case of PEG 20 %, it ranged from 11.1 (two genotypes) to 88.9 % (two genotypes) with a mean of 51.4 %. At 7th day after

Table 2. Mean sum of squares due to different sources of variation for different seedling traits under PEG induced drought in maize

Source of Variation	df	Germination per centage	GVI	Shoot length		Root length		Root : Shoot ratio	
				7th day	12th day	7th day	12th day	7th day	12th day
PEG levels	2	42471.7**	3.35**	2058.2**	7035.2**	1334.1**	1578.2***	21.2***	24.7**
Genotypes	27	1647.8**	0.11**	57.8***	123.6***	92.8**	138.9***	5.9**	3.1***
PEG levels × Genotypes	54	434.6**	0.03**	16.3**	38.1***	12.7**	22.4***	3.2**	2.5**
Error	168	51.8	0.003	0.005	0.43	0.13	0.33	0.008	0.003
Total	251	44277.5	3.49	2132.2	7197.2	1439.8	1739.8	30.3	30.3

Source of Variation	df	Seedling vigour index		Shoot vigour index		Root vigour index	
		7th day	12th day	7th day	12th day	7th day	12th day
PEG Levels	2	76759188**	178633680**	19649371**	67253276**	17528977**	26953016**
Genotypes	27	2888383**	5689144**	610025**	1385240**	993864**	1659205**
PEG Levels × Genotypes	54	440015***	898058**	173845**	416450**	130316**	191077**
Error	168	13426	23159	1282	8110	4460	8319
Total	251	11001012	185244041	20434523	69063076	18657617	28811617

*, ** and *** - Significant at 0.05 and 0.01 and 0.0001 level of probability, respectively.
df –Degrees of freedom GVI – Germination velocity index

PEG treatment, shoot length ranged from 3.3 (CML 580) to 19.1 cm (DIM 204) with a mean of 10.2 cm in control treatment (PEG-0 %). In PEG-10 %, shoot length ranged from 0.71 (CML 579-1) to 11.4 cm (DIM 204) with a mean of 5.1 cm and at 20 % of PEG, it ranged from 0 (5 genotypes) to 1.72 cm (PDM 4641) with a mean of 0.3 cm. At 12th day after PEG treatment, shoot length varied from 21.4 (3 genotypes) to 28.5 cm (PML 93) with a mean of 19.8 cm at 0 % of PEG. In case of PEG-10 %, shoot length varied from 2.0 (PML 9) to 20.9 cm (PML 46) with a mean of 11.6 cm and at 20 % of PEG, it varied from 0 (CML 580) to 4.2 cm (IMIC 2024) with a mean of 1.6 cm. At 7th day after PEG treatment, root length ranged from 5.8 (PML 9) to 19.6 cm (GPM 114) with a mean of 12.3 cm at control treatment (PEG -0%), while, it ranged from 2.6 (CML 451) to 16.7 cm (DIM 204) with a mean of 9.4 cm at 10 % of PEG and at 20 % of PEG, it varied from 0.2 (CML 580) to 11.1 cm (DIM 204) with a mean of 4.4 cm. At 12th day after PEG treatment, root length ranged from 10.5 (PML 102) to 25.2 cm (DIM 204) with a mean of 16.7 cm at 0 % of PEG concentration. In case of 10 % PEG concentration, root length ranged from 5.4 (CML 580) to 23.1 (PML 93) cm with a mean of 14.1 cm and at 20 % of PEG, it ranged from 0.8 (CML 580) to 16.4 (PML 93) cm with a mean of 8.3 cm (Table 3). These data indicated large amount of variability among 28 maize genotypes under study for these seedling traits.

Higher PCV and GCV was recorded for all the traits studied except germination percentage and germination velocity index at 10 % PEG. High heritability (> 60 %) coupled with high GAM was observed for germination percentage, germination velocity index, shoot length and root to shoot ratio (Table 3). In case of PEG 20 %, all the traits under study except germination velocity index showed higher heritability with high genetic advance as per cent of mean. This could be due to the role of additive gene action governing these traits hence selection can be practiced for improvement in drought tolerance for the seedling traits. Earlier, Rajarajan *et al.,* (2017) and Rajarajan *et al.,* (2018) have reported high PCV, GCV and high heritability with high GAM for shoot length and root length in sorghum genotypes.

Table 3. Range, mean and genetic components of variation for different seedling traits under PEG induced drought in maize

S.N.	Characters	DAS	Range			Mean			PCV		
			0 %	10%	20%	0%	10%	20%	0%	10%	20%
1	Germination per centage (%)	7th day	77.7-100	50.0–100.0	11.1-88.9	95.2	81.9	51.4	8.9	20.7	46.9
2	Germination velocity index	7th day	0.62-0.86	0.43-0.85	0.06-0.73	0.8	0.7	0.4	8.5	18.6	47.8
3	Shoot length (cm)	7th day	3.3-19.1	0.71-11.4	0.0-1.72	10.2	5.1	0.3	42.9	65.2	83.2
4	Shoot length (cm)	12th day	11.4-28.1	2.0-20.9	0.0-4.2	19.8	11.6	1.6	27.2	52.1	89.6
5	Root length (cm)	7th day	5.8-19.6	2.6-16.7	0.2-11.1	12.3	9.4	4.4	28.2	47.1	65.1
6	Root length (cm)	12th day	10.5-25.2	5.4-23.1	0.8-16.2	16.7	14.1	8.3	26.7	35.4	49.9
7	Root : Shoot ratio	7th day	0.8-2.4	1.2-6.9	0.0-5.6	1.3	1.6	2.3	31.7	50.4	81.1
8	Root : shoot ratio	12th day	0.5-1.5	0.77-4.9	0.0-6.9	0.9	1.5	1.9	25.5	56.4	71.2
9	Seedling vigour index	7th day	953-3679	183-2659	3.0-1102	2202	1253	290	35.6	61.4	93.3
10	Seedling vigour index	12th day	1720 - 5025	401 - 4062	29.0 - 1568	3476	2129	562.2	32.6	60.6	82.9
11	Shoot vigour index	7th day	276-1908	46.3-1141	0.0-152.6	985	443	21.2	46.7	74.3	85.2
12	Shoot vigour index	12th day	829 - 2850	89 - 1860	0.0 - 311	1886	980	97.3	44.6	66.9	84.4
13	Root vigour index	7th day	516-1963	129-1612	2.8-1042	1183	821	276	32.6	56.3	91.8
14	Root vigour index	12th day	764 - 2521	299 - 2284	26.0 - 1306	1589	1148	464.7	31.5	55.3	89.9

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S.N.	Characters	DAS	GCV			H			GAM		
			0%	10%	20%	0%	10%	20%	0%	10%	20%
1	Germination per centage (%)	7th day	6.4	18.3	44.5	50.0	78.2	89.8	9.3	33.4	44.6
2	Germination velocity index	7th day	6.9	14.8	46.8	65.0	63.5	96.1	11.4	24.3	10.5
3	Shoot length (cm)	7th day	42.8	65.1	82.1	98.4	99.9	99.2	20.5	40.6	99.3
4	Shoot length (cm)	12th day	26.9	51.4	89.2	98.4	97.8	99.1	10.3	17.5	132.1
5	Root length (cm)	7th day	27.9	46.8	65.0	98.5	99.9	99.8	12.2	15.5	10.3
6	Root length (cm)	12th day	26.6	34.9	49.5	99.9	99.1	98.4	12.2	14.4	24.6
7	Root : Shoot ratio	7th day	31.4	50.1	80.5	98.4	98.8	99.8	34.5	68.6	112.2
8	Root : shoot ratio	12th day	24.8	56.1	71.1	95.6	99.1	99.1	32.4	65.5	110.6
9	Seedling vigour index	7th day	35.1	60.3	91.9	97.1	96.5	97.1	9.5	16.8	78.6
10	Seedling vigour index	12th day	29.9	59.8	80.3	97.7	95.5	94.4	6.9	14.9	77.9
11	Shoot vigour index	7th day	46.4	73.8	84.9	98.8	98.8	97.6	10.6	17.8	74.8
12	Shoot vigour index	12th day	41.6	61.9	83.1	97.9	96.6	95.5	9.2	16.5	73.4
13	Root vigour index	7th day	31.9	55.5	91.0	95.8	97.2	98.3	11.2	15.9	97.6
14	Root vigour index	12th day	29.9	52.6	86.9	96.8	97.7	98.0	12.3	17.2	95.6

DAS: Days after sowing PCV – Phenotypic coefficient of variation GCV – Genotypic coefficient of variation
H – Heritability in broad sense GAM – Genetic advance as per cent of mean

Evaluation of 28 different maize genotypes by inducing water stress with different osmotic potentials (0, 10 and 20 % of PEG), indicated that, there was progressive decline in germination and seedling growth parameters across all the genotypes with increase in PEG from 0 to 20 % and was highest under 20 % PEG (Table 4). Among different PEG concentrations, 20 % PEG induced more moisture stress with highest reduction in germination and seedling growth parameters in all genotypes as compared to 0 % (control) and 10 % PEG indicating more pronounced differences among genotypes which helped in the identification of drought tolerant genotypes at seedling level. The genotypes PDM 4641, DIM 204, GPM114 recorded less reduction (<17 %) for germination percentage at both 10 % and 20 % PEG over control. The genotype PDM 4641 showed less per cent reduction (87.4 %) for shoot length (7th day) at 20 % PEG compared to 100 % reduction in PML 17, PML 102, D 2287, CML 579-1 and CML 580. Lowest per cent reduction in root length (7th day) over control was observed in the genotype CDM 112 (1.4 %) at 10 % PEG and 24.1 % in PDM 260-1 at 20 % PEG (Table 4). Therefore, the genotypes PDM 4641, DIM 204 and GPM 114 were considered as drought tolerant at seedling stage with less per cent reduction at both 10 % and 20 % PEG levels over control for germination and seedling traits. Genotypes PML102, DIM102, CML580, CML582, PML9, CML579-1 and CML579-2 were drought susceptible at seedling stage with highest reduction over control at both 10 % and 20 % PEG for germination and seedling traits (Table 4). These results were in agreement with the findings of Tripathi (2012), Alvarez *et al.* (2018), Nusrat *et al.* (2019) and Raj *et al.*(2020) who also indicated more noticeable differences in maize genotypes at 20 % PEG concentration compared to 0 % (control) and 10 % PEG and also reported that, 20 % PEG can be used as effective indicator for drought tolerance at seedling stage in maize genotypes. The genotypes PDM 4641, DIM 204 and GPM 114 can be tested for their drought tolerance under field conditions before utilizing them as sources of drought tolerance in crop improvement program.

Table 4. Mean performance and per cent change over control for seedling traits under PEG induced drought in selected maize genotypes

Genotype	Germination percentage (%)					Germination velocity index					Shoot length (cm, 7th day)				
	0 %	10 %	% C1	20 %	% C2	0 %	10 %	% C1	20 %	% C2	0 %	10 %	% C1	20 %	% C2
PDM 4641	100.0^{a}	100.0^{a}	0.0	88.8^{a}	-5.8	0.81^{abc}	0.80^{ab}	-1.2	0.72^{a}	-11.1	13.7^{e}	8.7^{f}	-36.4	1.72^{a}	-87.4
DIM 204	100.0^{a}	94.4^{ab}	-5.6	88.8^{a}	-11.1	0.83^{ab}	0.85^{a}	2.4	0.72^{a}	-13.2	19.1^{a}	11.4^{a}	-40.3	1.34^{b}	-92.9
PML 17	100.0^{a}	94.4^{ab}	-5.5	83.3^{ab}	-16.6	0.82^{abc}	0.80^{ab}	-2.4	0.72^{a}	-12.2	6.2^{s}	3.8^{n}	-38.7	0.00l	-100
GPM 114	100.0^{a}	100.0^{a}	0.0	83.3^{ab}	-16.6	0.81^{abc}	0.84^{a}	3.7	0.72^{a}	-11.1	15.7^{c}	9.1^{e}	-42.1	0.65^{e}	-95.8
PML 46	100.0^{a}	94.4^{ab}	-5.5	77.7^{ab}	-22.2	0.81^{abc}	0.82^{ab}	1.2	0.66^{ab}	-18.5	10.3^{l}	7.4^{g}	-28.2	0.50^{fg}	-95.2
CDM 112	100.0^{a}	94.4^{ab}	-5.5	77.7^{ab}	-22.2	0.82^{abc}	0.83^{a}	1.2	0.61^{b}	-25.6	17.8^{b}	11.1^{b}	-37.6	0.43^{g}	-97.5
D 1013	100.0^{a}	94.4^{ab}	-5.5	77.7^{ab}	-22.2	0.85^{a}	0.79^{ab}	-7.1	0.62^{b}	-27.1	12.4^{g}	5.8^{j}	-53.2	0.09^{ijk}	-99.2
PDM 77-4	100.0^{a}	83.3^{bcd}	-16.6	72.2^{bc}	-27.8	0.82^{abc}	0.74^{abcd}	-9.7	0.61^{b}	-25.6	7.2^{p}	4.3^{m}	-40.2	0.01^{kl}	-99.8
DIM 102	94.4^{ab}	88.8^{abc}	-5.8	61.1^{cd}	-35.3	0.79^{abcd}	0.76^{abcd}	-3.7	0.50^{cde}	-36.7	12.3^{g}	7.5^{g}	-39.1	0.16^{hi}	-98.6
PML 93	100.0^{a}	94.4^{ab}	-5.5	61.1^{cd}	-38.9	0.84^{a}	0.82^{ab}	-2.4	0.52^{c}	-38.1	13.5^{f}	6.2^{i}	-54.1	0.47^{g}	-96.5
PDM 4251	94.4^{ab}	88.8^{abc}	-5.8	16.6^{i}	-82.3	0.82^{abc}	0.74^{abcd}	-9.7	0.12^{l}	-85.3	6.2^{s}	5.2^{k}	-16.1	0.01^{kl}	-99.8
Mean	95.2	81.9		51.4		0.80	0.72		0.40		10.2	5.1		0.3	
CD (5 %)	9.8	12.9		12.6		0.07	0.13		0.08		0.12	1.7		0.07	
CV (%)	6.4	9.6		15		4.90	11.2		3.9		0.70	1.9		12.9	

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Genotypes	Shoot length (cm, 12th day)					Shoot vigour index (7th day)					Shoot vigour index (12th day)				
	0%	10%	% C1	20 %	% C2	0 %	10 %	% C1	20 %	% C2	0 %	10 %	% C1	20 %	% C2
PDM 4641	20.6^{i}	17.7^{cd}	-14.0	3.86^{b}	-81.2	1297de	879^{bc}	-32.2	152^{a}	-88.2	2060^{gh}	1776^{a}	-13.0	321^{a}	-84
DIM 204	26^{cd}	15.2^{e}	-41.5	3.15^{c}	-87.8	1908^{a}	1141^{a}	-40.2	119.3^{b}	-93.7	2600^{bcd}	1358de	-47.0	262^{b}	-89
PML 17	11.7^{o}	12.1^{gh}	3.4	3.74^{b}	-68.0	619^{lm}	380^{h}	-38.6	0.0^{g}	-100.0	1178^{lm}	1073^{gh}	-8.0	311^{a}	-73
GPM 114	25.2^{de}	17.7^{cd}	-29.7	2.18^{e}	-91.3	1574^{c}	906^{b}	-42.4	54.2^{c}	-96.5	2514^{cde}	1778^{a}	-29.0	181^{e}	-92
PML 46	27.3^{b}	20.9^{a}	-23.4	3.34^{c}	-87.7	1024^{i}	661^{e}	-35.4	38.0^{de}	-9.0	2734^{ab}	1860^{a}	-31.0	241^{bc}	-91
CDM 112	23.9^{fg}	19.7^{ab}	-17.5	1.30^{hi}	-94.5	1783^{b}	1108^{a}	-37.8	32.8^{ef}	-98.1	2393^{ef}	1757^{a}	-26.0	93^{g}	-96
D 1013	22.2^{h}	12.8^{fg}	-42.3	0.88^{j}	-96.0	1244^{ef}	516^{f}	-58.5	6.9^{g}	-99.4	2224^{fg}	1145^{fgh}	-48.0	63^{ghi}	-97
PDM 77-4	20.1^{ij}	18.1^{cd}	-9.95	1.64^{fg}	-91.8	718^{k}	362^{h}	-49.5	1.03^{g}	-99.8	2013^{h}	1507$^{b\ d}$	-25.0	90^{g}	-95
DIM 102	18.8^{kl}	15.6^{e}	-17.0	1.44^{gh}	-92.3	1162^{fg}	669de	-42.4	10.1^{g}	-99.1	1671^{jk}	1304^{def}	-21.0	88^{g}	-94
PML 93	28.5^{a}	19.1^{bc}	-32.9	3.76^{b}	-86.8	1352^{d}	614^{e}	-54.5	28.8^{ef}	-97.8	2850^{a}	1697^{abc}	-40.0	230^{cd}	-91
PDM 4251	11.4^{o}	12.5^{g}	9.6	0.08^{l}	-99.2	602^{lm}	457^{g}	-24.1	0.26^{g}	-99.9	1014^{mn}	1041^{h}	2.6.0	1.2^{l}	-99
Mean	19.8	11.6		1.55		985	443		21.2		1886	980		97.3	
CD (5 %)	1.13	1.45		0.21		82.6	58		9.4		170.1	189.2		28.8	
CV (%)	3.5	7.60		8.40		5.1	8		20.2		5.5	11.8		18.1	

Genotypes	Root length (cm, 7th day)					Root length (cm, 12th day)					Root : Shoot ratio (7th day)			Root : Shoot ratio (12th day)		
	0%	10%	% C1	20 %	% C2	0%	10%	% C1	20 %	% C2	0%	10%	20 %	0 %	10 %	20 %
PDM 4641	15.2^{cd}	11.2^{f}	-26.3	6.4^{e}	-57.8	22.3^{c}	16.8^{ef}	-24.6	7.9^{fgh}	-64.5	1.1^{f}	1.26^{op}	1.06^{k}	1.08^{cde}	0.94^{mn}	1.33^{o}
DIM 204	17.7^{b}	16.7^{a}	-5.6	11.1^{a}	-37.3	14.4^{m}	17.3^{e}	20.1	15.6^{a}	8.3	0.92^{hi}	1.46^{mno}	1.62^{gh}	0.55^{q}	1.13^{jkl}	2.96^{d}
PML 17	8.3^{lm}	9.3^{h}	12.1	4.8^{i}	-42.2	15.8^{k}	14.3^{gh}	-9.4	12.4^{cd}	-21.5	1.34^{de}	2.42^{gh}	0.00^{p}	1.35^{a}	1.17^{ijk}	1.85^{k}
GPM 114	19.6^{a}	16.3^{a}	-16.8	7.4^{cd}	-62.2	25.2^{a}	22.8^{ab}	-9.52	13.1^{bc}	-48.1	1.24^{e}	1.79^{kl}	1.41^{ij}	0.99^{fg}	1.28^{hi}	2.81^{e}
PML 46	14.4^{e}	13.8^{bc}	-4.2	7.9^{b}	-45.1	20.5^{e}	19.2^{cd}	-6.3	12.8^{bc}	-37.5	1.4^{d}	1.85^{jk}	1.33^{j}	0.74^{mn}	0.91^{no}	1.76^{l}
CDM 112	14.4^{e}	14.2^{b}	-1.4	7.2^{d}	-50.0	17.1^{i}	18.2^{de}	6.4	11.7^{d}	-31.5	0.8^{j}	1.27^{op}	1.44^{ij}	0.7^{nop}	0.91^{no}	1.71^{lm}
D 1013	15.7^{c}	10.3^{g}	-34.4	2.4^{mn}	-84.7	22.9^{b}	17.4^{e}	-24	5.25^{kl}	-77.1	1.26^{e}	1.77^{kl}	0.71^{lm}	1.02^{efg}	1.35^{gh}	0.81^{r}
PDM 77-4	12.5^{g}	13.4^{cd}	7.2	3.0^{k}	-76.0	22.5^{bc}	20.3^{c}	-9.7	10.1^{e}	-55.1	1.73^{c}	3.08^{d}	0.82^{l}	1.11^{cd}	1.12^{kl}	1.92^{j}
DIM 102	13.4^{f}	12.8^{de}	-4.4	4.1^{j}	-69.4	21.7^{d}	15.7^{fg}	-27.6	5.9^{jk}	-72.8	1.08^{f}	1.69^{klm}	0.75^{lm}	1.15^{bc}	1.00^{lmn}	1.15^{p}
PML 93	14.1^{e}	12.8^{de}	-9.2	7.6^{c}	-46.1	20.3^{ef}	23.1^{a}	13.7	16.2^{a}	-20.2	1.04^{fg}	2.08^{ij}	1.43^{ij}	0.71^{no}	1.2^{ijk}	2.84^{e}
PDM 4251	8.5^{lm}	11.3^{f}	32.9	1.9^{o}	-77.6	12.0^{r}	14.3^{gh}	19.2	6.4^{ij}	-46.6	1.32^{de}	2.19^{hi}	0.64^{m}	1.05^{def}	1.14^{ijkl}	1.34^{o}
Mean	12.3	9.34		4.43		16.7	14.1		8.28		1.33	1.55	2.29	0.87	1.48	1.95
C.D (5%)	0.69	0.69		0.22		0.49	1.28		0.85		0.087	0.21	0.11	0.08	0.13	0.05
CV (%)	3.42	4.5		3.08		1.8	5.6		6.28		3.97	5.6	4.44	5.32	5.4	1.42

CD – Critical difference @ 5 % CV – Coefficient of Variation % C1 – Per cent change at 10 % PEG over control

C2 – Per cent change at 20 % PEG

Note: Mean, CD and CV values are derived for the set of twenty-eight genotypes

Figures with same superscripts do not differ significantly at 5 % level of probability

Conclusion

The results of the present investigation identified PDM 4641as a drought tolerant genotype followed by DIM 204 and GPM 114 at seedling level. It also indicated that germination percentage, shoot length, root length and vigor index could be used as surrogates in the identification of drought tolerant lines in maize during germination and seedling establishment stages. In addition, the current study showed that lowest osmotic potential was induced at 20 % PEG in maize seedlings. High heritability (> 60 %) coupled with high GAM was observed for germination percentage, germination velocity index, shoot length and root to shoot ratio indicating probable role of additive gene action governing these traits. Hence, selection can be practiced for improvement of drought tolerance at seedling stage.

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