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Elucidating Drought Tolerance Potential of Maize (*Zea mays* L.) Inbred Lines through Polyethylene Glycol Induced Drought Stress

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Drought is one of the most distressing environmental stresses restraining the crop production . Drought undermines the plant growth from seedling to maturity and the studies have unveiled that the harmful impact of drought results in crops due to the damages perceived during crucial stages of development namely, germination, seedling development and flowering stages. Biometric elements and indices at an early growth stage could be employed in designing the selection criteria to figure out the drought tolerant genotypes. Breeding for drought-prone environments is constrained by lack of suitable selection indices of drought stress resistance. The present study was conducted to determine the reliability of *in-vitro* screening method for initiating drought breeding programme. Poly ethylene glycol (PEG) has been used often as abiotic stress inducer in many studies to screen drought tolerant germplasm. The present investigation was carried out to reveal the drought tolerance potential of 103 maize inbred lines by *in-vitro* screening under three levels of PEG levels *viz.,* 0% as control, 10% and 20% and evaluating their effect on the root parameters like primary root length, number of seminals roots , number of lateral roots and root biomass. The seedlings exhibited a significant variation for all the traits analyzed. All the root parameters had highest value under control and had significant decline with increasing PEG concentrations (0% < 10% < 20%). The inbreds showing the best level of drought tolerance at all levels of PEG induced stress can be used as a source of drought tolerance for the improvement of drought tolerant hybrids . The variation among maize inbreds for these traits was found to be an ideal indicator to screen the drought tolerant genotypes at early growth stages.

Keywords: Drought; drought tolerance; PEG (polyethylene glycol); primary root length; lateral roots; root biomass.

1. INTRODUCTION

“Maize (*Zea mays* L.) is one of the important food and industrial crops grown extensively in major part of the world and it ranks third after wheat and rice” [1,2]. “Maize is of worldwide importance as a food, feed and as a source of diverse industrially important products” [3]. “Due to the growing demand for dairy and meat products in developing countries and the decline in rice production in China and India, maize has been projected to become the most important crop by 2030” [4].

“ Maize is essential for global food security. The current trends of climatic changes increase water scarcity and reduce maize productivity by 15-30%” [5]. There are several abiotic factors limiting maize production in different parts of the world. Drought is one of the most distressing environmental stresses restraining the crop production These trends, coupled with an expansion of cropping into marginal production areas, are generating increasingly drought-prone maize production environments and persuades the need for drought tolerance in maize crop.

“Drought undermines the plant growth from seedling to maturity and the studies have unveiled that the harmful impact of drought results in crops due to the damages perceived during crucial stages of development namely, germination, seedling development and flowering stages” [6]. Biometric elements and indices at an early growth stage could be employed in designing the selection criteria to figure out the drought tolerant genotypes. Breeding for drought-prone environments is constrained by lack of suitable selection indices of drought stress resistance.

“Polyethylene glycol (PEG-6000) treatment can be applied to identify local maize varieties as sensitive or tolerant to drought stress before germination” [7]. “This method can be used to identify the best varieties for drought-prone areas and help in conservation efforts. PEG concentrations could act as a limiting factor by affecting maize plant growth during the germination and seedling stages” [8,9]. “The upsurge in concentration of PEG caused a decrease in germination percentage, seedling vigour in certain crop plants” [10]. “Poly ethylene glycol (PEG) has been used often as abiotic stress inducer in many studies to screen drought tolerant germplasm” [11,12]. “The germplasm which is showing better performance can be considered as drought tolerant. It is an established fact that tolerance at maturity is demonstrated by the tolerance at immature stage of plant. Therefore, it is necessary to develop effective screening criteria at early growth stages to get the maximum yield” [13]. The present study was conducted to determine the reliability of *in-vitro* screening method for initiating drought breeding programme. The aim of the present study was to investigate the effects of PEG induced stress on root traits of maize (*Zea mays* L.) inbreds to screen them for drought tolerance.

2. MATERIALS AND METHODS

This study was carried out at Division of Genetics and Plant Breeding, SKUAST-K. 103 maize (*Zea mays* L.) inbreds were used to study the effect of PEG induced stress on root traits to screen them for drought tolerance. In this experiment with polyethylene glycol, PEG-6000 (HIMEDIA) was used in three concentrations viz., control (0%), 10% and 20%. Four seeds of each genotype were surface sterilized with 0.5% NaOCl for one minute, rinsed thoroughly with distilled water and were put in petri plates containing moist filter paper with different concentrations of PEG-6000 and allowed to germinate in a germinator at 25^0C and 75% humidity in darkness. Primary root length, number of seminals, number of laterals and root biomass was measured after seven days. The design used was factorial CRD with three replications.

3. RESULTS AND DISCUSSION

The results of this study reveal that different concentrations of PEG-6000 (0-20%) had significant effect on the root traits of maize inbreds (Table 1). Analysis of variance and mean comparison revealed that there were significant differences between drought stress levels and genotypes. Analysis of variance for various root traits scored under PEG 6000 shows that mean square due to genotypes, PEG levels and genotypes x PEG levels was significant for all the traits (Table 2). The mean performance results also revealed that the root traits under different stress levels were different.

The results of *in-vitro* screening of maize inbreds under three levels of PEG levels *viz.,* 0% as control, 10% and 20% are explained below under appropriate headings:

Primary Root length (cm): The data on primary root length under different levels of PEG-6000 was;

- **0% Level (Control):**- Under controlled conditions primary root length had a mean value of 13.42 with highest value recorded in IMR- 55 and IMR- 416 (19.00) followed by IMR- 566 and IMR- 577 (18.33) each and was lowest in IMR- 4 and IMR- 43(7.00).
- **10% Level:-** Under 10% the primary root length had a mean value of 7.16 with highest value recorded in IMR- 7 and IMR- A (13.00) followed by IMR- 671 (12.00) and IMR- 5, IMR- 11, IMR- 566, IMR- 579 and IMR- B (11.00) and was lowest in IMR- 4, IMR- 76 and IMR- 220(3.33).
- **20% Level:**- Under 20% the primary root length had a mean value of 2.92 with highest value recorded in IMR- 7 (6.00) followed by IMR- A (5.67) and IMR- 116, IMR- 566 and IMR- 671 (5.00) and was lowest in IMR- 4, IMR- 43, IMR- 76, IMR- 128, IMR- 220, IMR- 445and IMR- 541(1.33).

Number of Seminals: The data on number of seminals under different levels of PEG-6000 was;

- **0% Level (Control):**- Under controlled conditions the number of seminals had a mean value of 5.86 with highest value recorded in IMR- 60 and IMR- 667 (9.00) followed by IMR- 565(8.67) and IMR- 134 and IMR- A (8.33) and was lowest in IMR- 292(3.33).
- **10% Level**:- Under 10% the number of seminals had a mean value of 3.92 with highest value recorded in IMR- 60 and IMR- 565 (7.00) followed by IMR- 151(6.67) and IMR- 134, IMR- 385, IMR- 576 and IMR- A(6.33) each and and was lowest in IMR- 11, IMR- 41, IMR- 87, IMR- 116, IMR- 217, IMR- 227, IMR- 245, IMR- 292, IMR- 368, IMR- 376, IMR- 413, IMR- 419, IMR- 579(2.00).
- **20% Level**:- Under 20% the number of seminals had a mean value of 2.05 with highest value recorded in IMR- 439 and IMR- 667(4.00) followed by IMR- 134, IMR- 385, IMR- 565 (3.33) and IMR- 7, IMR- 98, IMR- 268, IMR- 569, IMR- 580, IMR- 609 (3.00) and was lowest in IMR- 572(1.00).

Number of Laterals: The data on number of laterals under different levels of PEG-6000 was;

- **0% Level (Control):**- Under controlled conditions the number of laterals had a mean value of 29.77 with highest value recorded in IMR- 565 (63.00) followed by IMR- 155 (62.67) and IMR- 60 (62.00) and was lowest in IMR- 247(9.67).

Table 1. ***In vitro*** **response of maize (*Zea mays* L.) inbreds to different levels of PEG 6000**

Inbreds	Primary root length(cm)			Number of Seminals			Number of Laterals			Root Biomass(g)		
	Control	10%	20%	Control	10%	20%	Control	10%	20%	Control	10%	20%
IMR 3	15.00	5.33	2.33	6.00	4.00	1.67	26.00	12.00	6.00	0.21	0.12	0.03
IMR 4	7.00	3.33	1.33	7.00	5.00	3.00	22.00	13.00	9.00	0.25	0.17	0.06
IMR 5	17.00	11.00	3.33	6.00	4.00	2.00	18.00	9.00	2.00	0.54	0.47	0.41
IMR 7	18.00	13.00	6.00	8.00	6.00	3.00	25.00	16.00	7.00	0.45	0.38	0.25
IMR 8	11.00	6.67	2.67	6.00	4.00	1.67	45.00	34.00	19.00	0.37	0.29	0.18
IMR 11	15.67	11.00	3.67	4.00	2.33	1.33	33.00	21.00	10.00	0.57	0.51	0.43
IMR 19	16.00	6.67	2.67	5.00	3.00	1.33	31.00	20.00	11.00	0.24	0.14	0.08
IMR 20	10.00	4.33	1.67	4.67	2.67	1.33	24.00	13.00	5.00	0.17	0.09	0.04
IMR 26	12.00	5.67	2.33	3.67	2.67	1.67	15.00	9.00	3.00	0.34	0.26	0.13
IMR 34	11.00	6.33	2.00	6.33	4.33	2.33	32.00	21.00	10.00	0.34	0.28	0.18
IMR 41	16.00	8.33	3.33	4.00	2.33	1.00	18.00	11.00	6.00	0.23	0.16	0.09
IMR 42	11.00	6.00	2.33	5.67	3.67	1.67	20.00	10.00	5.00	0.52	0.43	0.31
IMR 43	7.00	3.67	1.33	4.67	2.67	1.33	25.00	14.00	7.00	0.45	0.36	0.21
1MR 50	11.00	5.33	2.33	4.67	2.67	1.33	50.00	36.00	19.00	0.31	0.25	0.13
1MR 55	19.00	9.33	3.00	5.33	3.33	1.33	25.00	13.00	7.00	0.20	0.13	0.08
1MR 60	14.00	10.00	4.67	9.00	7.00	4.67	62.00	36.00	19.00	0.30	0.20	0.12
1MR 63	14.00	8.67	3.67	6.00	4.00	2.33	58.33	37.00	21.00	0.63	0.52	0.43
1MR 76	8.00	3.33	1.33	6.00	4.00	2.00	33.00	24.00	13.00	0.23	0.16	0.09
1MR 77	17.00	8.00	3.00	7.00	4.67	2.33	36.00	26.00	11.00	0.40	0.31	0.15
1MR 82	15.00	6.67	2.33	7.33	5.33	2.67	40.00	32.00	15.00	0.26	0.19	0.11
1MR 87	14.00	6.67	2.67	4.33	2.33	1.33	22.00	11.67	5.00	0.54	0.45	0.24
1MR 91	13.00	6.33	2.33	4.33	2.67	1.33	33.00	21.00	10.00	0.20	0.13	0.03
1MR 97	17.00	9.67	4.00	5.00	3.00	1.33	42.00	25.00	12.00	0.54	0.47	0.24
1MR 98	16.00	7.00	3.33	8.00	6.00	3.00	34.00	21.00	10.00	0.47	0.36	0.25
1MR 103	12.00	6.67	3.00	7.00	5.33	2.33	48.00	32.00	14.00	0.37	0.28	0.20
1MR 114	16.00	9.67	4.33	6.67	3.67	1.33	26.00	16.00	11.00	0.45	0.39	0.25
1MR 115	16.00	8.33	4.00	5.67	3.67	1.67	35.00	12.00	4.00	0.39	0.25	0.12
1MR 116	18.00	9.67	5.00	4.33	2.33	1.33	44.00	28.00	14.00	0.59	0.50	0.33
1MR 121	13.00	8.00	4.33	5.00	4.00	2.00	42.00	24.00	11.00	0.61	0.51	0.41
1MR 127	15.00	9.00	3.33	4.33	3.33	1.33	30.00	18.00	8.00	0.23	0.17	0.11
1MR 128	9.00	4.33	1.33	6.67	5.00	2.33	45.00	31.00	18.00	0.39	0.31	0.14

Inbreds	Primary root length(cm)			Number of Seminals			Number of Laterals			Root Biomass(g)		
	Control	**10%**	**20%**	**Control**	**10%**	**20%**	**Control**	**10%**	**20%**	**Control**	**10%**	**20%**
1MR 132	10.00	5.00	3.00	5.67	3.00	1.67	24.00	11.00	5.00	0.25	0.18	0.11
1MR 133	14.00	4.33	1.67	6.67	4.67	2.67	23.00	12.00	4.00	0.53	0.47	0.26
1MR 134	12.00	7.33	3.67	8.33	6.33	3.33	34.00	22.00	12.00	0.44	0.37	0.22
1MR 137	15.33	7.67	2.67	5.00	3.00	1.33	22.00	11.00	6.00	0.53	0.48	0.30
1MR 145	9.67	5.67	2.33	7.33	5.33	2.33	32.00	16.00	11.00	0.46	0.38	0.28
1MR 149	10.67	5.33	2.00	6.33	4.67	2.33	38.00	22.67	13.00	0.35	0.28	0.16
1MR 151	9.00	5.00	1.67	9.00	6.67	2.67	40.00	23.00	9.00	0.44	0.34	0.21
1MR 152	16.00	5.00	2.67	6.00	5.00	2.00	25.67	10.67	3.67	0.21	0.12	0.02
1MR 155	17.33	8.33	3.33	7.67	4.67	2.67	62.67	29.33	13.00	0.29	0.19	0.09
1MR 209	12.00	4.67	1.67	5.67	3.67	2.67	36.67	20.00	6.00	0.39	0.22	0.11
1MR 217	11.00	6.00	3.33	4.33	2.33	1.33	42.67	20.67	8.67	0.45	0.30	0.15
1MR 220	8.67	3.33	1.33	5.33	3.33	2.33	27.67	11.67	4.00	0.23	0.15	0.05
1MR 222	8.00	4.33	1.67	4.67	2.67	1.67	34.67	14.67	5.00	0.24	0.15	0.05
1MR 223	10.33	4.67	1.67	4.67	2.67	1.67	21.33	7.33	2.33	0.51	0.37	0.17
1MR 224	13.67	7.33	3.33	4.67	3.00	2.00	10.00	2.33	1.33	0.37	0.24	0.09
1MR 227	12.33	7.67	4.67	4.33	2.33	1.33	13.33	6.00	1.67	0.30	0.16	0.08
1MR 230	13.33	5.67	2.67	5.00	3.00	2.00	14.33	5.33	2.67	0.25	0.16	0.10
1MR 245	14.00	8.67	4.00	4.33	2.33	1.33	25.33	11.00	4.00	0.22	0.15	0.08
1MR 247	11.67	6.67	2.67	5.33	3.33	2.33	9.67	3.67	1.67	0.24	0.15	0.07
1MR 248	8.33	4.67	2.33	5.33	3.33	2.33	25.67	9.67	3.33	0.17	0.11	0.06
1MR 268	12.00	6.33	3.33	6.00	4.00	3.00	12.67	5.67	1.33	0.33	0.18	0.09
1MR 272	18.00	8.33	3.67	5.00	3.00	1.67	34.33	16.33	9.67	0.34	0.17	0.10
1MR 292	11.00	5.67	2.67	3.33	2.33	1.33	14.00	2.67	1.67	0.22	0.12	0.08
1MR 368	9.00	3.67	1.67	3.67	2.33	1.33	17.33	7.33	2.33	0.50	0.28	0.12
1MR 376	15.33	6.33	2.33	3.67	2.33	1.33	25.33	11.33	2.67	0.46	0.28	0.14
1MR 377	15.00	6.67	2.67	7.33	4.33	2.33	48.67	18.67	5.33	0.31	0.19	0.08
1MR 379	15.67	8.33	2.67	6.67	4.00	2.00	27.00	10.00	4.00	0.20	0.10	0.04
1MR 384	11.33	4.67	1.67	5.67	3.67	2.67	59.33	27.33	14.00	0.62	0.36	0.16
1MR 385	15.00	5.00	2.00	8.67	6.33	3.33	36.00	22.00	11.00	0.22	0.16	0.10
1MR 386	17.00	9.67	3.67	5.00	3.00	2.00	11.67	4.67	1.33	0.24	0.13	0.06
1MR 387	18.00	7.67	2.67	6.00	3.67	2.67	16.67	6.67	2.67	0.42	0.21	0.10
1MR 413	11.00	5.67	3.67	4.33	2.33	1.33	20.33	9.33	3.67	0.25	0.11	0.07
1MR 414	15.33	9.00	4.00	5.33	3.33	2.33	11.33	4.33	2.67	0.53	0.31	0.16

Inbreds	Primary root length(cm)			Number of Seminals			Number of Laterals			Root Biomass(g)		
	Control	10%	20%	Control	10%	20%	Control	10%	20%	Control	10%	20%
1MR 415	17.33	9.00	3.67	4.67	2.67	1.67	12.67	6.67	2.67	0.25	0.13	0.06
1MR 416	19.00	10.00	4.00	4.67	2.67	1.67	40.67	18.67	8.67	0.55	0.29	0.13
1MR 417	17.00	9.00	3.67	5.33	3.33	1.33	34.33	13.67	9.33	0.47	0.25	0.07
1MR 419	11.33	7.00	2.67	4.33	2.33	1.33	48.33	18.33	8.33	0.39	0.22	0.06
1MR 420	18.00	9.33	3.67	6.33	4.33	2.33	15.33	5.33	2.33	0.45	0.23	0.08
1MR 424	15.00	7.33	3.33	6.67	3.67	1.67	42.67	17.67	12.67	0.60	0.34	0.13
1MR 425	17.00	8.00	3.33	7.00	5.00	2.33	24.00	14.00	7.00	0.50	0.37	0.24
1MR 429	11.00	5.67	2.33	4.67	2.67	1.67	43.00	27.00	13.00	0.46	0.39	0.23
1MR 439	11.00	6.00	2.00	8.00	5.00	4.00	31.00	20.00	11.00	0.22	0.16	0.11
1MR 445	9.67	4.67	1.33	4.67	3.33	1.33	46.00	32.00	15.00	0.24	0.19	0.11
1MR 447	8.67	4.33	1.67	5.33	3.33	1.33	34.00	22.00	10.00	0.52	0.46	0.33
1MR 450	9.00	4.67	2.33	7.33	5.33	2.33	24.00	13.00	6.00	0.36	0.29	0.18
1MR 451	12.00	6.67	2.33	5.33	4.00	2.33	14.33	9.00	4.00	0.31	0.25	0.14
1MR 526	13.00	7.00	2.67	6.33	5.33	2.33	12.67	7.00	2.00	0.26	0.19	0.10
1MR 534	10.67	7.00	3.00	5.33	3.67	1.33	16.33	9.00	3.00	0.23	0.17	0.07
1MR 540	13.00	8.00	3.33	5.67	3.67	1.67	19.67	10.00	5.00	0.37	0.30	0.16
1MR 541	8.00	4.33	1.33	6.67	5.00	2.33	27.00	14.00	7.00	0.34	0.29	0.17
1MR 564	10.00	4.67	1.67	6.33	4.33	2.33	17.00	8.00	3.00	0.36	0.24	0.15
1MR 565	11.67	6.00	2.33	8.67	7.00	3.33	63.00	42.00	24.00	0.33	0.26	0.12
1MR 566	18.33	11.00	5.00	4.67	3.33	1.33	38.00	23.00	12.00	0.23	0.17	0.09
1MR 569	10.33	6.00	2.67	8.00	6.00	3.00	40.00	28.00	14.00	0.49	0.41	0.29
1MR 571	9.33	5.00	2.00	5.33	3.33	1.67	27.00	18.00	10.00	0.47	0.42	0.30
1MR 572	17.00	10.00	3.67	4.00	2.67	1.00	34.00	21.00	8.00	0.31	0.27	0.14
1MR 573	15.00	8.00	2.67	5.33	3.33	1.50	20.00	11.00	4.00	0.20	0.13	0.07
1MR 574	15.67	9.00	3.67	7.67	5.67	1.67	21.00	13.00	7.00	0.61	0.56	0.43
1MR 576	11.00	6.00	2.33	7.67	6.33	3.33	15.00	9.00	3.00	0.23	0.18	0.06
1MR 577	18.33	10.00	3.67	5.33	3.33	1.67	23.00	12.00	6.00	0.43	0.37	0.25
1MR 579	18.00	11.00	4.33	4.67	2.33	1.33	19.00	10.00	3.00	0.26	0.20	0.11
1MR 580	12.00	7.33	3.33	8.00	6.00	3.00	15.00	9.00	5.00	0.28	0.19	0.11
1MR 582	11.67	7.00	2.33	5.00	2.67	1.67	25.00	14.00	7.00	0.52	0.47	0.34
1MR 583	15.00	8.00	3.67	6.33	4.33	2.67	14.00	11.00	6.00	0.31	0.26	0.23
1MR 585	18.00	8.67	2.67	4.67	3.33	1.33	35.00	24.00	14.00	0.56	0.48	0.36
1MR 609	17.00	10.00	3.67	8.00	6.00	3.00	26.00	13.00	8.00	0.47	0.41	0.33

Inbreds	Primary root length(cm)			Number of Seminals			Number of Laterals			Root Biomass(g)		
	Control	**10%**	**20%**	**Control**	**10%**	**20%**	**Control**	**10%**	**20%**	**Control**	**10%**	**20%**
1MR 667	14.00	9.00	3.33	9.00	7.00	4.00	27.00	11.00	6.00	0.39	0.32	0.25
1MR 668	11.00	7.00	2.00	5.33	3.33	1.33	32.00	21.00	13.00	0.47	0.39	0.33
1MR 671	17.33	12.00	5.00	6.33	4.33	2.33	48.00	29.00	15.00	0.59	0.53	0.44
1MR A	16.00	13.00	5.67	8.33	6.33	3.33	26.33	18.00	7.00	0.24	0.18	0.09
1MR B	18.00	11.00	4.33	5.00	3.00	1.33	58.00	37.00	18.00	0.51	0.45	0.35
1MR C	12.00	7.00	2.33	7.67	5.67	2.67	21.00	12.00	6.00	0.30	0.24	0.17
Mean	**13.42**	**7.16**	**2.92**	**5.86**	3.92	2.05	**29.77**	**16.64**	**8.04**	**0.37**	0.28	0.17
C.D(p ≤0.05)	Genotype =1.217			Genotype = 0.875			Genotype = 1.203			Genotype = 0.014		
				PEG Levels =0.149			PEG Levels =0.205			PEG Levels =0.002		
	PEG Levels =0.207			Genotype × PEG Levels = 1.515			Genotype × PEG Levels = 2.084			Genotype × PEG Levels = 0.025		
	Genotype × PEG Levels = 2.108											

Table 2. Analysis of variance for traits scored under different levels of PEG 6000 in maize (*Zea mays* L.) inbreds

Source of variation	d.f	Primary root length (cm)	Number of Seminals	Number of Laterals	Root Biomass (g)
Genotypes	102	37**	11**	677**	0.119**
PEG Levels	2	8615**	1126.6**	37041**	3.286**
Genotypes × PEG Levels	204	6**	0.8**	66**	0.005**
Error	618	2	0.9	2	0

*** Significant at 5% level*

Fig. 1. Roots of maize (*Zea mays*) inbreds under different PEG concentrations

- **10% Level:-** Under 10% the number of laterals had a mean value of 16.64 with highest value recorded in IMR- 565(42.00) followed by IMR- 63, IMR- B (37.00) and IMR- 50, IMR- 60(36.00) and was lowest in IMR- 224 (2.33).
- **20% Level:**- Under 20% the number of laterals had a mean value of 8.04 with highest value recorded in IMR- 565 (24.00) followed by IMR- 63 (21.00) and IMR- 8, IMR- 50, IMR- 60 (19.00) and was lowest in IMR-224, IMR-268 and IMR-386 (1.33).

Root Biomass(g): The data on root biomass under different levels of PEG-6000 was

- **0% Level (Control):**- Under controlled conditions the root biomass had a mean value of 0.37 with highest value recorded in IMR- 63(0.63) followed by IMR- 384 (0.62) and IMR- 121 and IMR- 574 (0.61) and was lowest in IMR- 20 and IMR-248(0.16).
- **10% Level:-** Under 10% the root biomass had a mean value of 0.28 with highest value recorded in IMR- 574 (0.56) followed by IMR- 671(0.53) and IMR- 60 (0.52) and was lowest in IMR- 20(0.09).
- **20% Level:-** Under 20% the root biomass had a mean value of 0.17 with highest value recorded in IMR- 671(0.44) followed by IMR- 11, IMR- 574 (0.43) and IMR-121(0.41) and was lowest in IMR- 152 (0.02).

In the present study all the root parameters including primary root length, number of seminals, number of laterals and root biomass decreased with increasing PEG concentrations from 0-20%. All the root parameters had highest value under control and had significant decline effect with increasing PEG concentrations (0% < 10% < 20%). Similar results were reported by [14] in maize who reported that increasing PEG concentrations led to a decline in key parameters such as germination rate, root elongation and shoot development. Bukhari, et al. [15] reported that the concentration of PEG 6000 affected the response of corn varieties to germination and seed vigor. Polyethylene glycol (PEG) creates osmotic stress and could be used to examine the effect of water stress on seed germination [16]. Polyethylene glycol is the best solute that is known of imposing a low water stress that is reflective of the type of stress imposed by a drying soil [17]. The effect of PEG in physiological processes has also been reported in maize by [18]. In a water deficit environment, development of a crop mainly depends on the germination of seeds and the establishment of seedlings [19]. The selection method against drought stress using PEG in the vegetative phase was used to simulate maize tolerance to drought stress in the vegetative phase [20]. (The germination process consists of enzymatic hydrolysis of stored food and the formation of new tissues [21]. Therefore, it is necessary to develop effective screening criteria at early growth stages to get the maximum yield [13]. It is an established fact that tolerance at maturity is demonstrated by the tolerance at immature stage of plant. Root system with the ability of better growth under stress conditions can be considered as tolerant germplasm [22]. Thus there is a scope to identify genotypes that have tolerance to drought at the primary growth stage. In our study, IMR- 7 recorded lowest reduction in primary root length, IMR- 439 and IMR- 667 recorded lowest reduction in number of seminals, IMR- 565 recorded lowest reduction in number of laterals and IMR- 671 recorded lowest reduction in root biomass across different concentrations of PEG-6000. Such inbreds having genetic potential to maintain the higher growth under stress conditions were identified as drought tolerant.

4. CONCLUSION

The variation among maize inbreds for these traits in the present study was found to be an ideal indicator to screen the drought tolerant genotypes at early growth stages. These results have significant implications for increasing maize production in drought prone areas. The inbreds showing the better level of drought tolerance at all levels of PEG induced stress could be used as a source of drought tolerance for the improvement of drought tolerant hybrids .

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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