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Polyethylene Glycol (PEG) induced Drought Stress on Seed Germination of Rice

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ABSTRACT: Water is now a scare commodity in all parts of world, projected climate changes will aggravate the situation in future. Drought is a abiotic stress that limits the production of all the crops, which affects growth, development and yield of rice. A laboratory experiment was conducted to evaluate the germination characteristics of 25 rice genotypes under two levels of osmotic stress under Completely Randomized Design (CRD) with three replications. Polyethylene glycol 6000 was used as an osmoticum. Total germination, mean germination rate, germination index, root length, shoot length, root length stress tolerance index and root shoot ratio were recorded. The results showed that with increasing of osmoticum concentration (water stress), germination and seedling morphological characters were decreased, when compared with control. The genotypes namely vedhividangan, naveen, swarnamukhi, improved kavuni, vellaichithiraikar, kayamma exhibited tolerance in the higher concentration of osmoticum. The variations among the genotypes for germination characters were observed and Root Length Stress Index (RLSI) was found to be a reliable indicator to screen the drought tolerant genotypes at germination and seedling stage in rice.

Keywords: Drought, Rice, Germination, Polyethylene glycol, Screening.

INTRODUCTION

Rice (*Oryza sativa* L.) is the consumed staple food overall part of the world's human population, especially in Asia (Samal and Babu 2018). Drought affects more than 23 million hectares of rainfed rice in Asia (Kumbhar *et al*., 2015). Asia is at the top in terms of the production and consumption of rice. The average production of rice is estimated at 5.9 to 7.7 mt. Asia is forecasted to be still the major region for paddy production in the world. By 2030 Asia's rice yields is estimated from 11.7 to 23.4% and reach 4.59 to 5.08 mt ha^{-1}, due to the rise in population. The present and foreseen worldwide sustenance requests a momentous enhancement in crop productivity on less favorable rainfed lands. Climate change, influencing the regularity and level of hydrological fluctuations, is a major threat to agriculture, particularly in developing nations, and causes various abiotic stresses for plants.

Among the abiotic factors, drought is the imperative and major limitation for rice production in rainfed ecosystems (Oladosu *et al.*, 2019). The detrimental results are reflected for changes in morphological, physiological, biochemical and molecular processes of the plant under drought stress. Seed germination and seedling development is very important for early establishment of plants under stress condition. Selecting genotypes for rapid and uniform germination under water stress conditions can contribute towards early seedling establishment. Hence analysis of germination and seedling growth traits and their response to drought can be useful for selection of rice genotypes tolerance to drought. In this view, the objective of the present study was to analyze the genotypic variations in drought tolerance of rice at germination and early seedling stage.

MATERIALS AND METHODS

The experiment was conducted in department of Crop Physiology TNAU. In *vitro* screening for drought tolerance was carried out using Poly Ethylene Glycol (PEG 6000) in germination paper; a horizontal line was drawn at 3 cm from the top and was marked with 25 points at 1 cm intervals. 25 seeds of each genotype were placed at the marked point on the moistened paper towel, a moistened second paper towel was carefully placed over the seeds. The paper towels along with a polythene sheet below it was then rolled loosely to form a tube and held with a rubber band. The rolls were placed in containers of different PEG concentrations. Drought stress was simulated at two different concentrations namely, -2.5 and -3.0 bars of osmotic potential created by dissolving 145 and 160 grams of PEG 6000 respectively in 1000 ml of water. Control was maintained using water.

PEG solutions were prepared according to the method described by Michel and Kaufmann (1973).

Osmotic Potential (OP) = $(-1.18\times 10^{-2}) \times C - (1.18 \times 10^{-4}) \times C2 + (2.67\times 10^{-4}) \times C \times T + (8.39\times 10^{-7}) \times C2$

T where, C = PEG concentration, T = Temperature (29°C)

At 12 Days after Sowing (DAS) data were recorded on Total germination percentage, mean germination time, Germination index, Root length, shoot length, Root length stress tolerance index and Root/shoot ratio calculated for different levels of treatment.

1. Total Germination (TG) measured in the 12^{th} day using formula

TG (%) = (Total number of germinated seeds/ Total number of seeds used) × 100.

2. Mean Germination Time (MGT) calculated according the formula of Ellis and Roberts (1981).

MGT= Σ (ni/di), where as ni: number of germinated seeds and di: day of counting.

3. Germination index (GI) was calculated at 12 DAS using the following formula

GI= (Germination percentage in each treatment/ Germination percentage in control) × 100

4. Shoot length and root length of seedling was measured from five randomly selected seedlings in each variety from each replication; it was calculated and expressed in cm.

5. RLSI (%) = (Root length of stressed plant / Root length of control plants) × 100

6. Root shoot ratio=Root length/ shoot length

The collected data were analyzed statistically by SPSS 16.0 following Completely Randomized Block Design.

RESULT AND DISCUSSION

Seed germination was greatly affected by drought stress. Polyethylene glycol (PEG) used in this research has an osmotic agent. The use of PEG is to slow down the moisture rate of seeds and this low water potential is a determining factor for inhibiting seed germination parameters (Jiao *et al*., 2009).

Effect of drought on germination: Germination is one of the critical stages in the life cycle of plants. Germination and seedling characteristics of rice genotypes were significantly influenced by various levels of drought stress (Table 1). Whereas, increasing PEG concentration seed germination percentage was reduced. Higher total germination percentage was observed in control *viz*., Swarnamukhi (80.32), Naveen (74.32) and Kavuni (74.0), Vedhividangan (73.12) and Mapillai samba (71.15) under -2.5 bars of PEG concentration and lowest total germination percentage were in Pantdhan (7.15%), Kalanamak (13.29%), Manulyan (24.12%) and Thondi (21.12%) distinguished when the level of PEG concentration increases (-3 bars).Normally, Water uptake by seed that leads to the activation of metabolic process. Whiling, using PEG it creates osmotic potential that decrease germination. The result was in agreement with the reports of Khodarahmpour (2011); Sokoto and Muhammad (2014).

MGT indicated that the time for faster germination of the first seed germinated. According to MGT, the days taken to initiate and complete the germination processes varied in different rice genotypes. In control, a minimum of 3 days' time taken by all rice varieties for initiation of germination and 7 days for completion. However, with increasing water stress, the time for seed emergence was increased and the rate of germination was decreased at various levels of PEG concentration. The higher rate of germination was recorded in Swarnamukhi (1.33), Kullakar (1.30), Surakurvai (1.26), and Mapillai samba (1.18) in -2.5 bars of PEG and the lower rate was observed in Pantdhan (0.12), Kalanamak (0.14), Thondi (0.26) at the concentration of -3 bars of PEG, respectively.

The germination index (GI) also reduced with the increase level of drought stress. But, the GI of Vedhividangan (91.40), Mapillai samba (93.92), Vellaichithiraikar (89.00), Naveen (89.00) and Mayur pankhi (88.55) was found to be higher in -2.5 bars PEG concentration. Genotypes namely Vedhividangan (86.25), Surakurvai (74.72), Swarnamukhi (71.87), Kayamma (71.91), Naveen (79.51), and Kavuni (74.38) recorded higher index even under -3 bars of PEG concentration. The results showed that these genotypes showed dominance over the other genotypes in relation to germination (Fig. 1). Swain *et al*. (2014) stated that seed germination and their rate were affected by drought stress, which is in line with the findings of this present study. All parameters indicated that negatively affect plant growth because of PEG.

Table 1: Effect of PEG at different levels on seedling characters in rice genotypes.

Genotypes	Total germination (%)			Mean germination Time			Shoot length			Root Length			Root/shoot ratio		
	Control	-2.5 bars	-3 bars	Control	-2.5 bars	-3 bars	Control	-2.5 bars	-3 bars	Control	-2.5 bars	-3 bars	Control	-2.5 bars	-3 bars
Swarnamukhi	96.50	80.07	69.81	1.33		0.99	12.41	10.20	7.56	13.23	9.70	6.80	1.07	0.95	0.90
Kayamma	89.40	70.10	64.51	1.78	1.00	1.07	7.80	6.20	2.60	13.51	5.60	2.30	1.73	0.90	0.88
Pokkali	95.70	68.31	57.09	1.36	0.97	0.81	10.85	9.34	6.80	18.67	11.30	6.00	1.72	1.21	0.88
Vellaichithiraikar	77.52	69.27	53.13	1.28	1.15	0.88	14.73	10.34	5.60	15.80	12.23	7.80	1.07	1.18	1.39
Naveen	83.15	74.07	66.25	1.19	1.06	0.94	11.43	9.46	10.66	18.32	13.80	8.97	1.60	1.46	0.84
Kattaikar	82.18	57.65	50.43	1.64	0.95	0.83	14.38	7.40	3.60	16.30	6.42	2.50	1.13	0.87	0.69
Kalanamak	75.50	29.12	13.29	1.25	0.48	0.14	12.50	5.00	1.70	15.90	2.40	1.46	1.27	0.48	0.86
Kakarathan	78.45	65.00	47.18	0.98	0.72	0.67	14.47	5.60	3.70	11.40	3.60	1.90	0.79	0.64	0.51
Maranellu	68.70	45.47	28.16	0.85	0.50	0.35	11.75	5.12	2.60	10.90	2.40	1.10	0.93	0.47	0.42
Manulyan	69.45	50.33	24.12	1.15	0.71	0.30	14.08	7.80	4.90	17.48	3.40	2.30	1.24	0.44	0.47
Thondi	76.60	36.10	21.12	1.14	0.60	0.26	10.66	8.40	5.23	13.40	5.80	4.09	1.26	0.69	0.78
Mayur pankhi	65.50	58.52	34.81	1.30	0.97	0.49	12.23	4.00	3.70	10.20	3.50	2.10	0.83	0.88	0.57
Kattuponni	63.00	43.00	30.23	1.05	0.61	0.38	11.86	6.90	0.00	18.40	4.76	0.00	1.55	0.69	0.00
Improved Kavuni	84.00	74.23	62.48	1.40	1.06	0.89	7.78	9.27	7.20	16.00	10.70	10.18	2.06	1.15	1.41
Kavya	97.60	60.40	40.25	1.42	1.00	0.67	8.35	8.58	6.90	17.89	9.32	6.50	2.14	1.09	0.94
Kasalth	76.25	64.01	61.15	1.27	0.83	1.02	11.50	10.57	5.70	12.69	9.86	4.81	1.10	0.93	0.84
Surakurvai	75.15	63.00	56.15	1.07	1.26	0.80	12.60	7.60	4.60	11.79	8.90	4.23	0.94	1.17	0.92
Vedhividanya	80.00	73.12	69.00	1.33	1.04	0.86	15.09	11.70	8.65	13.09	8.00	6.23	0.87	0.68	0.72
Mapillai samba	76.15	71.52	53.15	1.52	1.18	0.76	12.89	7.89	6.23	16.45	8.34	5.85	1.28	1.06	0.94
Kullakar	84.57	65.23	57.56	1.40	1.30	0.71	13.09	7.90	5.90	13.03	6.23	4.78	1.00	0.79	0.81
Koshinikarai	78.25	56.15	57.15	0.98	0.93	0.62	9.78	8.10	2.89	7.80	6.90	3.23	0.80	0.85	1.12
Jeerga samba	85.15	53.25	40.00	0.94	0.76	0.57	7.67	6.32	2.14	6.98	5.34	1.40	0.91	0.84	1.46
White ponni	73.00	65.09	57.27	1.04	0.93	1.74	8.09	6.23	4.78	5.32	4.21	3.10	0.66	0.68	0.65
Pantdhan	32.15	14.40	7.15	0.40	0.23	0.12	1.78	0.50	0.12	1.09	0.70	0.43	0.61	0.71	3.58
Wita	65.82	52.00	39.15	1.08	0.87	0.56	7.54	5.20	2.60	4.87	3.80	1.15	0.65	0.73	0.44
Mean	**77.44**	**58.56**	**46.39**	**1.21**	**0.91**	**1.20**	**11.00**	**7.42**	**4.65**	**12.80**	**6.68**	**3.96**	**1.16**	**0.86**	**0.92**

	SEd	CD (5%)	SEd	CD (5%)	SEd	CD (5%)	SEd	CD (5%)	SEd	CD (5%)
Treatment	0.218	0.431	0.004	0.007	0.024	0.047	0.032	0.063	0.003	0.007
Genotype	0.630	1.246	0.010	0.020	0.068	0.135	0.092	0.181	0.010	0.019
(GXT)	1.091	2.157	0.018	0.035	0.119	0.235	0.159	0.314	0.017	0.034

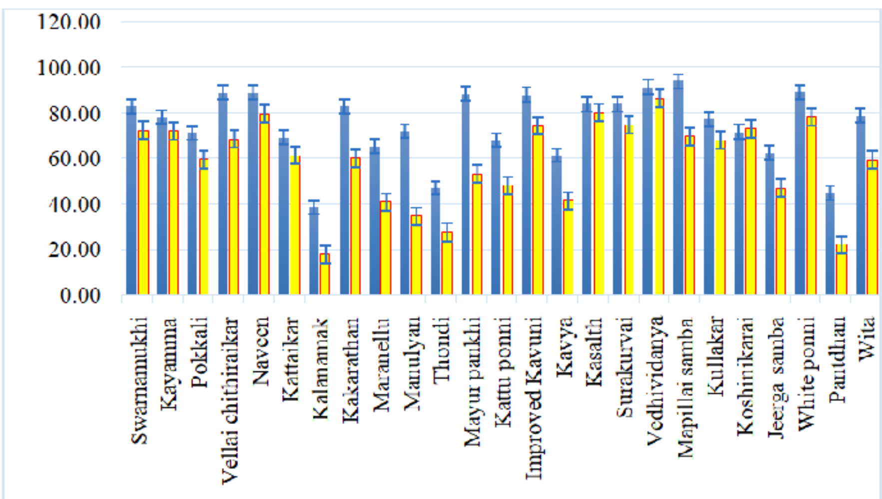

Fig. 1. Effect of drought stress on germination index in rice genotypes.

Effect of drought on shoot length: The effect of drought is revealed on the aerial parts of the plant, which will bear most economic parts of the crops. In the present study, Vedhividangan (11.70cm), Kasalth (10.57cm), and Vellaichithiraikar (10.34cm) recorded significantly higher shoot length in a higher concentration of -2.5 bars PEG solution out of the 25 genotypes studied (Table 1). Even though few genotypes recorded significant values at -3 bars of PEG solution and but rest of the genotypes the shoot length was decreased with an increase of water stress. However, this hindrance was found to be higher in Pantdhan (0.12), Kattuponni (0.00), and Kalanamak (1.70cm) at a high concentration of PEG at -3 bars. These results corroborate the findings of Pandey and Shukla (2015). Under water stress, it has been shown that the inhibition of radicle emergence is mainly because of a decrease in the water potential gradient between the external environment and the seed and consequently impairs seedling height (Sokoto and Muhammad 2014).

Effect of drought on root length: Rapid root elongationis a signal of drought tolerance (Lawlor, 1970). In the present examination, the root length pointedly declined with increased external water potential. Among the 25 genotypes tried, Kavuni (10.18 cm), Naveen (8.97cm) Vellaichithraikar (7.80cm) recorded higher root length in higher concentrations of drought (-3 bars). Long roots were described as a component trait for drought tolerance by Govindaraj *et al*. (2010) and play a direct role in high penetration ability and large xylem vessel radii and lower axial resistance to water flux aiding in greater water acquisition. Hence, the same genotypes recorded a higher root length stress tolerance index which provides an important clue to the response of plants to drought stress (Fig. 2).

Effect of drought on root/shoot ratio: The ratio ranged from 0.44 to 2.6. In control, a high root/shoot ratio was exhibited by all genotypes in the case drought stress ratio is reduced. The genotypes namely, Vellaichithiraikar (1.39) and Kavuni (1.41) showed higher root/shoot ratio than other genotypes that performed lower root/shoot ratio in -3.0 bars of PEG (Table 1). Moreover, genotypes Naveen (1.46), Vellaichithiraikar (1.21) and Pokklai (1.21) showed higher root/shoot ratio in -2.5 bars PEG and also above-mentioned genotypes are considered as drought tolerant genotypes. A high root-to-shoot ratio has been reported as element that attribute for drought avoidance by Govindaraj *et al.* (2010). Salt stress reduces water uptake there by result in decrease cell division and elongation and biomass (Farooq *et al*., 2015; Sagar, 2017).

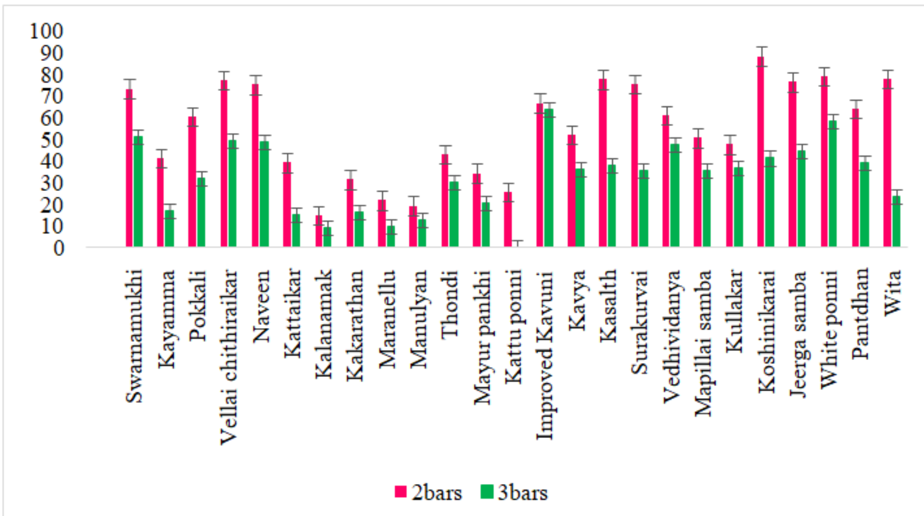

Fig. 2. Effect of drought stress on root length stress tolerance in rice genotypes.

CONCLUSION

Rice genotypes remained highly sensitive to drought stress during seed germination. The present investigation also determined that germination and seedling growth were affected in rice genotypes by increasing the levels of water stress. In response to water stress, Vedhividangan, Naveen, Swarnamukhi, Kavuni, Vellaichithiraikar, and Kayamma exhibited tolerance to the higher concentration of -2.5 bars of PEG as compared to others.

FUTURE SCOPE

To screen a large population for drought stress, at early growth stage, it would be cost-effective, less time-consuming, less laborious. It is concluded that, the optimum concentration of PEG is the -2.5 bars based on the observation to screen a large population for drought stress.

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Conflict of Interest. None.

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