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Original Research Article

Effect of Peg-Induced Drought Stress on Germination Early Seedling Growth of Foxtail Millet Varieties

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Keywords

Foxtail Millet, polyethylene glycol (PEG-6000, Drought Stress

A B S T R A C T

The response of sixty foxtail millet varieties against five levels (0%, 15%, 20%, 25% and 30%) of polyethylene glycol (PEG-6000) was studied for assessing germination and early seedling growth stage to screen the entries for their relative ability to tolerate drought under laboratory condition. Data were analyzed statistically for final germination percentage (FGP), plumule and radicle length. PEG-induced drought stress decreased final germination percentage led to reduction in shoot and root length in all varieties and the magnitude of reduction increased with increasing drought stress concentrations. Germination was highly inhibited in all sixty varieties at 30% PEG concentration. Foxtail millet varieties Suryanandi, Prasad, SiA 3551 and SiA 3615 showed the highest stress tolerance in terms of higher per cent seedlings survival and lower reduction in root and shoot growth. The result suggested that Suryanandi, Prasad, SiA 3551 and SiA 3615 might be used for further study of drought stress under field conditions to assess growth processes and its physiological consequences at an advanced stage of growth to continue their ability to tolerate drought under field situation.

Introduction

Foxtail millet (*Setaria italica* L.) is one of the oldest cultivated small millets both for food and fodder. It ranks second in the total world production of small millets and it continues to have an important place in world agriculture providing food for millions of people in arid and semiarid regions. It is native to China, India and Pakistan with the rainfall ranging from 150-700 mm and regarded as an elite drought tolerant crop. In India, it is cultivated in Andhra Pradesh, Karnataka, Maharastra, Tamilnadu, Odissa, Rajasthan and Madhya Pradesh for staple food as well as fodder. In India, foxtail millet is cultivated in 98,000 ha. area with a production of 56 t ha^{-1} and productivity of 565 kg ha^{-1} and in Andhra Pradesh, it is cultivated in an area of 23,005 hectares with a production of 28,348 tonnes and productivity of 1232 kg ha^{-1} (Annual report, AICPMIP, 2015-16).

Foxtail millet (*Setaria italica* L.) is one of the oldest domesticated plants in India and has the highest amount of calcium and potassium. It is known to survive under severe drought and osmotic stress and is able to recover from alleviation from stress.

Selection of plants with a better drought tolerance is critical in dry environments. Successful crop establishment in semiarid regions depends on effective seed germination, which is strictly associated with the ability of seeds to germinate under low water availability. The main objective of this study was to evaluate the influence of PEG induced drought stress on seeds of sixty different foxtail millet genotypes and to understand the effect of drought on seed germination. This will in turn allow plant breeders to select cultivars which are best suited for developing drought resistant cultivars.

Materials and Methods

Seeds of sixty different foxtail millet varieties used in the study were collected from Agricultural Research Station, Nandyal, Andhra Pradesh, India. Healthy and uniform seeds of 60 foxtail millet germplasm lines were surface sterilized with 1% sodium hypochlorite for 3 min, 70% ethanol and washed with distilled water and surface dried. Twenty seeds for each cultivar in each treatment were allowed to germinate on a filter paper in 9 cm diameter Petri dishes. Each filter paper was moistened with solutions of 0 (distilled water) as a control, or 15%, 20%, 25% and 30% of PEG (MW 6000) concentration.

PEG 6000 was used as it is small enough to influence the osmotic potential but cannot be fully absorbed by the plant and is not phytotoxic. A quantity of 10 ml of appropriate solution was applied to each Petri dish. The Petri plates were arranged in completely randomized design (CRD) with three replicates for each treatment. Germination room temperature was maintained at 25 ± 1°C and a relative humidity of 70%. Petri plates were periodically checked and respective solutions were applied to compensate evaporation. Seeds were considered germinated when the radicle had extended for at least 2mm. Seedling shoot and root length of randomly selected seedlings from each replication were measured after 4 and 9 days after treatment application by using a scale. After final count, final germination percent (FGP) was calculated by the following formula

$$GP\ (\%) = \frac{\text{Number of final germinated seeds}}{\text{Total number of seeds tested}} \times 100$$

Results and Discussion

This study was to evaluate the influence of PEG induced drought stress on seeds of 60 different foxtail millet genotypes and to understand the effect of drought on seed germination by using different concentrations of standardized polyethylene glycol (PEG) protocol. Data recorded on germination percentage, plumule length and radicle length parameters is presented in Table 3.

The PEG induced stress response of top ten genotypes revealed that Prasad showed the lowest percent reduction in root and shoot growth at different concentrations of PEG with 100% of survival of seedlings followed by SiA 3539 (100%) and Narasimharaya (96%) (Table 2). Hence, these can be used as a potential donor parents for breeding for selecting varieties for water stress tolerance.

The genotypes showed high genetic variability for per cent survival of seedlings, per cent reduction in root and shoot growth respectively. The per cent survival of seedlings, shoot and root growth of high stress tolerant and stress sensitive genotypes varied for different concentrations of PEG *viz.*, control, 15%, 20%, 25% and 30% (Fig 1 and Fig 2) (Plate 1). Among all the

genotypes, Suryanandi, Prasad, SiA 3551 and SiA 3615 showed the highest stress tolerance in terms of higher per cent seedlings survival and lower reduction in root and shoot growth (Table 2). These varieties showed ability to survive even when they were exposed to higher concentrations of Polyethylene glycol (PEG) compounds used to induce osmotic stress. PEG induced osmotic stress is inducted to decrease cell water potential (Govindaraj *et al*, 2010). These results are in conformity with several studies, which showed that in vitro screening technique using PEG is one of the dependable approaches for the selection of desirable genotypes to study in detail on water scarcity on plant germination indices (Kocheva *et al*, 2003).

The seedling survival, shoot and root growth were completely affected in the genotypes SiA 3563, SiA 3558, SiA 3600 and SiA 3623 due to their lesser tolerance ability to osmotic stress conditions induced by higher concentrations of PEG. In spite of treated with higher concentrations of PEG *viz.*, 15%, 20%, 25% and 30% germination and seedling growth were not affected in the genotypes Suryanandi, Prasad, SiA 3551 and SiA 3615 probably due to higher acquired stress tolerance.

Plate.1 An experimental view of Polyethylene glycol (PEG) technique in laboratory

Table.1 Effect of PEG induced drought stress on germination %, Plumule length and Radicle length of 60 foxtail millet genotypes under different concentrations

S.No	Genotype	Germination per cent at					Plumule length (cm) at					Radicle length (cm) at				
		Control	15%PEG	20%PEG	25%PEG	30%PEG	Control	15%PEG	20%PEG	25%PEG	30%PEG	Control	15%PEG	20%PEG	25%PEG	30%PEG
1	Suryanandi (Check)	100.00	99.33	88.67	79.33	44.00	7.0	7.0	5.3	3.4	2.0	9.5	3.9	5.1	3.2	1.4
2	SiA-3539	100.00	92.00	84.67	78.00	38.00	5.5	4.7	3.2	4.0	1.8	4.7	6.6	4.3	3.2	2.8
3	SiA-3542	100.00	86.67	72.67	72.67	38.67	5.0	4.9	4.7	4.0	1.9	4.9	5.4	5.0	3.9	1.3
4	SiA-3543	100.00	80.00	75.33	82.00	38.67	4.5	5.2	4.1	3.0	1.4	5.6	3.4	2.1	2.1	1.4
5	SiA-3545	96.00	88.00	75.33	62.00	23.33	4.8	4.7	4.4	3.6	2.2	5.7	3.7	5.9	1.7	2.8
6	SiA-3546	100.00	68.00	52.00	65.33	40.67	5.3	5.5	4.7	3.4	1.7	3.3	4.1	2.6	3.6	2.0
7	SiA-3550	100.00	86.67	90.00	70.67	18.00	4.7	5.2	4.9	3.0	1.8	7.3	2.9	4.7	2.5	2.6
8	SiA-3551	97.00	84.00	82.00	66.00	40.00	5.5	5.1	4.1	3.3	2.0	6.1	4.5	5.0	3.0	1.5
9	SiA-3554	98.00	88.00	84.00	70.00	30.00	6.1	5.4	3.8	2.4	2.0	5.2	4.2	4.2	2.8	2.0
10	SiA-3555	96.00	88.00	84.00	74.00	18.00	5.8	5.2	3.8	2.6	1.5	6.3	5.1	3.5	3.4	1.8
11	Narasimharaya (Check)	96.00	82.67	78.00	40.67	32.67	6.5	5.5	4.2	3.1	1.5	6.1	4.0	2.7	3.1	1.6
12	SiA-3558	86.00	62.67	47.33	16.67	2.00	5.8	4.6	4.9	1.5	0.3	3.8	3.7	3.9	2.6	1.4
13	SiA-3559	84.00	91.33	82.67	48.00	6.67	5.4	4.8	3.4	1.9	0.6	4.3	4.9	3.2	1.2	0.4
14	SiA-3560	98.00	74.67	62.00	47.33	9.33	7.4	5.1	4.7	2.4	0.4	8.1	5.2	3.2	3.6	1.0
15	SiA-3562	80.00	61.33	52.67	17.33	0.00	5.0	5.3	3.7	1.2	1.2	5.6	5.3	3.4	2.5	1.2
16	SiA-3563	90.00	79.33	76.00	49.33	3.33	4.4	3.7	3.5	1.8	0.8	3.4	3.1	2.5	2.3	0.9
17	SiA-3569	70.00	84.67	84.67	72.00	8.67	5.4	3.9	2.6	2.7	0.2	5.8	4.4	3.2	2.8	0.6
18	SiA-3570	78.00	66.00	60.00	48.00	24.00	5.9	4.2	2.9	2.4	1.3	7.1	5.1	3.6	4.0	1.2
19	SiA-3572	90.00	80.00	70.00	58.00	12.00	6.1	4.9	3.5	1.9	1.7	5.9	5.4	3.8	3.5	0.9
20	SiA-3574	94.00	84.00	68.00	50.00	30.00	5.4	4.8	4.0	2.3	1.4	6.4	4.9	4.0	3.8	0.5
21	Prasad (Check)	100.00	94.00	98.00	82.67	40.00	6.3	6.4	4.6	3.1	1.2	4.7	5.1	2.5	2.8	1.0
22	SiA-3575	88.00	80.00	66.00	56.00	14.00	6.2	5.2	3.3	3.2	1.7	6.3	5.2	2.9	2.9	2.0
23	SiA-3578	90.00	80.00	72.00	54.00	8.00	6.1	5.0	3.6	2.7	1.9	5.8	4.8	3.8	2.2	1.5
24	SiA-3580	98.00	78.00	64.00	50.00	22.00	5.7	4.8	3.5	2.8	1.4	5.9	6.1	4.0	3.2	1.6
25	SiA-3581	100.00	92.00	78.00	58.00	24.00	5.4	4.2	4.0	3.5	1.3	6.1	5.4	4.1	2.5	0.9
26	SiA-3582	88.00	80.00	76.00	60.00	28.00	5.3	4.4	4.1	3.3	1.0	5.5	5.7	3.5	3.1	0.7
27	SiA-3583	92.00	82.00	62.00	48.00	16.00	2.4	3.5	4.0	3.4	1.2	5.3	5.8	3.6	2.8	2.0
28	SiA-3584	100.00	96.67	82.00	62.00	20.00	6.0	4.4	3.7	2.8	2.0	6.1	4.9	3.9	3.5	0.9
29	SiA-3585	100.00	97.33	88.67	76.67	28.00	6.1	4.0	3.8	2.6	0.5	7.2	5.4	2.8	2.9	1.4
30	SiA-3586	100.00	95.33	93.33	71.33	18.67	5.8	3.6	3.4	3.5	0.9	5.8	5.6	2.5	1.5	1.2

Table 1. Contd……

S.No	Genotype	Germination per cent at					Plumule length (cm) at					Radicle length (cm) at				
		Control	15%PEG	20%PEG	25%PEG	30%PEG	Control	15%PEG	20%PEG	25%PEG	30%PEG	Control	15%PEG	20%PEG	25%PEG	30%PEG
31	Sri Lakshmi (Check)	94.00	96.00	94.00	63.33	21.33	5.5	5.6	3.9	2.5	1.4	5.1	3.7	2.2	1.5	0.9
32	SiA-3589	100.00	95.33	92.67	86.00	4.67	4.6	4.2	4.1	1.5	0.7	5.5	4.5	4.6	1.7	1.2
33	SiA-3591	98.00	98.00	94.00	48.00	2.00	4.6	4.8	4.4	1.7	0.4	4.5	3.6	3.8	1.7	0.8
34	SiA-3595	98.00	97.33	92.00	48.00	0.00	5.8	5.7	3.8	1.2	0.3	5.4	5.9	3.6	1.9	0.6
35	SiA-3596	98.00	98.00	94.00	50.67	10.67	4.7	5.5	3.6	0.9	0.5	4.9	5.5	3.6	0.9	0.5
36	SiA-3598	98.00	93.33	84.00	46.67	17.33	5.9	5.5	4.1	1.3	1.1	5.3	5.1	3.0	2.4	1.2
37	SiA-3600	96.00	56.67	30.67	12.67	0.67	5.1	5.0	3.4	2.1	1.5	4.8	4.6	3.6	2.9	1.5
38	SiA-3604	96.00	84.00	90.67	32.67	13.33	5.2	5.1	3.1	1.1	1.6	4.5	4.9	2.5	1.9	1.4
39	SiA-3605	100.00	98.00	94.67	41.33	6.67	5.0	3.5	3.5	2.6	0.4	5.4	4.0	3.6	2.3	2.0
40	SiA-3607	94.00	88.00	78.00	60.00	18.00	4.9	3.2	3.5	2.7	0.5	5.5	5.1	3.8	1.5	1.5
41	Krishnadevaraya (Check)	100.00	86.00	80.00	21.33	2.67	4.3	4.2	4.3	1.6	1.4	4.6	3.5	2.7	2.6	1.6
42	SiA-3608	92.00	88.67	77.33	60.00	25.33	5.3	6.1	4.5	2.7	2.0	5.7	5.6	4.2	3.1	0.7
43	SiA-3610	90.00	86.00	76.00	58.00	24.00	7.3	5.9	6.4	3.7	1.5	5.7	3.8	4.6	2.8	0.5
44	SiA-3611	96.00	82.00	84.67	80.00	33.33	6.6	5.5	4.3	4.4	1.7	4.8	4.7	3.7	2.4	0.9
45	SiA-3613	100.00	88.67	76.00	75.33	24.00	6.4	4.9	2.7	2.8	0.4	4.6	5.0	2.6	3.0	0.8
46	SiA-3615	98.00	88.00	90.00	76.00	33.33	6.1	4.5	3.9	3.1	1.0	6.1	5.2	3.5	1.7	0.7
47	SiA-3618	94.00	93.33	91.33	80.00	18.67	6.2	3.9	3.0	2.5	0.8	5.4	4.8	3.6	1.9	0.8
48	SiA-3619	90.00	90.00	50.67	76.67	18.00	4.8	4.1	3.7	2.2	0.6	5.8	5.1	2.8	2.0	0.9
49	SiA-3622	98.00	84.67	74.67	62.00	12.67	5.6	4.4	3.5	3.2	0.9	5.3	6.0	2.9	1.5	0.7
50	SiA-3623	90.00	80.00	42.67	23.33	6.00	5.8	4.7	2.8	1.9	0.4	4.8	4.0	3.1	2.5	0.4
51	SiA-3085 (Check)	84.00	66.67	66.67	46.67	20.67	5.7	3.5	3.7	2.8	1.1	5.7	4.7	4.0	3.1	0.8
52	SiA-3625	96.00	88.00	76.00	62.00	30.00	5.9	2.8	3.9	2.4	0.8	5.4	4.2	3.5	2.8	0.9
53	SiA-3626	100.00	96.00	82.00	64.00	24.00	6.1	4.1	3.8	2.6	1.8	5.2	5.8	3.9	2.4	0.7
54	SiA-3628	94.00	88.00	78.00	60.00	18.00	5.8	4.0	3.8	2.5	1.4	6.1	4.3	2.7	2.9	0.9
55	SiA-3631	98.00	90.00	78.00	58.00	14.00	5.3	3.3	3.9	3.5	1.2	7.2	5.1	3.0	3.0	0.8
56	SiA-3632	100.00	94.00	82.00	52.00	12.00	4.9	3.9	3.4	3.4	1.5	6.9	5.0	2.8	1.8	0.8
57	SiA-3634	94.00	90.00	76.00	58.00	22.00	5.8	4.0	4.0	3.2	1.0	6.8	3.8	2.9	1.4	0.9
58	SiA-3636	96.00	94.00	82.00	60.00	24.00	6.1	5.0	4.0	3.4	1.2	5.8	5.0	2.8	2.5	0.8
59	SiA-3637	88.00	80.00	72.00	56.00	22.00	4.9	4.0	3.9	2.5	1.1	6.4	3.9	3.0	2.6	0.7
60	SiA-3156 (Check)	98.00	92.00	80.00	58.00	28.00	5.8	4.1	4.1	1.5	1.1	6.2	4.8	2.8	3.1	0.9
	Mean	94.82	87.22	78.51	58.81	19.90	5.6	4.7	3.8	2.6	1.2	5.7	4.8	3.5	2.6	1.2
	SE(m)	1.52	0.90	1.64	1.45	1.12	0.12	0.15	0.15	0.36	0.55	0.13	0.14	0.23	0.34	0.44
	C.D. at 5%	4.31	2.56	4.60	4.87	4.35	0.43	0.42	0.52	0.36	0.61	0.38	0.42	0.67	0.85	0.44

Table.2 Stress tolerant performance of top ten high yielding foxtail millet genotypes

S.No	Genotype	Germination % at different PEG concentrations					Shoot length (cm) at different PEG concentrations					Root length (cm) at different PEG concentrations				
		Control	15%	20%	25%	30%	Control	15%	20%	25%	30%	Control	15%	20%	25%	30%
1	SiA 3636	96	94	82	60	24	6.1	5.0	4.0	3.4	1.2	5.8	5.0	2.8	2.5	0.8
2	Sri Lakshmi	94	96	94	63	21	5.5	5.6	3.9	2.5	1.4	5.1	3.7	2.2	1.5	0.9
3	Narasimharaya	96	82	78	40	32	6.5	5.5	4.2	3.1	1.5	6.1	4.0	2.7	3.1	1.6
4	SiA 3598	98	93	84	46	17	5.9	5.5	4.1	1.3	1.1	5.3	5.1	3.0	2.4	1.2
5	SiA 3604	96	84	90	32	13	5.2	5.1	3.1	1.1	1.6	4.5	4.9	2.5	1.9	1.4
6	SiA 3539	100	92	84	78	38	5.5	4.7	3.2	4.0	1.8	4.7	6.6	4.3	3.2	2.8
7	SiA 3584	100	96	82	62	20	6.0	4.4	3.7	2.8	2.0	6.1	4.9	3.9	3.5	0.9
8	SiA 3628	94	88	78	60	18	5.8	4.0	3.8	2.5	1.4	6.1	4.3	2.7	2.9	0.9
9	SiA 3611	92	82	84	80	33	6.6	5.5	4.3	4.4	1.7	4.8	4.7	3.7	2.4	0.9
10	Prasad	100	94	98	82	40	6.3	6.4	4.6	3.1	2.2	4.7	5.1	2.5	2.8	1.0

Table.3 Identification of promising stress tolerant foxtail millet genotypes through PEG technique

Tolerance range	Genotype	Germination % at different PEG concentrations					Shoot length (cm) at different PEG concentrations					Root length (cm) at different PEG concentrations				
		Control	15%	20%	25%	30%	Control	15%	20%	25%	30%	Control	15%	20%	25%	30%
Highly Stress Tolerant Lines	Suryanandi	100	99	88	79	44	7.0	7.0	5.3	3.4	2.0	9.5	3.9	5.1	3.2	1.4
	Prasad	100	94	98	82	40	6.3	6.4	4.6	3.1	2.2	4.7	5.1	2.5	2.8	1.0
	SiA 3551	97	84	82	66	40	5.5	5.1	4.1	3.3	2.0	6.1	4.5	5.0	3.0	1.5
	SiA 3615	98	88	90	76	33	6.1	4.5	3.9	3.1	1.0	6.1	5.2	3.5	1.7	0.7
Highly Stress Sensitive Lines	SiA 3563	90	79	76	49	3	4.4	3.7	3.5	1.8	0.8	3.4	3.1	2.5	2.3	0.9
	SiA 3558	86	62	47	16	2	5.8	4.6	4.9	1.5	0.3	3.8	3.7	3.9	2.6	1.4
	SiA 3600	96	56	30	12	0.6	5.1	5.0	3.4	2.1	1.5	4.8	4.6	3.6	2.9	1.5
	SiA 3623	90	80	42	23	6	5.8	4.7	2.8	1.9	0.4	4.8	4.3	3.1	2.5	0.4

Fig.1 Effect of PEG induced drought stress on plumule length (cm) of stress tolerant and sensitive foxtail millet lines

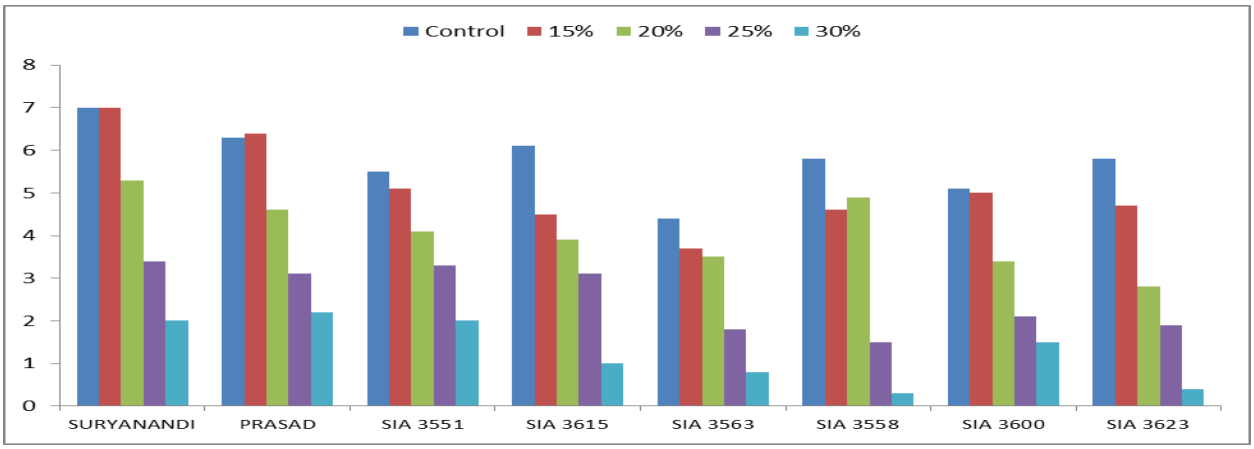
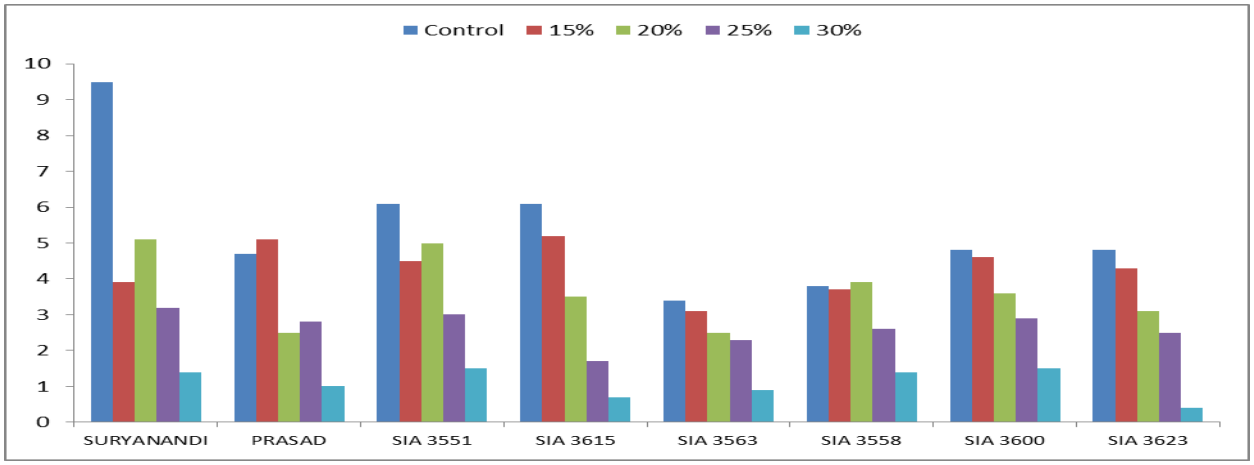


Fig.2 Effect of PEG induced drought stress on radicle length (cm) of stress tolerant and sensitive foxtail millet lines



The technique of treating germplasm lines to different concentration of PEG has been validated in many crop species (Osman *et al.*, 2015 in tomato; Khafagy *et al.*, 2014 in rice; Toosi *et al.*, 2014 in *B. juncea*; Muscolo *et al.*, 2014 in lentil; Sani *et al.*, 2014 Pearl millet; Naveena *et al.*, 2015 in finger millet). The present study also revealed that the PEG technique can very well be used in foxtail millet crop for identification of stress tolerant genotypes. The identified genotypes *viz.*, Suryanandi, Prasad, SiA 3551 and SiA 3615 were found to possess high level of water stress tolerance. These genotypes can be used as potent donors for developing a wide spectrum of foxtail millet varieties against severe water stress conditions.

In this study, the effect of PEG-induced drought stress on the germination of sixty varieties of foxtail millets was determined. Characters such as final germination percentage, root length and shoot length were collected and recorded. From this data, it can be concluded that low concentrations

of PEG (0, 15 and 20%) did not have any significant effect on the germination percentage, however, higher PEG concentrations (25 and 30%) negatively affected germination. The highest PEG concentration of 30% showed least impact on germination foxtail millet variety Prasad. These research results can be used by plant breeders to select cultivars which are best suited for developing drought resistant cultivars and for further studies in this field.

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