The Bioscan 9(2): 1419-1424, 2014
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

EVALUATION OF COTTON GENOTYPES FOR DROUGHT TOLERANCE USING PEG-6000 WATER STRESS BY SLANTING GLASS PLATE TECHNIQUE

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KEYWORDS
Cotton
Germination
Osmotic potential
PEG-6000
seedling vigour

Received on :
18.12.2013

Accepted on :
14.10.2014

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ABSTRACT
Twelve *Gossypium hirsutum* genotypes *viz.,* CPD-750, Sahana, ARB-9701, CNH-120MB, GIHV-218, BS-279, RAH-101, GJHV-477, F-2228, KH-155, L-761 and LH-2076 were evaluated for drought tolerance using PEG-6000 water stress at germination stage. The genotypes were subjected to different osmotic potentials (0.0 MPa, -0.05 MPa, -0.148 MPa, -0.295 MPa, -0.491 MPa, -0.735 MPa and -0.846 MPa) by slanting glass plate technique. The genotypes were evaluated for percent seed germination and seedling vigour traits at 12th and 18th day showed maximum concentration of PEG-6000 for the germination is 25% (-0.735 MPa) and at this concentration the shoot growth was completely inhibited in all the genotypes. As the PEG concentration increases there was an increase in root to shoot ratio. In conclusion the genotypes which found tolerant to the increased osmotic potential were BS-279, CNH-120MB, GIHV-218 and ARB-9701 whereas, L-761, KH-155 and LH-2076 were found as drought sensitive genotypes.

INTRODUCTION

Cotton is grown in arid and semi-arid regions of the world. *Gossypium hirsutum L.* and *Gossypium barbadance L.* are the two predominant elite cotton species, usually grown during the summer in arid and semiarid regions exposed to drought, which adversely affects both yield and lint quality. Water stress commonly attributed to situations where the water loss exceeds sufficient absorption intensity causing a decrease in plant water content, turgor reduction and consequently, a decrease in cellular expansion and alterations of various essential physiological and biochemical processes that can effect growth and productivity (Pettigrew, 2004).

During the germination phase, the water absorbed is required for several enzymatic reactions, for solubilization and transport of metabolites and as a reagent in the hydraulic digestion of proteins, carbohydrates and lipids from the tissue reserve of the seed towards the embryo (Khajeh *et al.,* 2003). Severe water stress results in a metabolic imbalance (Blackman *et al.,* 1992) and a reduction of metabolic activities in seedlings. Water deficiency causes various responses on plant metabolism, where osmotic adjustment is an extremely important physiological mechanism for preparing these plants to tolerate hydric stress, where diverse organic compounds accumulate as osmoregulators (Pimentel, 2004).

In the year 1979, first time PEG was used as an inducer and identifier to screen and select drought-resist- ant tobacco cell lines. Use of PEG to study of drought-resistant tomato cells, drought-resistant sorghum regeneration and identification of anti-PEG stress alfalfa cell lines has been attempted. Chinese researchers used to do cotton drought evaluation and identification by repeated drought induction method. It is still in the experimental stage to use PEG solution for the identification. PEG-6000 was used to establish a rapid and effective cotton-drought tolerance evaluation system for selection and breeding of the drought-tolerant cotton genotypes (Yu *et al.,* 1999).

Earlier germination studies have been carried out with aqueous solutions of polyethyleneglycol-6000 (PEG-6000) and mannitol (Fanti and Perez, 2004). Laboratory assays simulating water stress circumstances have aided researchers for the identification of cultivars with an elevated level of resistance to such adverse conditions in other crops, such as maize (Tonin *et al.,* 2000) and rice (Pirdashti *et al.,* 2003). Water stress induced by PEG, leads to decrease in the germination index and the morphological development of organs from young cotton plants and also reported that water absorption, retention and biomass gain were affected by water stress (Fernandez and Mariaelena, 1998).

Performance of cotton genotypes for drought tolerance using PEG water stress at germination, bud-stage, cotyledon-stage and real-leaf stage revealed that at 17% PEG-6000 treatment, the seedlings growth rate showed inhibition. Physiological quality of cotton cultivar seeds were evaluated in laboratory by the simulation of water potentials with polyethyleneglycol-

6000 (0.0; -0.2; -0.4; -0.6; -0.8 and -1.0 MPa), at 25ºC using germitest paper as substrate. The effect of water stress on seed viability and on plantlet vigor was severe at potentials below -0.4 MPa. Differential viability and vigor between cultivars were observed under the water stress levels with polyethyleneglycol-6000 (Carlos *et al.,* 2011).

Evaluation of the germination capacity of seeds is one of the most common methods used to determine the tolerance of plants to abiotic stresses (Larcher, 2000). PEG has been used to establish a rapid and effective cotton-drought tolerance evaluation system for selection and breeding of the drought tolerant resources (Yu *et al.*, 1999). Zhang Xue-yan *et al.* (2007) found that osmotic adjustment using PEG-6000 in cotton could be used to evaluate the drought tolerance of cotton. This method is simple, fast and easily operated, could be used to evaluate the drought tolerance of cotton.

Hence in this direction by knowing the economic importance of cotton all over the India and of the factors which interfere in its cotton seed germination, the present study aimed to evaluate the effect of drought stress on the viability and vigor of cotton cultivar seeds in germination phase. Hence the objective of this paper is to evaluation and identification of twelve Indian cotton genotypes for drought tolerance using PEG 6000 as an osmotic stress inducer by slanting glass plate method.

MATERIALS AND METHODS

Twelve cotton genotypes *viz.*, CPD-750, Sahana, ARB-9701, CNH-120MB, GIHV-218, BS-279, RAH-101, GJHV-477, F-2228 and KH-155, L-761 and LH-2076 were used to assess their performance for drought tolerance during the year 2012-13. The genotypes were evaluated for tolerance to different osmotic stress conditions by slanting glass plate technique using different concentrations of Poly ethylene glycol-6000 (PEG-6000) at germination stage.

To obtain information on seed quality and viability, initial germination tests were performed with 200 seeds in BOD-biological oxygen demand incubator (Nanolab, India), as described in Gonela *et al.* (2004), at 25ºC (data not shown). PEG-6000 solutions were prepared with osmotic potentials of 0.0 MPa, -0.05 MPa, -0.148 MPa, -0.295 MPa, -0.491 MPa, -0.735 MPa and -0.846 MPa which is equivalent to PEG percent concentrations of 0%, 5%, 10%, 15%, 20%, 25%, and 27% respectively. The concentrations of PEG-6000 required to obtain these values were determined by using the equation of Michel and Kaufmann (1973): $\Psi s = -(1.18 \times 10^{-2}) C - (1.18 \times 10^{-4}) C_2 + (2.67 \times 10^{-4}) CT + (8.39 \times 10^{-7}) C_2T$, where Ψs = osmotic potential (bar); C = concentration (g L^{-1} PEG-6000 in water); T = temperature (ºC). As a control, a solution with osmotic potential Ψs = 0.0 MPa was used. The germination percentage, root length and shoot length parameters were recorded from all the germinated seedlings at 12th and 18th days after imposing the treatments and the mean values are presented in tables.

Slanting glass plate technique methodology

This method is similar to the routinely used seed germination testing methods using petri plates. But in the present study to allow the roots to grow freely and linearly the glass plate is used in vertical slanting position instead of petri plate. In the present study the glass plates having 3 mm thickness with 25 cm length and 30 cm breadth were used. The length and breadth depends on the number of seeds used for the germination study in the laboratory. The glass plates were covered with 560 × 570 mm fine quality filter paper sheets from bottom to top. Uniform sized good quality delinted seeds were selected from each of 12 different genotypes.

Figure 1: General view of the slanting glass plate technique experiment

The delinted seeds were initially disinfected with 0.1 per cent $HgCl_2$ for 5 minutes. Ten seeds were kept on top portion of the filter paper/glass plate at 3 cm spacing. The seeds were covered with a small strip of filter paper. Suitable holding material was used to avoid the fall of seeds in slanting position. Initially little quantity of respective prepared PEG solutions was 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 transferred on the supporting wooden block in slanting position. 400 ml of corresponding concentrations (0%, 5%, 10%, 15%, 20%, 25% and 27%) PEG-6000 osmotic solutions were added separately into the respective polythene cover carrying separate genotype seeds in slanting plate. The PEG solution moved upward and reached to the seeds by capillary movement through filter paper. Seedlings were allowed to grow under room temperature. Fresh PEG solutions were added in regular intervals of three days to maintain the level of solution. No need of providing aeration to roots, since regularly exchange of fresh PEG solutions was done (Fig. 1).

Observations

Germination (%) - The seedlings emerged from PEG-6000 solutions were considered as germinated and observation was recorded on 12th and 18th DAS and expressed in percentage.

Root length (cm) - One randomly selected seedling was scooped out without damaging the seedling roots in each replication and measured from collar region to the tip of the longest root on12th and 18th DAS and was expressed in cm.

Shoot length (cm) - The shoot length of above selected seedling was measured from collar region to tip of the shoot on 12th and 18th DAS and was expressed in cm.

Root: shoot ratio - The ratio of root length and the shoot length of each seedling selected above was calculated. Observations were recorded on 12th and 18th DAS.

Seedling vigour - Shoot and root vigour indices were calculated at 12th and 18th DAS as described by Abdulbaki and Anderson (1973). Shoot vigour index = Shoot length x germination %, Root length index = root length × germination %, seedling vigour index = (root length + shoot length) × germination %.

RESULTS AND DISCUSSION

Germination percentage

The seed germination percentage decreased as the PEG 6000 concentration increases from 0% to 27%. The mean value at PEG solutions of 0.0, -0.05, -0.148, -0.295, -0.491, -0.735 and -0.846 was 100%, 86%, 78%, 63%, 31%, 05% and 0% respectively (Table 1).

The genotypes BS-279 (60%) and CNH-120MB (60%), followed by ARB-9701 (56%), and GIHV-218 (56%) were germinated well under all the PEG concentrations. These genotypes appeared to be PEG osmotic stress tolerant genotypes. Whereas PEG stress sensitive least germinators were L-761 (44%), KH-155 (47%) and LH-2076 (47%). This experiment showed the maximum level of PEG 6000 concentration for cotton seed germination was 25% (-0.735 MPa), above this concentrations the seed germination was inhibited in all the twelve genotypes. Similar observations are found by Bohnert and Sheveleva (1998), reported more injurious effects of initial moisture stress, however, they found extended drought periods allowed plants to cope better. In the present experiment the decreased germination might be due to increased osmotic stress results water deficit which damages cellular machinery. 25%-27% PEG is the lethal water potential for germination of cotton seeds, hence the germination was ceased.

Shoot length

The shoot length decreased with the increase in PEG-6000 concentrations from 0% to 25%. This might be due to under moisture stress condition the plant increases the root length, root volume, root weight and lateral roots to absorb water form deeper surfaces, this caused decrease in shoot biomass. The decreased shoot organs helps in reducing transpiration water loss from shoot surfaces. BS-279, CNH-120MB, GIHV-218 and ARB-9701 performed well for shoot length at all the PEG-6000 concentrations. It was found that at 25% PEG-6000 (-0.735 MPa) the cotton shoot growth was completely

Table 1: Effect of different concentrations of PEG-6000 on germination (%) of cotton

Genotype	Germination (%) PEG-6000 Concentration							Mean
	0%	5%	10%	15%	20%	25%	27%	
CPD-750	100	90	80	70	40	0	0	54
Sahana	100	80	80	60	30	0	0	50
ARB-9701	100	90	80	70	40	10	0	56
CNH-120MB	100	100	90	70	40	20	0	60
L-761	100	70	70	50	20	0	0	44
LH-2076	100	80	70	60	20	0	0	47
GIHV-218	100	90	80	70	40	10	0	56
BS-279	100	100	90	70	40	20	0	60
RAH-101	100	90	80	60	30	0	0	51
GJHV-477	100	80	70	60	20	0	0	47
F-2228	100	80	80	60	30	0	0	50
KH-155	100	80	70	60	20	0	0	47
Mean	100	86	78	63	31	5	0	52

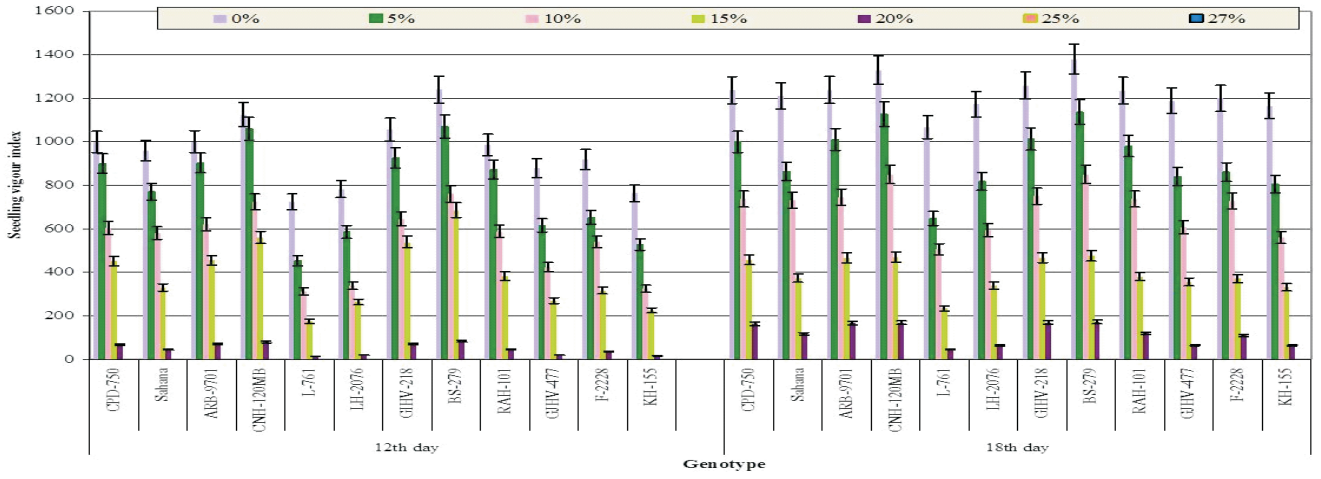

Figure 2: Effect of different concentration of PEG-6000 on seedling vigor index of cotton at different growth stages

Table 2: Effect of different concentrations of PEG-6000 on cotton shoot length (cm) at different growth stages

Genotype	12th day							18th day						
	PEG-6000 Concentration						Mean	PEG-6000 Concentration						Mean
	0%	5%	10%	15%	20%	25%		0%	5%	10%	15%	20%	25%	
CPD-750	10.0	10.0	7.6	6.5	1.7	0.0	6.0	12.4	11.1	9.2	6.5	4.1	0.0	7.2
Sahana	9.6	9.6	7.3	5.5	1.5	0.0	5.6	12.1	10.8	9.2	6.2	3.9	0.0	7.0
ARB-9701	10.0	10.0	7.8	6.5	1.8	0.0	6.0	12.4	11.2	9.3	6.7	4.2	0.0	7.3
CNH-120MB	11.3	10.6	8.1	8.0	2.0	0.0	6.7	13.3	11.3	9.4	6.7	4.2	0.0	7.5
L-761	7.3	6.5	4.5	3.5	0.7	0.0	3.8	10.7	9.3	7.2	4.7	2.2	0.0	5.7
LH-2076	7.8	7.3	4.8	4.4	1.0	0.0	4.2	11.7	10.2	8.5	5.7	3.2	0.0	6.6
GIHV-218	10.6	10.3	8.1	7.7	1.8	0.0	6.4	12.6	11.3	9.4	6.7	4.2	0.0	7.4
BS-279	12.4	10.7	8.5	9.8	2.1	0.0	7.3	13.8	11.4	9.4	6.8	4.3	0.0	7.6
RAH-101	9.9	9.7	7.4	6.4	1.5	0.0	5.8	12.4	10.9	9.2	6.3	4.0	0.0	7.1
GJHV-477	8.8	7.7	6.1	4.5	1.0	0.0	4.7	11.9	10.5	8.7	5.9	3.2	0.0	6.7
F-2228	9.2	8.2	6.8	5.3	1.2	0.0	5.1	12.0	10.8	9.1	6.2	3.7	0.0	7.0
KH-155	7.6	6.6	4.6	3.8	0.8	0.0	3.9	11.7	10.1	8.0	5.5	3.2	0.0	6.4
Mean	9.5	8.9	6.8	6.1	1.4	0.0	5.5	12.2	10.7	8.9	6.2	3.7	0.0	7.0

Table 3: Effect of different concentrations of PEG-6000 on cotton root length (cm) at different growth stages

Genotype	12th day								18th day							
	PEG-6000 Concentration							Mean	PEG-6000 Concentration							Mean
	0%	5%	10%	15%	20%	25%	27%		0%	5%	10%	15%	20%	25%	27%	
CPD-750	8.0	9.1	13.2	9.1	5.0	0.0	0.0	6.3	12.1	14.8	18.5	14.5	7.7	0.0	0.0	9.6
Sahana	7.4	8.3	12.9	8.4	4.8	0.0	0.0	6.0	11.7	13.5	15.8	11.5	5.5	0.0	0.0	8.3
ARB-9701	8.2	9.4	13.4	9.2	5.4	0.0	0.0	6.5	12.9	14.8	19.2	14.6	10.2	1.2	0.0	10.4
CNH-120MB	8.5	10.0	16.4	9.5	5.9	0.5	0.0	7.3	13.0	15.1	19.7	15.4	11.3	1.5	0.0	10.8
L-761	4.5	6.4	10.6	6.2	2.0	0.0	0.0	4.2	9.9	12.3	14.9	10.0	2.4	0.0	0.0	7.1
LH-2076	5.1	7.1	11.5	6.9	3.3	0.0	0.0	4.8	10.5	12.7	15.5	10.9	3.0	0.0	0.0	7.5
GIHV-218	8.3	9.9	13.4	9.4	5.7	0.4	0.0	6.7	13.0	15.1	19.3	14.7	10.3	1.3	0.0	10.5
BS-279	8.8	11.5	16.6	9.7	6.1	0.6	0.0	7.6	13.1	15.1	20.2	15.6	11.4	2.1	0.0	11.1
RAH-101	7.4	8.7	13.1	8.6	4.8	0	0.0	6.1	11.7	13.8	18.2	13.9	7.1	0.0	0.0	9.3
GJHV-477	5.7	7.4	11.9	7.6	3.6	0.0	0.0	5.2	11.6	12.7	15.6	11.3	4.8	0.0	0.0	8.0
F-2228	6.9	7.9	12.6	8.0	3.9	0.0	0.0	5.6	11.7	12.9	15.6	11.4	5.3	0.0	0.0	8.1
KH-155	4.6	6.5	11.1	6.3	2.4	0.0	0.0	4.4	10.5	12.5	15.2	10.6	2.7	0.0	0.0	7.3
Mean	7.0	8.5	13.1	8.2	4.4	0.1	0.0	5.9	11.8	13.8	17.3	12.9	6.8	0.5	0.0	9.0

Table 4: Effect of different concentrations of PEG-6000 on cotton root: shoot ratio at different growth stages

Genotype	12th day							18th day						
	PEG-6000 Concentration						Mean	PEG-6000 Concentration						Mean
	0%	5%	10%	15%	20%	25%		0%	5%	10%	15%	20%	25%	
CPD-750	0.8	0.9	1.7	1.4	2.9	0.0	1.3	1.0	1.3	2.0	2.2	1.9	0.0	1.4
Sahana	0.8	0.9	1.8	1.5	3.2	0.0	1.4	1.0	1.3	1.7	1.8	1.4	0.0	1.2
ARB-9701	0.8	0.9	1.7	1.4	3.0	0.0	1.3	1.0	1.3	2.1	2.2	2.4	0.0	1.5
CNH-120MB	0.8	0.9	2.0	1.2	3.0	0.0	1.3	1.0	1.3	2.1	2.3	2.7	0.0	1.6
L-761	0.6	1.0	2.4	1.8	2.9	0.0	1.5	0.9	1.3	2.1	2.1	1.1	0.0	1.3
LH-2076	0.7	1.0	2.4	1.6	3.3	0.0	1.5	0.9	1.2	1.8	1.9	0.9	0.0	1.1
GIHV-218	0.8	1.0	1.7	1.2	3.2	0.0	1.3	1.0	1.3	2.1	2.2	2.4	0.0	1.5
BS-279	0.7	1.1	2.0	1.0	2.9	0.0	1.3	0.9	1.3	2.1	2.3	2.6	0.0	1.5
RAH-101	0.8	0.9	1.8	1.3	3.2	0.0	1.3	0.9	1.3	2.0	2.2	1.8	0.0	1.4
GJHV-477	0.6	1.0	2.0	1.7	3.6	0.0	1.5	1.0	1.2	1.8	1.9	1.5	0.0	1.2
F-2228	0.8	1.0	1.9	1.5	3.3	0.0	1.4	1.0	1.2	1.7	1.8	1.4	0.0	1.2
KH-155	0.6	1.0	2.4	1.7	3.0	0.0	1.5	0.9	1.2	1.9	1.9	0.8	0.0	1.1
Mean	0.7	1.0	2.0	1.4	3.1	0.0	1.4	1.0	1.3	1.9	2.1	1.8	0.0	1.4

inhibited in all twelve genotypes (Table 2).

Root length

Root length was increased with the increasing PEG-6000 concentrations up to 10% PEG-6000 concentrations it declined thereafter. The increased root length might be due to under water stress the plant partitioned more photosynthates for the growth of roots rather than shoots, helps in absorbing more water from deeper surfaces. The decreased shoot organs helps in reduction of transpiration water loss from shoot surfaces. Similarly, Taylor and Klepper (1971) observed that water

Table 5: Effect of different concentrations of PEG-6000 on cotton root length index at different growth stages

Genotype	12th day								18th day							
	PEG-6000 Concentration							Mean	PEG-6000 Concentration							Mean
	0%	5%	10%	15%	20%	25%	27%		0%	5%	10%	15%	20%	25%	27%	
CPD-750	800	817	1057	634	199	0	0	501	1209	1330	1476	1015	308	0	0	763
Sahana	740	666	1032	501	144	0	0	440	1170	1080	1260	687	165	0	0	623
ARB-9701	820	847	1072	641	215	0	0	513	1290	1334	1538	1019	408	12	0	800
CNH-120MB	850	1004	1479	667	236	10	0	607	1297	1506	1773	1078	452	30	0	877
L-761	450	450	742	308	41	0	0	284	994	861	1042	500	48	0	0	492
LH-2076	510	570	805	411	67	0	0	338	1053	1013	1085	653	60	0	0	552
GIHV-218	830	894	1072	655	229	4	0	526	1297	1356	1544	1031	412	13	0	808
BS-279	880	1153	1494	676	244	12	0	637	1310	1513	1815	1094	456	42	0	890
RAH-101	740	785	1049	513	145	0	0	462	1173	1245	1457	835	213	0	0	703
GJHV-477	570	591	832	453	71	0	0	360	1159	1016	1091	677	96	0	0	577
F-2228	690	628	1008	479	117	0	0	417	1165	1033	1247	684	159	0	0	613
KH-155	460	518	777	375	48	0	0	311	1046	998	1063	635	54	0	0	542
Mean	695	744	1035	526	146	2	0	450	1180	1182	1355	814	210	3	0	678

Table 6: Effect of different concentrations of PEG-6000 on shoot vigour index of cotton at different growth stages

Genotype	12th day							18th day						
	PEG-6000 Concentration						Mean	PEG-6000 Concentration						Mean
	0%	5%	10%	15%	20%	25%		0%	5%	10%	15%	20%	25%	
CPD-750	1000	900	605	452	68	0	504	1237	1000	737	458	164	0	599
Sahana	960	771	581	330	45	0	448	1211	864	733	374	117	0	550
ARB-9701	1001	903	621	455	72	0	509	1239	1011	746	467	168	0	605
CNH-120MB	1125	1060	725	560	80	0	592	1330	1128	850	470	169	0	658
L-761	725	454	312	175	14	0	280	1067	648	506	234	45	0	417
LH-2076	783	586	339	264	20	0	332	1173	818	594	340	64	0	498
GIHV-218	1056	927	645	539	72	0	540	1259	1013	750	468	169	0	610
BS-279	1240	1070	761	686	84	0	640	1380	1136	850	476	173	0	669
RAH-101	986	873	589	384	45	0	480	1236	981	737	380	120	0	576
GJHV-477	880	616	424	270	20	0	368	1189	840	607	356	65	0	510
F-2228	919	652	541	317	36	0	411	1200	861	729	372	110	0	545
KH-155	764	528	325	225	16	0	310	1165	806	560	331	64	0	488
Mean	953	778	539	388	48	0	451	1224	921	696	391	114	0	558

extraction per unit length of root was greater in wet soil and decreased exponentially with soil water potential and they found that deep roots were effective in extracting in water from soil.

In the present study at 18th day, the mean root length at with osmotic potentials of 0.0 MPa, -0.05 MPa, -0.148 MPa, -0.295 MPa, -0.491 MPa, -0.735 MPa and -0.846 MPa were 11.8cm, 13.8cm, 17.3cm, 12.9cm, 6.8cm, 0.5cm and 0.0cm respectively. BS-279, CNH-120MB, GIHV-218 and ARB-9701 genotypes performed well in all PEG concentrations. Whereas, L-761, KH-155 and LH-2076 performed least (Table 3).

Carlos *et al.* (2011) study on exposing the cotton seedlings with different levels of PEG-6000 revealed that differential viability and vigor between cultivars were observed under the water stress levels.

Root shoot ratio

Higher ratio was observed with the increase in PEG-6000 concentrations up to 20% PEG at 12th DAS. Whereas at 18th DAS it was up to 15% PEG, there after it declined (Table 4). The mean ratio at all the PEG-6000 concentrations at 18th DAS was higher in CNH-120MB, BS-279, GIHV-218 and ARB-9701 whereas, least in KH-155, LH-2076 and F-2228. The increased ratio could be due to absolute increase in root weight and the plant spends more photosynthates for root biomass development helped in absorption of more water under water stress. Decreased shoot biomass helped plant to reduction transpiration loss. This might have been modified under moisture stress as a survival mechanism rather than contributing to yield.

Similarly Carlos *et al.* (2011) found the effect of water stress on seed viability and on plantlet vigor was severe at potentials below -0.4 MPa. From the present study it found that at both 12th DAS and 18th DAS the ratio was maximum in 10% PEG followed by 5%, 27% and 25%PEG. Similarly, cotton shoot vigour index decreased with the increase in PEG concentrations due to increase in root:shoot ratio and also due to decreased leaf numbers, reduced plant height, and other shoot organs.

Root length index

In both stages this value was maximum in 10% PEG followed by 5%, whereas least in 27% PEG. The mean value at all the PEG concentrations at both stages was highest in BS-279, followed by CNH-120MB and GIHV-218 whereas it was least in L-761, and KH-155. At 12th day, the mean value at PEG-6000 solutions of 0.0 -0.05, -0.148, -0.295, -0.491, -0.735 and -0.846MPa were 695, 744, 1035, 526, 146, 2.0 and 0.0 respectively. Whereas, at 18th day, the corresponding values were 1180, 1182, 1355, 814, 210, 03, and 0.0 respectively (Table 5).

Shoot vigour index

The mean value at both stages was highest in BS-279, followed by CNH-120MB, GIHV-218 and ARB-9701. Whereas, least in L-761, KH-155 and LH-2076. At 12th day, the mean value at PEG solutions of 0.0, -0.05, -0.148, -0.295, -0.491 and -0.735 MPa were 953, 778, 539, 388, 48 and 0.0 respectively. Whereas at 18th DAS, the corresponding values were 1224, 921, 696, 391, 114 and 0.0 respectively (Table 6).

Seedling vigour index

The seedling vigour index decreased with the increase in PEG-6000 concentrations (Fig 2). The mean value at both stages was highest in BS-279, followed by CNH-120MB, GIHV-218 and ARB-9701. Whereas, it was least in L-761, KH-155 and LH-2076. Similarly Zhang Xue-yan *et al.* (2007) studied 13 cotton varieties with varied levels of drought stress by exposing the cotton samples at germination, bud-stage, cotyledon- stage and real-leaf stage with PEG6000 stress for 12 hours. After 12-hour osmotic treatment, the survival rates showed with mutative level of drought tolerance, proving that the 3～6-leaf stage is the key period related to cotton drought tolerance.

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