Journal of Crop and Weed, 13(3):135-143(2017)

Response to water stress on some seedling characters of tossa jute (*Corchorus olitorius* L.)

S. YUMNAM, A. SAWARKAR AND S. MUKHERJEE

Department of Genetics & Plant Breeding, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741 252, Nadia, West Bengal

Received : 07-11-2017 ; Revised : 21-11-2017 ; Accepted : 25-11-2017

ABSTRACT

The present investigation dealt to determine moisture stress tolerant genotypes to overcome stress. Genotypes were raised in laboratory using PEG 6000 and field in rainfed conditions. Out of genotypes, OIJ 213 and OIJ 299 showed superior performance with respect to almost all the root characters in field and laboratory experiments. It could be used as donor parents to develop hybrids having tolerance to water stress at early stages of growth as well as for studying the inheritance pattern of stress tolerance. OIJ 246, OIN 986 JRO 524, OEX 008, OIJ 284, and JRO 8432 were considered as susceptible on the basis of reduction of most of the root and shoot characters in both conditions. Tolerance index of these genotypes were also found to be comparatively low. These genotypes might be used in hybridization programme for crop improvement.

Keywords : Jute, moisture stress, PEG 6000, seedling

Jute is sown within 1st fortnight of April in West Bengal. This period is often accompanied by unpredictable and very low rainfall creates moisture stress in early part of life may affect the crop severely in extremely dry year which leads to the poor fibre yield and quality. Timely sowing and uniform seedling establishment of jute mostly depend on availability of assured irrigation which the farmers cannot always afford. It is the second most important fibre crops after cotton in terms of production, productivity, consumption and availability. Its fibre is known as bast fibre in contrast to seed fibre in cotton. The fibre comes from two important species as *Corchorus capsularis* and *Corchorus olitorius* and fibre of *olitorius* is shiny and golden in colour and adorably christened as 'Golden Fibre'. Jute fibre has high tensile strength, low extensibility and ensures better breathability of fibre, therefore, it has proved its importance in packaging of agricultural commodity, textiles and non-textiles industries and construction work. Evaporation loss and mean maximum temperature decline considerably during the monsoon month while relative humidity increases. Thus in the early part of life, jute plant often exposed to water stress in the form of atmospheric and soil drought which may affect the jute crop severely in extremely dry year which leads to the poor fibre yield and quality. However, no comprehensive information is available regarding the effect of moisture stress in jute particularly in seedling stage, especially, physiological related traits like germination, root length, shoot length *etc*. Root length is an important trait against drought stress in plant varieties, deep root penetration has been referred as prime means of drought resistance in field crops (Kaydan and Yagmur 2008). The rate of growth of jute plant up to the age of six weeks is always impaired by excess water (Wahab, 1978). The requirement of water at different stages of growth of jute plants has not yet been established. It has been noticed that if the jute crop can survive the adverse initial dry spell, with the advent of monsoon and attendant favourable weather conditions like adequate rainfall, high relative humidity and warm temperature condition, luxuriant growth and yield of jute can occur (Ghorai and Mitra, 2008). Therefore, screening for drought tolerant genotypes at early seedling stage has made paramount importance to develop drought tolerant lines. PEG was also found to use for creating artificial moisture stress for evaluating tolerant genotypes in an early stage like cotton (Zhang *et al.*, 2007) and rice (Anaytullah *et al.*, 2007), Maize (Khodarahmpour, 2011), Sorghum (Bibi *et al.*, 2012). Keeping this view, an alternative approach to induce water stress through polythene glycol (PEG) solutions were used for screening germplasm against drought stress using glass plate method and in field under rainfed condition.

MATERIALS AND METHODS

Twenty germplasm of jute (*Corchorus olitorius* L.) including 3 exotic, 2 national released varieties, 9 indigenous and 6 accessions of International Jute Organization (IJO) were evaluated for drought tolerant in laboratory using PEG 6000 and field over two years (2010 and 2011). The laboratory experiment was arranged in factorial completely randomized design (FCRD) design with three replications and two factors. Two factors were genotypes and irrigation levels i.e. control and stress. In the beginning to find out the suitable external water potential, all the twenty genotypes were tested in three different ranges of external water potential (*viz*, -2.0, -3.0 and -4.0 bars). These solutions were prepared by using PEG 6000 following the method described by Michael and Kaufmann (1973). On the

Email: annu.sawarkar@gmail.com

Table 1: Mean values of different seedling characters of *C.olitorius* under normal and moisture stress condition in field (1st year)

Germplasm	Normal				Moisture stress			
	Root length (cm)	Root volume (cc)	Root fresh weight(g)	Root dry weight (g)	RootLength (cm)	Root volume (cc)	Root fresh weight (g)	Root dry weight (g)
OIJ 216	7.910	0.077	0.119	0.072	10.418(31.707)	0.073(-5.195)	0.182(52.941)	0.050(-30.556)
OIJ 213	7.418	0.065	0.136	0.082	13.068(76.166)	0.074(13.846)	0.168(23.529)	0.057(-30.488)
OIN 981	6.960	0.071	0.163	0.086	11.415(64.009)	0.090(26.761)	0.209(28.221)	0.053(-38.372)
OIJ 257	7.913	0.068	0.149	0.091	11.433(44.484)	0.086(26.471)	0.172(15.436)	0.043(-52.747)
OEX 019	7.023	0.055	0.114	0.071	11.263(60.373)	0.074(34.545)	0.182 (59.649)	0.047(-33.803)
OIN 941	7.258	0.067	0.142	0.087	10.760(48.250)	0.067(0.000)	0.169(19.014)	0.053(-39.080)
OIN 921	7.193	0.069	0.159	0.097	11.188(55.540)	0.080(15.92)	0.182(14.465)	0.052(-46.392)
OEX 008	7.338	0.072	0.158	0.084	9.110(24.148)	0.079(9.722)	0.184(16.456)	0.045(-46.429)
OIN 955	7.870	0.084	0.179	0.113	10.038(27.548)	0.065(-22.619)	0.124(-30.726)	0.053(-53.097)
OIN 976	7.785	0.083	0.197	0.090	11.440(46.949)	0.086(3.614)	0.178(-9.645)	0.056(-37.778)
OIJ 284	7.152	0.072	0.170	0.091	7.240(1.230)	0.102(41.667)	0.161(-5.294)	0.110(20.879)
OIJ 246	7.363	0.087	0.224	0.084	7.555(2.608)	0.084 (-3.448)	0.130(-41.964)	0.058(-30.952)
OIN 986	7.940	0.092	0.215	0.086	8.435(6.234)	0.094(2.174)	0.272(26.512)	0.064(-25.581
OIN 937	7.803	0.090	0.252	0.086	10.003(28.194)	0.090(0.000)	0.232(-7.937)	0.088(2.326)
OIN 994	7.213	0.077	0.175	0.107	10.447(44.836)	0.069(-10.390)	0.154(-12.000)	0.059(-44.860)
OIN 915	7.495	0.087	0.223	0.142	10.968(46.338)	0.076(-12.644)	0.172(-22.870)	0.077(-45.775)
OEX 024	6.680	0.090	0.197	0.121	8.100(21.257)	0.056(-37.778)	0.121(-38.579)	0.050(-58.678)
OIJ 299	7.493	0.090	0.204	0.129	11.390(52.009)	0.085(-5.556)	0.171(-16.176)	0.073(-43.411)
JRO 8432	5.765	0.060	0.124	0.074	7.508(30.234)	0.046(-23.333)	0.096(-22.581)	0.031(-58.108)
JRO 524	6.220	0.053	0.112	0.066	7.073 (13.714)	0.049(-7.547)	0.095(-15.179)	0.028(-57.576)
Mean	**7.289**	**0.075**	**0.170**	**0.093**	**9.942**	**0.077**	**0.167**	**0.057**
LSD(0.05)	**3.733**	**0.068**	**0.231**	**0.112**	**7.147**	**0.082**	**0.179**	**0.098**

Contd...

Table 1 Contd...

Germplasm	Normal					Moisture Stress				
	Shoot length (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Leaf fresh weight (g)	Leaf dry weight(g)	Shoot length (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Leaf fresh weight (g)	Leaf dry weight (g)
OIJ 216	22.440	0.661	0.286	1.120	0.212	22.263(-0.789)	0.452(-31.619)	0.206(-27.972)	0.799(-28.661)	0.183(-13.679)
OIJ 213	28.117	0.807	0.362	0.929	0.171	21.998 (-21.763)	0.567(-29.740)	0.264(-27.072)	0.871(-6.243)	0.202(18.129)
OIN 981	27.055	0.874	0.386	1.160	0.214	24.705(-8.686)	0.669(-23.455)	0.307(-20.466)	0.868(-25.172)	0.196(-8.411)
OIJ 257	27.405	0.766	0.331	1.109	0.201	21.955(-19.887)	0.661(-13.708)	0.300(-9.366)	0. 953(-14.066)	0.211(4.975)
OEX 019	27.257	0.552	0.292	0.984	0.180	22.035(-19.158)	0.588(6.522)	0.203(-30.479)	0.704(-28.455)	0.155(-13.889)
OIN 941	24.020	0.632	0.326	0.982	0.176	20.618(-14.163)	0.663(4.905)	0.239(-26.687)	0.815(-17.006)	0.180(2.273)
OIN 921	30.138	0.822	0.407	1.006	0.181	26.755(-11.225)	0.504(-38.686)	0.176(-56.757)	0.962(-4.374)	0.209(15.470)
OEX 008	27.810	0.943	0.386	1.066	0.192	25.830(-7.120)	0.478(-49.311)	0.241(-37.565)	0.859(-19.418)	0.189(-1.563)
OIN 955	26.840	1.060	0.478	1.152	0.210	25.983(-3.19)	0.523(-50.660)	0.233(-51.255)	0.729(-36.719)	0.164(-21.905)
OIN 976	33.225	1.130	0.511	1.176	0.213	28.063(-15.536)	0.666(-41.062)	0.307(-39.922)	0.998(-15.136)	0.225(5.634)
OIJ 284	30.837	0.915	0.405	0.997	0.180	25.130(-18.507)	0.467(-48.962)	0.207(-48.889)	0.904(-9.328)	0.201(11.667)
OIJ 246	29.627	1.240	0.572	1.203	0.227	26.878(-9.279)	0.553(-55.403)	0.249(-56.469)	0.872(-27.515)	0.197(-13.216)
OIN 986	34.233	1.269	0.583	1.432	0.267	26.733(-21.909)	0.467(-63.199)	0.209(-64.151)	1.084(-24.302)	0.245(-8.240)
OIN 937	33.340	1.692	0. 796	1.458	0.275	27.533(-17.418)	0.669(-60.461)	0.310(-61.055)	1.169(-19.822)	0.274(-0.364)
OIN 994	29.040	1.075	0.487	1.147	0.208	24.528 (-15.537)	0.653(-39.256)	0.296(-39.220)	0.844(-26.417)	0.189(-9.135)
OIN 915	28.165	1.323	0.613	1.417	0.266	23.325(-17.184)	0.654(-50.567)	0.303(-50.571)	0.980(-30.840)	0.227(-14.662)
OEX 024	26.393	0.918	0.412	1.079	0.200	22.775(-13.708)	0.648(-29.412)	0.303(-26.456)	0.803(-25.579)	0.178(-11.000)
OIJ 299	27.060	1.319	0.605	1.320	0.242	28.360(4.804)	0.689(-47.763)	0.315(-47.934)	0.905(-31.439)	0.204(-15.702)
JRO 8432	20.470	0.677	0.290	0.738	0.131	18.625(-9.013)	0.478(-29.394)	0.215(-25.862)	0.583(-21.003)	0.123(-6.107)
JRO 524	24.718	0.647	0.273	0.665	0.117	23.218(-6.068)	0.414(-36.012)	0.181(-33.700)	0.661(-0.602)	0.144(23.077)
Mean	**27.909**	**0.966**	**0.440**	**1.107**	**0.203**	**24.365**	**0.573**	**0.253**	**0.868**	**0.195**
LSD(0.05)	**15.186**	**1.358**	**0.711**	**1.042**	**0.208**	**12.145**	**0.602**	**0.272**	**0.858**	**0.208**

Note: Figures in the parentheses are the percent change over normal

Table 1 Contd...

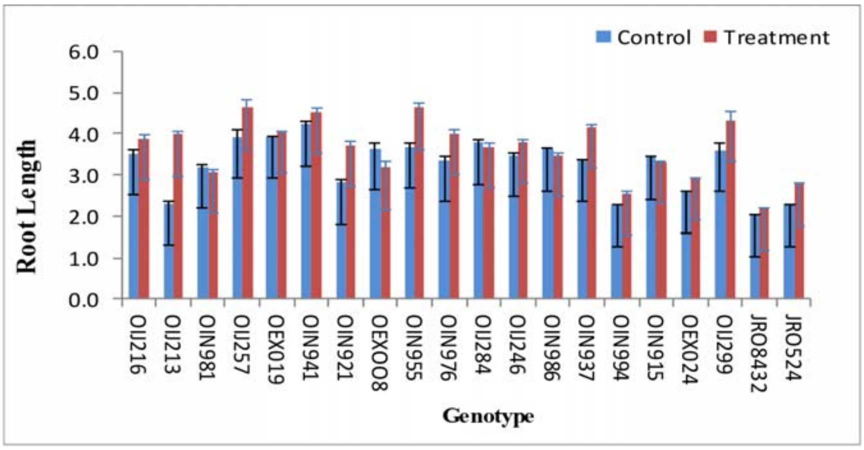

Fig. 1 : Root length (RL) of 20 genotypes of *Corchorus olitorius* under control and moisture stress.

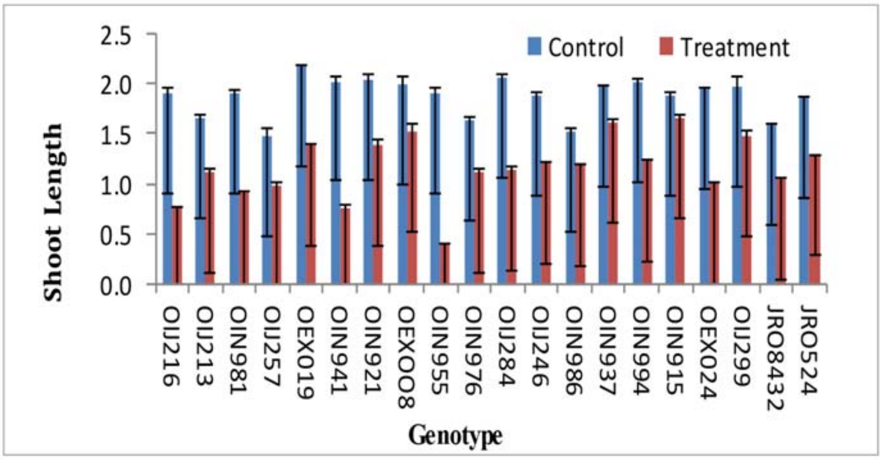

Fig. 2 : Shoot length (SL) of 20 genotypes of *Corchorus olitorius* under control and moisture stress.

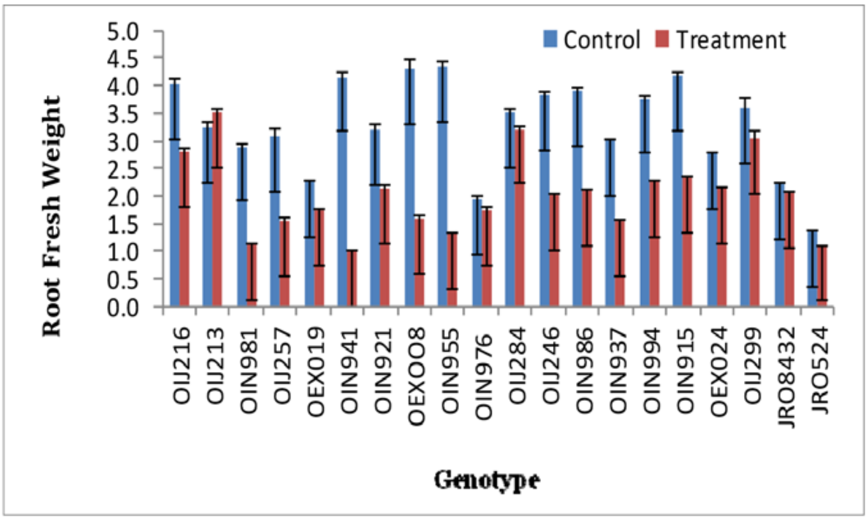

Fig. 3 : Root Fresh Weight (RFW) of 20 genotypes of *Corchorus olitorius* under control and moisture stress.

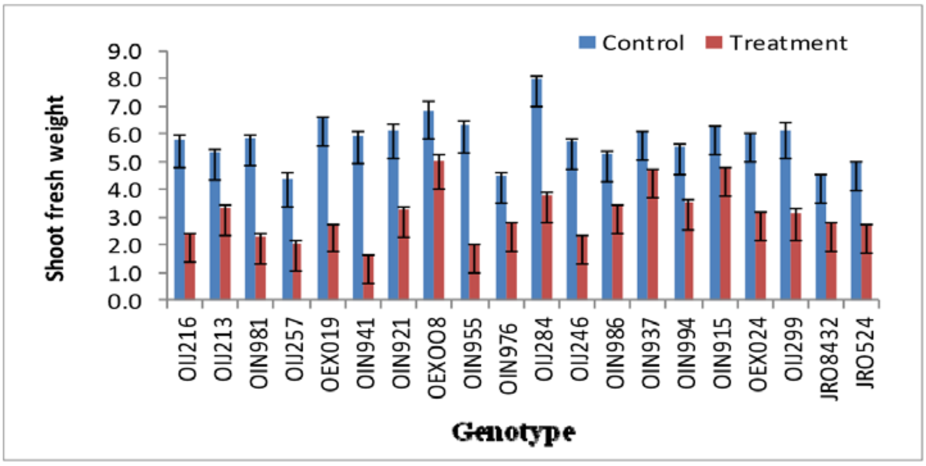

Fig. 4 : Shoot Fresh Weight (SFW) of 20 genotypes of *Corchorus olitorius* under control and moisture stress.

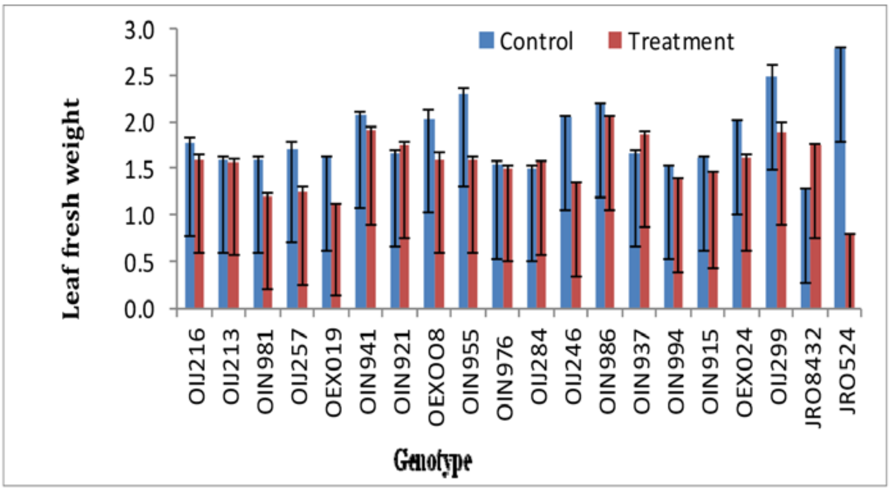

Fig. 5 : Leaf Fresh Weight (LFW) of 20 genotypes of *Corchorus olitorius* under control and moisture stress.

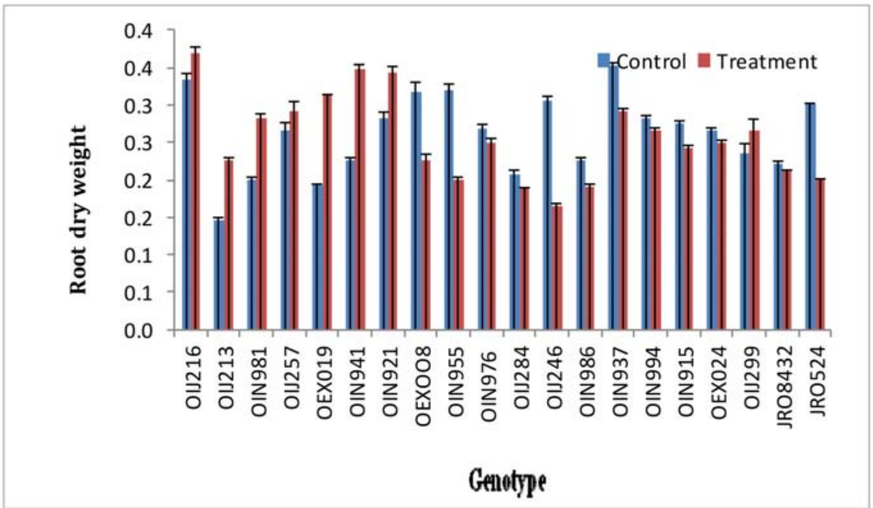

Fig. 6 : Root Dry Weight (RDW) of 20 genotypes of *Corchorus olitorius* under control and moisture stress

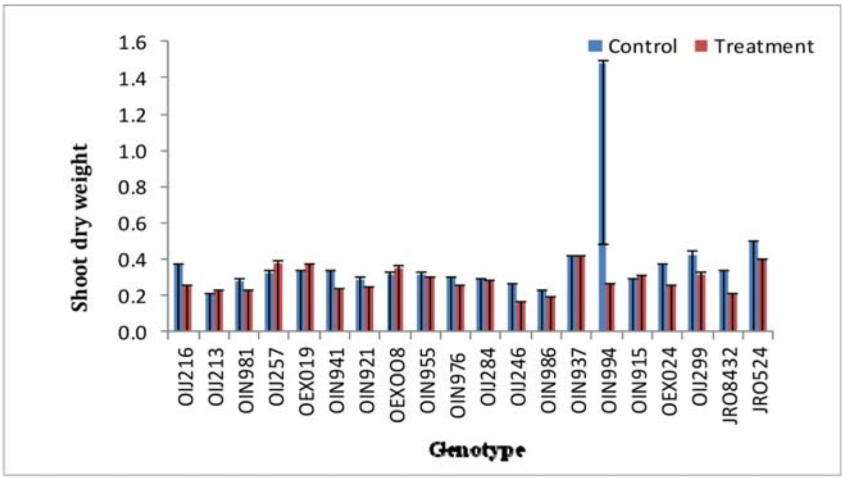

Fig. 7 : Shoot Dry Weight (SDW) of 20 genotypes of *Corchorus olitorius* under control and moisture stress.

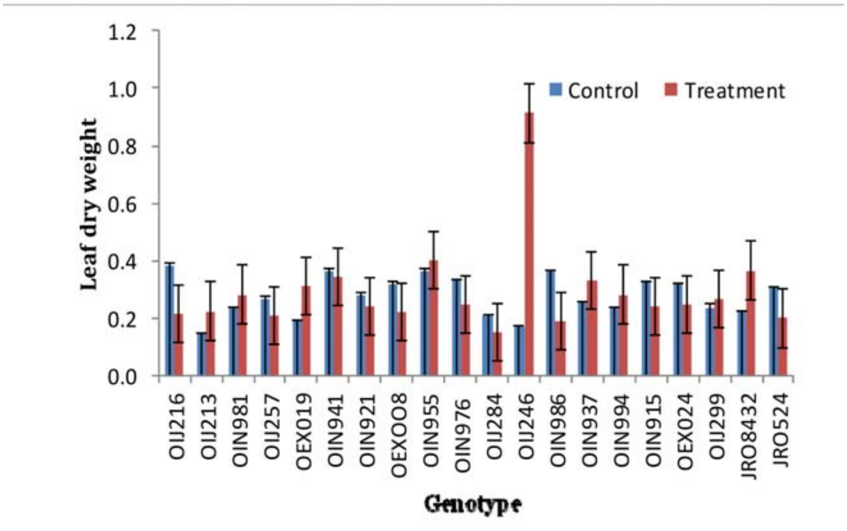

Fig. 8 : Leaf Dry Weight (LDW) of 20 genotypes of *Corchorus olitorius* under control and moisture stress.

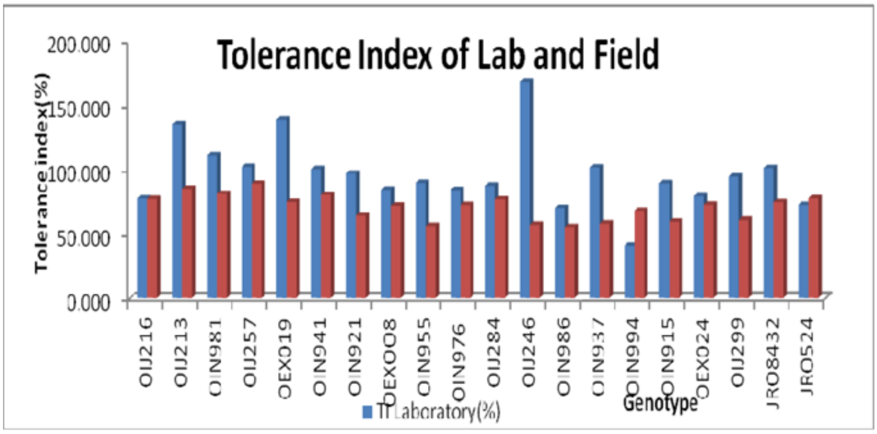

Fig. 9 : Tolerance Index (TI) of 20 genotypes of *Corchorus olitorius* in laboratory as well as field condition

basis of growth performance of the seedlings of different genotypes grown in all the three ranges of external water potential of PEG, a suitable range at -3.0 bar was identified for screening the genotypes. Fifteen seeds of each genotype were surface sterilized with 0.1% $HgCl_2$ solution for 2 minutes followed by thorough washing in distilled water. Fifteen seeds of each genotype were arranged in a row in between glass plates (20×30 cm) covered with blotting paper and glass slides (5×30 cm) which were tied by rubber band. The whole set was then placed in a transparent polythene bag. Then the seeds were allowed to germinate in the plates in presence of sufficient light and aeration. PEG solution was applied to the seedlings 2 days after initiation of the experiment. Similar control set was maintained in double distilled water. The PEG solution and distilled water were applied to each plates at regular interval to keep the blotting paper moistened with PEG solution and distilled water respectively for the treated set and the control set. The seedlings were allowed to grow for 8 days and data were recorded for the seedling characters *viz*. root length (cm), shoot length (cm), root fresh weight (g), shoot fresh weight (g), leaf fresh weight (g), root dry weight (g), shoot dry weight (g) and leaf dry weight (g). From the above data tolerance index (TI) was calculated as per Garg and Singla (2004).

These genotypes were also grown in field in two varying water regimes *viz*, i) fully under rainfed condition and ii) irrigated condition. The experiment in each environment was laid out in Randomized Block Design with three replications. In each replication each genotype was grown in a plot of 5 rows of 3 meter length maintaining 30 cm space between the rows. The size of each plot was 3 × 1.5 m and plot to plot distance was 0.5 m. Sowing was done on 10^{th} April 2010 and 13^{th} April 2011. Recommended doses of major nutrients (N, P and K) were applied and normal cultural practices were followed. Under irrigated condition the irrigation were given in different growth stages– 1^{st} irrigation- pre-sowing irrigation, 2^{nd} irrigation- after 15 days of sowing, 3^{rd} irrigation- 21 days after 2^{nd} irrigation and 4^{th} irrigation- 30 days after 3^{rd} irrigation. 21 days old seedlings (10 nos.) from both the rainfed and irrigated field were randomly selected from each replication for each genotypes and data were recorded as per above mentioned and tolerance index was calculated. All the statistical analysis carried out with the help of IndoStat software version 8.6.

RESULTS AND DISCUSSION

Analysis of variance showed significant differences for all the seedlings characters among the genotypes and their interactions under control and moisture stress in laboratory conditions. This supported the differential behaviour of various accessions under water stress. The expression of the mean performance of 20 germplasm of the studied traits like root length (RL) (Fig. 1), shoot length (SL) (Fig. 2), root fresh weight (RFW) (Fig. 3), shoot fresh weight (SFW) (Fig. 4), leaf fresh weight (LFW) (Fig. 5), root dry weight (RDW) (Fig. 6), shoot dry weight (SDW) (Fig. 7), leaf dry weight (LDW) (Fig. 8), tolerance index (Fig. 9) were represented, indicating reduction in length and weight after imposing osmotic stress stimulated by PEG. Fifteen of the twenty genotypes showed increased root length over control under stress condition and maximum increase was found in OIJ 213 followed by OIN 921, OIN 955, OIN 937 and OIJ 299. The genotype OEX 008 was found to be the most susceptible showing maximum reduction in root length *i.e.* -12.53%. Shamin *et al.* (2009) also reported increased root length in sunflower hybrid in stress induced by PEG and in rice by Hirai *et al.* (1994). Zekri (1991) in citrus, Materechera *et al.* (1992) in dicots, Zaifnejad *et al.* (1997) in sorghum observed decreased root length when subjected to PEG induced stress. Shoot length decreased over control in all the genotypes and the worst affected genotype was OIN 955 but comparative reduction in low magnitude was observed in OIN 915 and OIN 937. Reduction in shoot length possibly due to less water absorption and decrease in external osmotic potential created by PEG 6000. (Kaydan and Yagmur 2008). Khodarahmpour (2011) also reported decreased shoot length with increased water potential. In case of root fresh weight, it decreased in all the genotypes except OIJ 213. The elongation of root under water stress condition might be due to fact that root become increased in search of water (Bibi *et al.*, 2012). Lowest reduction was observed in JRO 8432 followed by OIJ 284, OIN 976 and OIJ 299. Highest reduction was observed in OIN 941. Increased root dry weight over control was observed in thirteen genotypes out of which OEX 019 had the highest magnitude followed by OIJ 213, OIN 941 and OIN 981. Maximum reduction was found in OIJ 246 followed by OIN 955 and JRO 524. Dry root weight has been utilized as a selection criterion for drought tolerance by many plant breeders. Water uptake by the root is a complex parameter that depends on root structure, root anatomy and the pattern by which different parts of the root contribute to overall water transport. All the genotypes suffered under water stress condition showing reduction in fresh shoot weight and of which lowest reduction was showed by OIN 937 followed by OIN 915 and OEX 008. Highest reduction was observed in OIN 941 followed by OIN 955 and OIN 981. Drought has significantly affected fresh shoot weight in some cultivars of wheat, maize and sunflower (Bibi *et al.*, 2012). Maximum increased shoot dry weight was observed in OIJ 257 followed by OEX 019, OEX 008 and OIJ 213 and maximum reduction was found in OIN 994 which was followed by JRO 8432, OIJ 246 and OEX 024. Leaf fresh weight under stress condition increased in four genotypes and the increase was highest in JRO 8432 which was followed by OIN 937, OIN 921 and OIJ 284 and minimum reduction was observed in OIJ 213 followed by OIN 976. Maximum reduction in this character was evident in JRO 524 followed by OIJ 246 and OEX 019. OIJ 246 had the highest increased in magnitude of leaf dry weight over control following it were JRO 8432, OEX 019 and OIJ 213 and maximum reduction was observed in OIN 986.

Significant variations were also shown in field by all the seedling characters studied in normal and stress environments for two consecutive years (2010 and 2011). All the genotypes showed increased root length over their respective control and among them OIJ 213 was longest and following it were OIN 981, OEX 019 and OIN 921 while the shortest root length was noticed in OIJ 284 followed by OIJ 246 and OIN 986 (Table 1). Nine genotypes (OIJ 213, OIN 981, OIJ 257, OEX 019, OIN 921, OEX 008, OIN 976, OIJ 284 and OIN 986) were found to have increased root volume in moisture deficit condition. OIJ 284 was the highest followed by OEX 019 and OIN 981 whereas genotypes OIN 941 and OIN 937 remained unaffected. OEX 024 followed by JRO 8432, OIN 955 and OIN 915 was the most affected genotype. Genotype OEX 019 followed by OIJ 216 , OIN 981, OIN 986, OIJ 213, OIN 941, OEX 008, OIJ 257 and OIN 921 had increased root fresh weight over their respective controls and OIJ 246 had the maximum reduction *i.e*. -41.96% and following it were OEX 024 , OIN 955 and OIN 915. Basak and Chaudhuri (1967) observed increased root weight in tossa jute and decreased root weight in white jute in stress condition. Under stress regime, OIJ 284 was the highest and being followed by OIN 937, OIN 915 and OIJ 299 while genotypes OIJ 284 and OIN 937 had increased root dry weight over control. OEX 024 followed by JRO 8432, JRO 524 and OIN 955 showed the highest reduction. Khandakar *et al*. (1987) also found jute accessions having longest tap root with highest dry matter production and also accessions having lower root length but with higher dry weight. Only the genotype OIJ 299 (4.80%) had increased shoot length over control and OIN 986 followed by OIJ 213, OIJ 257 and OEX 019 was found to be the most affected genotype. OEX 019 and OIN 941 showed increased shoot fresh weight and maximum reduction was observed in OIN 986 followed by OIN 937, OIJ 246 and OIN 955. Highest reduced shoot dry weight was evident in OIN 986 followed by OIN 937, OIN 921 and OIJ 246 and lowest reduction was noted in OIJ 257 followed by OIN 981, JRO 8432 and OEX 024. In case of leaf fresh weight, OIN 955 (-36.71%) followed by OIJ 299, OIN 915 and OIJ 216 was the most affected and JRO 524 (-0.60%) was the least sufferer followed by OIN 921, OIJ 213 and OIJ 284. Maximum reduced leaf dry weight was evident in OIN 955 followed by OIJ 299, OEX 019 and OIJ 216 while JRO 524 had the minimum increment *i.e.* 23.07 per cent and it was followed by OIJ 213, OIN 921 and OIJ 284.

Tolerance Index used as an indicator to identify drought tolerant genotypes that perform well in stress environments. A high value implies higher tolerance to drought stress regimes (Fig. 9). In case of laboratory condition, significantly highest value was noted in OEX 019 and OIN 937 which was followed by OIJ 213. OIJ 246 was found to have the minimum value followed by OIN 986 and JRO 8432. Similarly, while field condition OIJ 257 was highest tolerance index followed by OIJ 213, OIN 981 and least was observed in OIN 986 and being followed by OIN 955 and OIJ 246.

From the above experimental results, most promising stress responsive eight genotypes were recognized. Out of eight, two (OIJ 213 and OIJ 299) could be considered as tolerant and other six genotypes *viz*. OEX 008, OIJ 284, OIJ 246, OIN 986, JRO 8432 and JRO 524 could be considered as susceptible. It can be concluded that these genotypes may be used in hybridization programme for crop improvement. Genotypes OIJ 213 and OIJ 299 could be used as donor parents to develop hybrids having tolerance to water stress at early stages of growth as well as for studying the inheritance pattern of stress tolerance.

REFERENCES

Anaytullah., Bandana, B. and Yadav, R. S. 2007. PEG induced moisture stress: Screening for drought tolerance in rice. *Indian J Pl. Physiol.* **12** : 88-90.

Basak, S. L. and Chaudhuri, B. B. 1967. Genetic variability and phenotypic plasticity of roots in two cultivated species of jute (*Corchorus olitorius* L. and *C. capsularis* L.). *Bio. Plant.* **9** : 292-300.

Bibi, A., Sadaqat, H. A., Tahir, M. H. N. and Akram, F. M. 2012. Screening of sorghum (*Sorghum bicolor* var Moench) for drought tolerance at seedling stage in polyethylene glycol. *J Anim. Pl. Sci.,* **22** : 671-78.

Garg, S. and Singla, R. 2004. Growth, photosynthesis, nodule nitrogen and carbon fixation in the chickpea cultivars under salt stress. *Braz. J Pl. Physiol.,* **16** : 137-46.

Ghorai, A. K. and Mitra. S. 2008. Water management in jute and ramie. In: *Jute and Allied Fibre Updates:Production and Technology* pp. 162-74,

Hirai, G., Chujo, H., Tanaka, O., Okumura, T. and Takenchi S. 1994. Studies on the effect of the relative humidity of the atmosphere on the growth and physiology of rice (*Oryza sativa*) plants, IX: Effect of water stresses induced by low humidity and the addition of polyethylene glycol to the medium on growth. *Jap. J Crop. Sci.*, **63** : 265-70.

Kaydan, D. and Yagmur, M. 2008. Germination, seedling growth and relative water content of shoot in different seed sizes of triticale under osmotic stress of water and NaCl. *Afric. J Biotech.*, **7** : 2862-68.

Khandakar, A. L., Begum, S. and Hossain, A.1987. Root characteristics, dry matter production and drought tolerance in jute (*Corchorus olitorius*). *Bangla. J Agri.*, **12** : 275-77.

Khodarahmpour, Z. 2011. Effect of drought stress induced by polyethylene glycol (PEG) on germination indices in corn (*Zea mays* L.) hybrids. *Afric. J Biotech.*, **10 :** 18222-27.

Materechera, M. A., Dexter, A. R., Aeston, A. M. and Kriby, J. M. 1992. Growth of seedling roots in response to external osmotic stress by polyethylene glycol 20,000. *Pl. Soil.*, **143**: 85-91.

Michel, B. E. and Kaufmann, M. R. 1973. The osmotic potential of polyethylene glycol 6000. *Pl. Physiol.*, **51**: 914-16.

Shamim, A., Rashid, A., Muhammad, Y. A., Ashraf. M. and Ejaz, A. W. 2009. Sunflower (*Helianthus annuus*) response to drought stress at germination and seedling growth stages. *Pak. J Biol. Sci.*, **41** : 647-54.

Wahab, M, A., 1978. Influence of waterlogging on the yield of *Capsularis* jute. *Proc. 3rd Bangladesh Sci. Conf.*, Section-II, pp. 14-15.

Zaifnejad, M., Clark, R. B. and Sullivan, C. Y. 1997. Aluminium and water stress effect on growth and proline of Sorghum. *J Pl. Physiol.*, **150** : 338-44.

Zekri, M. 1991 Effect of PEG induced water stress on two citrus cultivars. *J Pl. Nutn.*, **14** : 59-74.

Zhang, X., Liu, C., Wang, J., Li, F. and Ye, W. 2007. Drought tolerance evaluation of cotton with PEG water stress method. *Cot. Sci.*, **19** : 205-09.