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Screening for Moisture Stress Tolerant Genotypes in *C. olitorius* L. on the Basis of Seedling Characters

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Most cultivars of *C. olitorius* (tossa jute) suffer extremely during early growth phase either due to lean season or insufficient rainfall to maintain steady growth. Tolerant genotypes may overcome this problem maintaining sustainable growth at early growth. Sixty genotypes of *C. olitorius* were evaluated for identification of moisture stress tolerant genotypes using PEG, in field and pot under rainfed condition. The characters considered were root length, root volume, shoot length, root fresh weight, shoot fresh weight, leaf fresh weight, root dry weight, shoot dry weight, leaf dry weight, and tolerance index which showed significant differences among genotypes under different water regimes for stress tolerance. On the basis of seedling characters OEX 29 was found to be consistent by highly tolerant to moisture stress after evaluation in laboratory, field and pot culture. Genotypes OIJ 177 and OIN 791 showed tolerance, whereas, JRO 524 followed by JRO 632, JRO3690, JRO 8432, OIJ214 and OIN 970 were found to be the most susceptible genotypes.

Key Words: *Corchorus olitorius* L., Drought tolerant, Moisture stress, PEG 6000, Seedling characters

Introduction

Drought is a multifaceted stress condition with respect to timing and severity, ranging from long drought seasons where rainfall is much lower than demand, to short periods where plants depend completely on available soil water which severely impairs plant growth and development, performances and productivity (Lafitte *et al.,* 2006). However, the susceptibility of plant to drought stress varies among plant species and their developmental stages (Demirevska *et al.,* 2009). Two cultivated jute species *viz.*, *Corchorus capsularis* and *Corchorus olitorius*, are grown for fibre in South East Asian countries like India, Bangladesh, Nepal, China, Indonesia, Thailand, Myanmar and some South American countries. West Bengal in India, the main jute producing state of which 80 per cent of its total cultivated area (6.4 lakhs ha) is at the mercy of rain particularly at the early growth stage (Basu, 1997). Therefore, timely sowing and assured rainfall play important role for successful cultivation but farmers are not always in a position to afford improved technology with artificial irrigation. Owing to the erratic nature of rainfall the crop is often subjected to phasic spell of moisture stress during early growth stage. The germination of delicate jute seed is often hampered due to an un-assured moisture reserve in soil coupled with high temperature in summer months (March to May), which frequently leads to crop failure or poor fibre yield that necessitates development of tolerant genotypes which can survive moisture stress with sustainable growth at initial period. It has been noticed that if jute crop can survive the adverse initial dry spell then with the advent of monsoon with favourable weather conditions like adequate rainfall, high relative humidity and warm temperature it will show luxuriant growth with high fibre yield. Therefore, to tackle the moisture stress at the early growth stage identification or development of moisture stress tolerant genotypes could be one of the best options to accomplish good harvest from jute, particularly from more profitable *olitorius* species. The present investigation was initiated for identification of such tolerant genotypes by carrying out different experiments in laboratory, field and pot for evaluation of sixty genotypes. Artificial stress was created with PEG 6000 solution in laboratory and experiments in field and pot culture were conducted under rainfed condition.

Materials and Methods

The experimental materials consisted of sixty genotypes of *Corchorus olitorius* collected from All India Network Project on Jute and Allied Fibres, Kalyani

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Centre, B.C.K.V. in collaboration with CRIJAF, ICAR, Barrackpore, Kolkata. Out of sixty genotypes, 25 were indigenous, 16 standard varieties, 14 accessions of International Jute Organization (IJO) and five exotic varieties. The identified genotypes were evaluated to identify moisture stress tolerant genotypes by conducting experiments in laboratory using PEG 6000, field and earthen pots under rainfed condition for consecutive two years (2012 and 2013). In each experiment percentage of reduction was calculated by, % R = [1–Mean performance as measured for a character under treatment or rainfed condition / Mean performance as measured for the same character under control or irrigated condition] x 100.

Laboratory Experiment

The laboratory experiment was arranged in factorial completely randomized design (FCRD) with three replications and with two factors namely genotypes and irrigation levels i.e. control and stress. In the beginning to find out the suitable external water potential, all the sixty genotypes were tested in three different ranges of external water potential (viz, -2.0, -3.0 and -4.0 bars). These solutions were prepared using PEG 6000 following the method described by Michael and Kaufmann (1973). On the basis of growth performance of the seedlings of different genotypes grown in all three ranges of external water potential of PEG, a suitable range at -3.0 bar was identified. Subsequently all the genotypes were evaluated in -3.0 bar of PEG 6000 solution by growing them in glass plate 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). For identification of stress tolerant genotypes tolerance index could be an important selection indicator and high value of tolerance index implied tolerance of the genotypes under stress. The tolerance index was calculated as = TI = [Dry weight of seedling grown in water stress condition / Dry weight of seedling of the same genotype grown in non stress condition (Control condition)] X 100.

Field Experiment

These genotypes were grown under field in two varying water regimes viz, i) rainfed condition and ii) irrigation conditions. 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 five rows of three meter length maintaining 30 cm space between the rows. The size of each plot was 3 m X 1.5 m and plot to plot distance was 0.5 m. Sowing was done in two consecutive years, on 5th April 2012 and 29th March 2013. Recommended doses of major nutrients (N, P and K) were applied and normal cultural practices were followed. Randomly ten 21 days old seedling from both regimes, the moisture stress and the irrigated, were selected from each replication. The observations on each genotypes were recorded for nine characters viz. root length (cm), root volume (cc), root fresh weight (g), root dry weight (g), shoot length (cm), shoot fresh weight (g), shoot dry weight (g), leaf fresh weight (g), leaf dry weight (g) and tolerance index (%).

Pot Experiment

Earthen pots of 25 cm and 30 cm base and top diameter, respectively and 35 cm height, were filled with FYM mixed soil and fertilizers recommended as basal dose. In each pot thirty seeds were sown in two consecutive years, on 11th April 2012 and 10th April 2013 and the seedlings were thinned out every week. Seven seedlings were maintained in each pot. Five seedlings from each pot were uprooted carefully on 21 days after sowing (DAS) and similar observations were recorded on different characters as mentioned for field experiment. Correlations among characters were calculated in all three experiments. All the statistical analysis carried out with the help of IndoStat software version 8.6. (Indostat services, Hyderabad).

Results and Discussion

Laboratory Experiment

Analysis of variance from laboratory experiment showed significant treatment and genotype x treatment interactions for all the characters which revealed enough variation among the genotypes and for the characters. Significant treatment and also interaction effect highlighted differential performance in two different water regimes. Osmotic stress experiments highlighted some genotypes as tolerant, some as susceptible and rest with average performance when compared against normal condition (Table 1). The genotype OEX 29 showed maximum percent increase for shoot length, root fresh weight, leaf fresh weight and minimum reduction shoot

Table 1. Best identified tolerant and susceptible genotypes on the basis of seedling characters in laboratory condition

S.No	Root length (cm)		Shoot length (cm)		Root fresh weight (g)		Root dry weight (g)		Shoot fresh weight (g)	
	G	% R	G	% R	G	% R	G	% R	G	% R
Five genotypes showing highest increment or minimum reduction										
1	OIN791	26.545	OEX29	13.748	OEX29	6.838	OIJ177	48.596	OEX 29	-1.679
2	OEX29	21.176	OIJ177	12.052	OIN791	6.753	OIN926	42.133	OIJ 177	-1.749
3	OIJ177	20.060	OIN791	11.986	OIJ177	4.260	OEX29	34.940	OIN 791	-2.106
4	OIJ218	19.229	OIJ266	9.828	KOM62	3.560	OIN791	34.424	OIN 976	-2.956
5	OIN937	17.684	OIN986	9.441	OIN378	2.521	OIN378	32.827	OIJ 266	-3.453
Five genotypes showing maximum reduction										
1	OIN 970	3.559	OIN 309	-44.127	JRO 8432	-58.128	OIJ 214	-79.151	OIJ 937	-61.426
2	JRO 524	2.548	CO 58	-35.522	OIJ 214	-58.000	JRO 524	-71.894	TJ 40	-51.037
3	OIJ 214	2.054	TJ 40	-34.998	JRO3690	-56.912	JRO 632	-71.200	B.RUPALI	-49.570
4	JRO 632	2.555	OIN 970	-34.029	OIN 970	-56.513	JRO3690	-70.597	S 19	-48.915
5	JRO3690	2.015	OEX 019	-31.596	JRO 524	-53.576	OIN 970	-70.039	CO 58	-48.485
CD@5%		**0.103**	**CD@5%**	**0.096**	**CD@5%**	**0.042**	**CD@5%**	**0.014**	**CD@5%**	**0.207**

Table 1. contd…

S.No	**Shoot dry weight (g)**		**Leaf fresh weight (g)**		**Leaf dry weight (g)**	
	G	**% R**	**G**	**% R**	**G**	**% R**
Five genotypes showing highest increment or minimum reduction						
1	OIN 926	-1.029	OEX 29	20.008	OIN378	38.514
2	OIN 791	-1.164	OIN581	15.735	OIN581	20.362
3	OEX 29	-1.575	OIN791	11.940	OIN791	17.805
4	JRO7835	-2.055	OIJ104	10.663	JRO878	14.815
5	OIJ 177	-2.104	OIJ177	10.553	OEX 29	13.380
Five genotypes showing maximum reduction						
1	OIJ 214	-59.077	OIJ 257	-49.279	OIJ 257	-55.882
2	OIN 714	-54.646	OIN 926	-49.219	JRO3690	-47.488
3	OIN 970	-53.928	JRO 524	-43.932	JRO 632	-46.577
4	OIJ 104	-53.659	OIJ 213	-43.774	JRO8432	-43.333
5	JRO 524	-53.542	OIN 427	-42.463	OIJ 214	-42.544
CD@5%		**0.017**	**CD@5%**	**0.055**	**CD@5%**	**0.009**

(G=Genotype, %R=Percentage of reduction)

fresh weight. The genotype OIN 791 showed minimum reduction for root length, OIJ 177 for root dry weight, tolerance index, OIN 926 for shoot dry weight, OIN 378 for leaf dry weight and these genotypes showed superior performance for all these character when subjected to moisture stress. Maximum reduction for root length was observed in OIN 970, shoot length in OIN 309, root fresh weight in JRO 8432, dry weight of root and shoot in OIJ 214, shoot fresh weight in OIJ 937 and dry and fresh weight of leaf in OIJ 257. In contrast to the present investigation, Ayodele and Fawusi (1990) reported significant reduction in root length due to moisture stress in all the genotypes. Garg and Singla (2004), Shiwachi *et al.* (2008) also reported reduction in total length of jute seedlings but the present investigation depicted increase of root length in eight genotypes due to their inherent capacity to tolerate stress. Under moisture stress environment, seven genotypes and nineteen genotypes showed significant increase in root fresh weight and dry weight, respectively. Maximum reduction in root fresh weight was noticed in JRO8432 and for root dry weight maximum reduction was noticed in OIJ 214 followed by

JRO 524 and JRO 632. None of the genotypes showed increase for fresh dry weight of shoot under stress. Maximum reduction of genotypes for shoot fresh weight were OIJ 937 followed by TJ 40 and shoot dry weight was OIJ 214 followed by OIN 714. Eight and thirteen genotypes showed increase in fresh and dry weight of leaf respectively. Maximum reduction of genotype for leaf fresh and dry weight was found to be OIJ 257. OIJ 177 showed highest tolerance index and OIN 378, OIN 791, OEX 29 had tolerance index very close to OIJ 177. Lowest tolerance index was evident OIN 970 followed by JRO 524. From the laboratory experiment, OEX 29, OIJ 177, OIN 791 could be considered as most tolerant genotypes at seedling stage (Table 4).

The seedling characters under field as well as pot also showed significant variations among genotypes in stress situation which provides enough scope for selection of moisture stress tolerance genotypes.

Field Experiment

Enhanced root length over control under moisture stress was evident in all the genotypes and maximum elongation was shown by OIJ 177, OIN 791, CO 58, Bidhan Rupali and OEX 29 and minimum elongation was shown by JRO 632, OIJ 214, OIN 970, JRO 3690 and JRO 524 (Table 2). Under stress, all genotypes had reduced root volume but least reduction was shown by four genotypes viz., OEX 29, OIJ 177, OIN 791 and S 19 which also showed maximum root elongation and while the genotypes which showed minimum root elongation had maximum reduction in root volume. Almost all genotypes except S 19, showed reduction in shoot length and minimum reduction was revealed by OIJ 177, OIN 791, OEX 019 while maximum reduction in JRO 3690, OIJ 214, JRO 632, JRO 8432. Maximum reduction for almost all seedlings characters like root dry weight, shoot fresh weight and dry weight, leaf fresh and dry weight was exhibited under water stress condition and three genotypes OEX 29, OIJ 177, OIN 791 showed minimum reduction for these characters. The genotypes JRO 632, JRO 8432 showed maximum reduction for all these characters and OIJ 214 for fresh and dry weight of root, shoot as well as leaf. Incremental effect on root fresh weight was noticed in ten genotypes, out of them three genotypes OEX 29, OIN 791 and OIJ 177 showed maximum enhanced effect for the same. On the other hand, genotypes OIJ 214, JRO 524, JRO 3690, JRO 8432, JRO 632 also showed maximum reduction in root fresh weight.

Pot experiment

Enhanced effect as a result of exposure to moisture stress was evident in pot culture for root length, root volume, root fresh weight, root dry weight and shoot length in seven, eight, eight, four and two genotypes respectively (Table 3). All the genotypes showed maximum reduction for shoot fresh and dry weight of shoot and leaf. The genotypes, OIN 791, OIJ 177 and OEX 29 consistently showed maximum enhancement effect or minimum reduction effect due to moisture stress. Genotypes JRO 3690, JRO 632 and OIN 970, JRO 8432 and JRO 524 were badly suffered genotypes under moisture stress and were also found as most affected genotypes for many of the seedlings characters. Tolerance index of OIJ 177, OIN 791, and OEX 29 was found to be consistently superior in field and pot experiments too and JRO 8432, JRO 3690, JRO 524 showed least tolerance index (Table 4).

Tolerance index from all these set of experiments showed significant correlations with all other seedling characters except for shoot length, root fresh weight, shoot fresh weight and the characters also showed positive significant inter-se relationship. Selection at seedling stage on the basis of these characters will help to identify high fibre yielding genotypes at maturity. Under field condition, tolerance index proved as an important selection criteria as it showed significant associations with all the seedling characters. Root volume, root fresh weight, fresh and dry weight of shoot and leaf showed significant inter-se relations and could be favourably considered for selection of moisture stress tolerant genotypes. Tolerance index along with a few other seedling characters could be proved useful for isolation of moisture stress tolerant genotypes.

On the basis of tolerance index and other seedling characters genotypes OIJ 177, OIN 791 and OEX 29 could be considered as the most tolerant and JRO 8432, JRO 3690 and JRO 524 as the most susceptible under moisture stress environment. These tolerant genotypes could be recommended as varieties to be grown under moisture stress environment as they will maintain their growth satisfactory under such environment. Further these genotypes can be utilized for improvement of other high yielding genotypes.

Table 2. Best identified tolerant and susceptible genotypes on the basis of seedling characters in field condition

S.No	Root length (cm)		Root volume (cc)c		Root fresh weight (g)		Root dry weight (g)		Shoot length (cm)	
	G	% R	G	% R	G	% R	G	% R	G	% R
Five genotypes showing highest increment or minimum reduction										
1	OIJ177	31.910	OEX29	-5.333	OEX29	13.424	OEX 29	-12.967	S 19	14.978
2	OIN791	31.389	OIJ177	-5.684	OIN791	12.422	OIN 791	-13.989	OIJ 177	-5.809
3	CO 58	30.788	OIN791	-8.759	OIJ177	9.715	OIJ 177	-15.821	OIN 791	-7.486
4	B.RUPALI	30.615	S19	-10.204	OIN 990	7.061	OIN 990	-19.561	OEX019	-8.792
5	OEX 29	30.142	JR0128	-10.435	OEX014	5.958	OEX014	-20.210	OIJ 263	-8.796
Five genotypes showing maximum reduction										
1	JRO 632	4.329	OIN970	-33.784	OIJ 214	-37.891	OIJ 214	-51.853	JRO3690	-46.653
2	OIJ 214	5.367	JRO632	-28.816	JRO 524	-35.414	JRO3690	-51.130	OIJ 214	-45.895
3	OIN 970	5.985	OIJ 214	-28.369	JRO 3690	-35.269	JRO 524	-50.650	JRO 632	-42.740
4	JRO 3690	6.156	JRO524	-28.169	JRO 8432	-32.968	JRO8432	-48.308	JRO 524	-42.688
5	JRO 524	6.453	JRO8432	-23.188	JRO 632	-31.617	JRO 632	-48.050	JRO8432	-40.673

Table 2. Cond. .....

S.No	Shoot fresh weight (g)		Shoot dry weight (g)		Leaf fresh weight (g)		Leaf dry weight (g)	
	G	% R	G	% R	G	% R	G	% R
Five genotypes showing highest increment or minimum reduction								
1	OEX29	-2.689	OEX 29	-4.456	OIN791	-10.608	OIN791	-9.687
2	OIJ177	-3.037	OIN581	-5.880	OIJ177	-11.423	OIN976	-10.164
3	OIN791	-3.442	OIN791	-6.746	OEX29	-12.715	OIN409	-10.277
4	OIN082	-10.070	OIJ104	-12.918	OIN975	-15.517	CO 58	-10.300
5	JRO878	-10.499	OIJ177	-13.906	OIN976	-15.721	OIJ213	-11.079
Five genotypes showing maximum reduction								
1	JRO 632	-46.769	OIJ 257	-69.611	OIN 970	-52.213	JRO 524	-55.643
2	JRO8432	-45.085	OIN 926	-57.197	JRO 524	-44.227	JRO 632	-53.807
3	JRO3690	-36.373	JRO 524	-55.017	OIJ 214	-43.209	OIJ 214	-52.316
4	OIN 970	-35.212	OIJ 213	-52.131	JRO8432	-41.782	JRO 8432	-50.784
5	OIJ 214	-34.375	OIN 427	-51.762	JRO 632	-40.984	JRO 66	-48.187

(G=Genotype, %R=Percentage of reduction)

References

Ayodele VI and MOA Fawusi (1990) Studies on drought susceptibility of *Corchorus olitorius* L. II. Effects of moisture stress at different physiological stages on vegetative growth and seed yield of *C. olitorius* cv. '*Oniyaya*'. *Biot.* **19**: 33-37.

Basu NC (1997) Status of raw jute production in India. In "Proceedings of the central workshop on jute, sunhemp, mesta and ramie", held between April 21 and 25, Central Research Institute for Jute and Allied Fibres, Barrackpore, pp. A1-A8.

Demirevska K, D Zasheva, R Dimitrov, L Simova-Stoilova, M Stamenova and U Feller (2009) Drought stress effects on Rubisco in wheat: changes in Rubisco large subunit. *Acta Physiol. Plant*. **31:** 1129-1138.

Table 3. Best identified tolerant and susceptible genotypes on the basis of seedling characters in pot condition

S.No	Root length (cm)		Root volume (cc)		Root fresh weight (g)		Root dry weight (g)		Shoot length (cm)	
	G	% R	G	% R	G	% R	G	% R	G	% R
Five genotypes showing highest increment or minimum reduction										
1	OIN 791	16.556	OIN 791	44.275	OIJ 177	13.636	OIN791	6.311	OIJ 177	3.779
2	OEX 29	13.180	OIJ 177	37.209	OEX 29	10.145	OEX29	6.207	OEX 29	0.567
3	OIJ 177	9.781	OEX 29	31.163	OIN 791	8.955	OIJ177	3.280	OIN 791	-2.154
4	OIJ 263	7.729	OIJ 263	18.532	OIJ 263	7.759	OIJ218	1.850	JRO 878	-8.168
5	OIJ 218	1.855	OIJ 218	16.216	OIN 259	4.669	OIJ263	-3.073	OIJ 264	-9.125
Five genotypes showing maximum reduction										
1	JRO 632	-51.029	OIN 981	-52.038	JRO3690	-32.362	JRO3690	-34.850	OIN 970	-58.588
2	OIN 970	-44.694	JRO 632	-43.243	JRO8432	-27.351	OIN 970	-33.600	JRO3690	-43.612
3	JRO3690	-42.547	OIN 970	-42.581	JRO 524	-27.333	JRO8432	-30.526	OIJ 214	-42.206
4	OIN926	-42.221	JRO 524	-40.268	OIJ 214	-27.167	JRO 632	-30.444	OEX 019	-39.532
5	JRO524	-41.188	JRO3690	-40.268	JRO 632	-26.936	OIJ 214	-30.432	JRO 632	-39.084

Table 3.

S.No	Shoot fresh weight (g)		Shoot dry weight (g)		Leaf fresh weight (g)		Leaf dry weight (g)	
	G	% R	G	% R	G	% R	G	% R
Five genotypes showing highest increment or minimum reduction								
1	OIJ 177	-1.127	OIJ177	-6.734	OEX 29	-1.146	OEX 29	-7.945
2	OEX 29	-2.849	OEX29	-8.279	OIJ 177	-1.780	OIJ 177	-8.483
3	OIN 791	-5.042	OIN791	-10.238	OIN 791	-3.794	OIN 791	-10.280
4	OIN 515	-8.465	OIN515	-13.223	OIN 533	-5.322	OIJ 213	-11.664
5	OIN 976	-9.325	OIN976	-14.083	OIJ 213	-5.431	OIN 533	-11.681
Five genotypes showing maximum reduction								
1	JRO3690	-50.886	JRO3690	-51.110	JRO 632	-61.164	JRO 632	-60.684
2	JRO 632	-43.819	JRO 632	-44.871	JRO3690	-60.177	JRO 3690	-59.465
3	JRO 524	-43.490	JRO 524	-44.340	JRO8432	-59.396	JRO 8432	-59.112
4	JRO8432	-42.925	JRO8432	-44.318	JRO 524	-58.926	JRO 524	-58.498
5	OIN 970	-42.619	OIN 970	-44.293	OIN 970	-57.697	OIN 970	-57.865

(G=Genotype, %R=Percentage of reduction)

Table 4. Tolerance index in laboratory, field and pot condition

Laboratory condition TI= TDWT/ TDWC*100		Field condition TI= TDWR/ TDWI*100		Pot condition TI= TDWR/ TDWI*100		Laboratory condition TI= TDWT/ TDWC*100		Field condition TI= TDWR/ TDWI*100		Pot condition TI= TDWR/ TDWI*100	
Five genotypes showing highest TI						Five genotypes showing lowest TI					
G	TI	G	TI	G	TI	G	TI	G	TI	G	TI
OIJ 177	117.804	OIN 791	93.604	OIJ177	94.152	OIJ 214	35.456	JRO 8432	36.228	JRO 3690	48.441
OIN 378	114.268	OIJ 177	91.833	OEX29	94.139	JRO 8432	42.551	JRO 524	44.067	JRO 632	51.037
OIN 791	113.258	OEX 29	91.585	OIN791	92.189	JRO 3690	42.563	OIJ 214	46.104	JRO 8432	51.892
OEX 29	112.969	OIN 976	86.561	JRO878	83.697	JRO 524	42.753	JRO 632	48.032	OIN 970	51.966
OIN 581	106.926	OIN 986	83.780	OIN915	82.813	OIJ 257	43.192	JRO 3690	50.917	JRO 524	52.374
Mean	80.536		68.862		71.669		80.536		68.862		71.669
CD@5%	3.430		2.653		2.702		3.430		2.653		2.702

(G=Genotype, TI= Tolerance Index, TDWT= Total Dry Weight of Treatment, Total Dry Weight of Control, TDWR= Total Dry Weight of Rainfed condition , TDWI= Total Dry Weight of Irrigated condition)

Garg S and R Singla (2004) Growth, photosynthesis, nodule nitrogen and carbon fixation in the chickpea cultivars under salt stress. *Braz. J. Plant Physiol.* **16**: 137-146.

Lafitte HR, ZK Li, CHM Vijay Kumar, YM Gao, Y Si, JL Xu, Fu, BY, Yu SB, AJ Ali, J Domingo, R Maghirang, R Torres and D Mackill (2006) Improvement of rice drought tolerance through backcross breeding: evaluation of donors and selection in drought nurseries. *Field Crop Res*. **97**: 77-86.

Michel BE and MR Kaufmann (1973) The osmotic potential of polyethylene glycol 6000. *Plant Physiol.* **51**: 914-916.

Shiwachi H, M Komoda, K Koshio and H Takahashi (2009) Effect of soil moisture stress on the growth of *Corchorus olitorius* L. *Afri. J. Agril. Res.* **4**: 289-293.