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Evaluation of Exotic Genotypes under Controlled Drought Conditions at Reproductive Phase

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ABSTRACT

A study was conducted in the Plant Physiology Division, Bangladesh Rice Research Institute (BRRI), Gazipur during T. Aman seasons 2018 to evaluate the genotypes collected from India under controlled drought conditions. Seven genotypes (CR Boro Dhan 2 (CR-898), CR Dhan 300, CR Dhan 10, Naveen, CR Sugangh Dhan 907, Geetanjali, and DRR Dhan 44) along with drought tolerant check BRRI dhan56, BRRI dhan71 and susceptible check IR64 were tested. Regarding growth characteristics genotype x treatment interaction effect was not significant but plant height, tiller number and straw weight were reduced due to drought stress indicating growth was arrested by drought stress. A similar observation was also found in panicle number. Under drought stress, more than 90% of panicle could exert fully only in CR Sugangh Dhan 907 and DRR Dhan 44 among the exotic genotypes which also showed 44.1% and 39.0% yield reduction, respectively compared to control plants. The grain yield reduction was mainly due to increased percent sterility (41.4% and 33.4% respectively) under stress conditions. Below 30 cm soil depth, the highest cumulative root length (CRL) was found in CR Sugangh Dhan 907 and DRR Dhan 44. DRR Dhan 44 also had the highest root length density (RLD) (0.73 cm cm^{-3}) and root weight density (RWD) (0.44 mg cm^{-3}). The exotic genotype DRR Dhan 44 produced the highest amount of root (572.7 mg) per gram of shoot. The results suggest that genotypes DRR Dhan 44 and CR Sugangh Dhan 907 appear to be suitable for cultivation in drought-prone areas and these could be used for the development of drought-tolerant variety as donor parents in the hybridization program.

Key words: Rice (*Oryza sativa* L.), drought stress, drought tolerance, reproductive phase.

INTRODUCTION

Drought is a major abiotic constraint in areas of rainfed rice (*Oryza sativa* L.) cultivation. About 50% of the world's rice is grown in a rainfed culture where drought stress may cause a substantial amount of yield loss (Lilley and Fukai, 1994). The rainfed lowland rice of Bangladesh is popularly known as transplanted Aman rice, which is usually seeded in July and transplanted in August. The seeding and transplanting may be delayed due to unpredictable drought, which causes the crop to have mild to severe drought stress at the reproductive and ripening phase when rainfall is minimal or none during October to November.

Drought is a complex phenomenon than most of the stresses like salinity, submergence, pests and diseases. It may occur at any crop growth stage and affects a large array of physiological, biochemical and molecular processes. Severe drought stress

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can be detrimental to plant development at all stages. However, the rice plant is most sensitive to the reduction division stage (Yoshida *et al.,* 1981). Yield loss can arise up to 100 % due to drought stress depending on the growth stage of the plant (Oladosu *et al.,* 2019). Yang *et al.* (2019) reported that drought stress at the flowering stage has a strong influence on rice physiological traits and yield. They also stated that stronger recovery capability can contribute to maintaining relatively high grain production, which could be a great target for the breeder in developing drought-tolerant rice cultivars.

Drought tolerance is a complex quantitative trait with a complicated phenotype (Oladosu *et al.,* 2019). However, the physiological pathways of both yield and drought tolerance are very complex. The development of drought-resistant cultivars will considerably improve rice production. According to Fukai and Cooper (1995) a drought-resistant genotype will have a higher grain yield than others when all the genotypes are exposed to the same level of water stress. Deep rooting ability can contribute to drought tolerance in several plants such as peanuts (Junjittakaran *et al.,* 2014), common beans (Polania *et al.,* 2017) and rice (Nakata *et al.,* 2011). Under water-limited conditions, the root length and thickness are important traits that determine the uptake of water from the sub-surface layer of soil (Pinta *et al.,* 2018). Seven genotypes were collected from India which were evaluated based on drought-tolerant mechanisms. The present study was undertaken to observe the performance of these materials under control drought stress at the reproductive phase in greenhouse conditions.

MATERIALS AND METHODS

Seven genotypes namely CR Boro Dhan 2 (CR-898), CR Dhan 300, CR Dhan 10, Naveen, CR Sugangh Dhan 907, Geetanjali, and DRR Dhan 44 collected from India were evaluated along with check variety BRRI dhan56, BRRI dhan71 and IR64 under control drought condition for reproductive stage drought tolerance in Plant Physiology Division at BRRI HQ, Gazipur during T. Aman season 2018. Twenty-five-day-old seedlings were transplanted in the aluminium pot (56 cm x 43 cm) containing 110 kg of puddled soil in a net house shaded by a polythene sheet. The soil was fertilized with Urea-TSP-MP@ 50-25-25 g/drum. Four hills were maintained in each drum using one seedling per hill. The experiment was laid out in two sets where the 1st set was grown in well-watered conditions and the 2nd set under stress conditions. At the panicle initiation stage water was drained out from the 2nd set so that the plants experience drought stress from the reduction division stage. Cultural operations were applied as and when necessary. The experiment was laid out in a completely randomized design with three replications. The water table depth was measured daily by installing a PVC pipe. The portion of PVC pipe (35 cm) below the ground surface was perforated. Soil moisture was recorded at 3-day intervals. At severe drought stress some lifesaving water was applied and calculated as follows: $= \Pi r^2h$

Where, r = 56/2 = 28 cm (The radius of the circumference of the pot at the base of the hill.)

h = 0.5 cm/day (the approximate evapotranspiration at the period of Nov-Dec.

For the root study of these genotypes, another experiment was conducted following the protocol of screening for deep rooting ability with the deep-rooted check variety Morichboti (BRRI, 2005). Sprouted seeds were sown in a root elongation tube in the net house. The root elongation tube is a 70 cm long and 9.5 cm diameter perforated polyethylene tube filled up with 60:40 sand: soil mixture. Three seedlings were maintained in each tube and the tubes were irrigated with Yoshida's culture solution throughout the experimental period. At 35 days after sowing the plants were harvested and the following observations were recorded: root length, cumulative root length (CRL), root length density (RLD), root and shoot dry weight, root weight density (RWD), and root shoot ratio.

RESULTS AND DISCUSSIONS

Water table depth and soil moisture

Plants were grown under an artificial rain-out shelter made of polythene sheet. So that plants could not receive any rainwater. Water was withheld from the drum at the PI stage. At severe drought stress leaf rolling symptoms were found. When it existed overnight till the next morning then some lifesaving water was applied. Fig. 1 shows the average water table depth. Seven days after withholding of irrigation water the parched water table remained more than 30 cm depth below surface in all the variety. About eight days after withholding water there was no water in the PVC pipe in all the variety. The average soil moisture ranged from about 24.8 to 35.9 percent during the reduction division stage and 17.1 to 28.4 percent during the flowering stage to maturity, which reveals plants experience water stress in both the reproductive and ripening phases (Fig. 2).

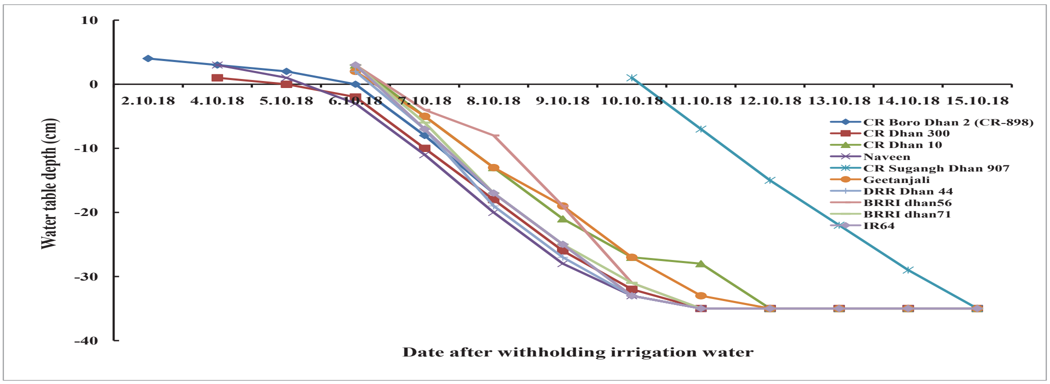

Fig. 1. Parch water table depth at pot after withholding of irrigation water.

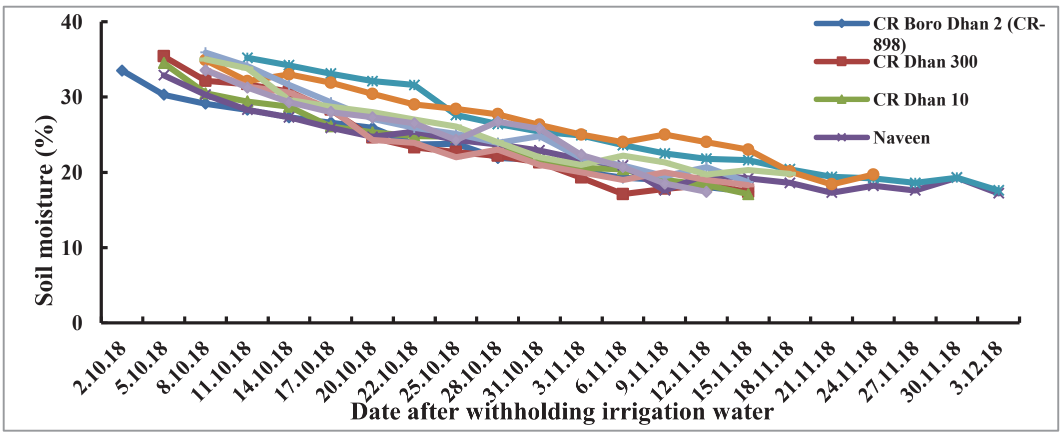

Fig. 2. Soil moisture status at pot after withholding of irrigation water.

Growth characteristics

Seven genotypes were tested for drought tolerance under control conditions. Due to water stress plant height, tiller number and straw weight all the growth characters were reduced in all the genotypes but the genotype treatment interaction effect was not significant (Fig. 3, 4 and 5). Plant height was reduced significantly only in CR dhan 10 among the tested genotypes. The tiller number was statistically similar under control and drought conditions in all the genotypes except CR BORO Dhan2 (CR-898) and IR64. Similarly, straw weight was reduced significantly only in CR BORO Dhan 2 (CR-898), CR Dhan 300, CR Dhan 10, Naveen, Geetanjali and BRRI dhan56. Rice plants are very sensitive to water stress during their entire growth period (Zeng and Shannon, 2000; Khan Abdullah, 2003). For its growth and development, it requires a considerable amount of water. Rice plants can transpire at their potential rate. Under soil moisture below field capacity, it cannot meet the demand of evapotranspiration and the plant begins running under water stress conditions. As a result, growth was arrested due to water stress compared to control plants. Murthy and Ramakrishnayya (1982) found that stem and leaf elongation decreased due to water deficit during vegetative and reproductive growth, which ultimately reduced plant height. Decreased tiller number due to water stress has also been reported in upland rice by Cruz *et al.* (1986). Decreased straw weight under drought stress might be due to a reduction of leaf area, plant height and a lower number of tillers.

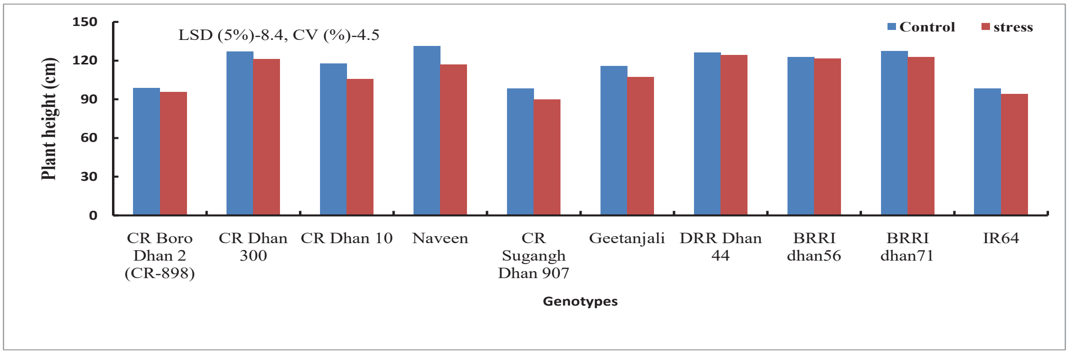

Fig. 3. Plant height of seven genotypes as affected by water stress at reproductive phase.

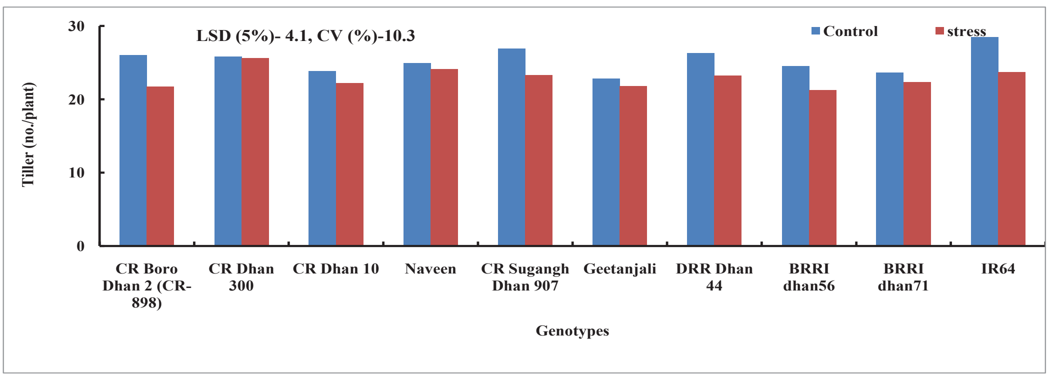

Fig. 4. Tiller number of seven genotypes as affected by water stress at reproductive phase**.**

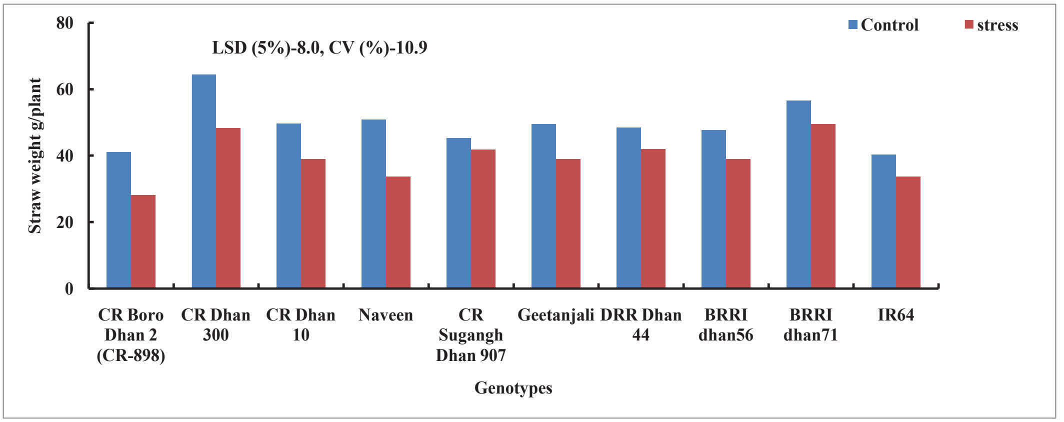

Fig. 5. Straw weight of seven genotypes as affected by water stress at reproductive phase.

Panicle characteristics

Generally, panicle number was reduced in all the genotypes due to water stress but a significant difference was not observed in control and stress conditions (Fig. 6). While a highly significant difference was found regarding panicle exertion percentage. Irrespective of genotypes, under control conditions, the panicle exertion rate was 94.1 to 99.4% but in stress conditions, the exertion rate varied from 68% to 96.4% (Table 1). The highest exertion rate (99.4%) was found in Naveen and DRR Dhan 44 under control conditions. However, under drought conditions, the highest exertion rate was observed in tolerant check BRRI dhan56. Among the tested genotypes, the highest exertion rate was observed in DRR Dhan 44 (93.6%) followed by Sugangh Dhan907 (91.7%). Under the control condition, the last internode length was higher than the last leaf sheath length or more or less equal, which contributed to the exertion of the panicle fully while under stress condition last internode length was smaller than the last leaf sheath length (Table 1). So that, panicle could not exerted fully in some genotypes. Normally tiller production continues up to the heading but when soil moisture stress was applied at the panicle initiation and booting stage plant could not attain the maximum tillers as well as panicle number was reduced. It might be possible that severe drought impeded panicle exertion or caused the death of some of the panicles eventually reducing the number of panicles per hill (Mamin, 2003). These results conform with the findings of earlier research (BRRI, 2011; 2012; 2014). O'Toole and Namuco (1983) found that panicle exertion rate decreased linearly with a decrease in leaf water potential.

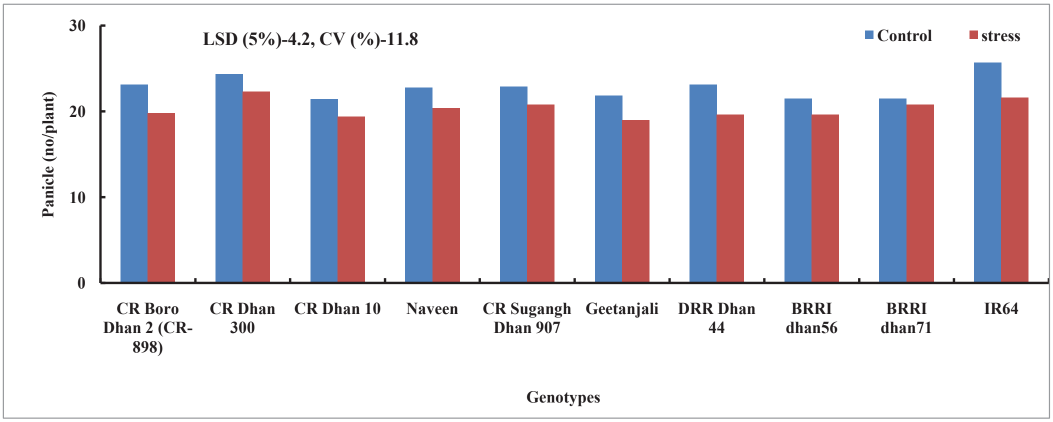

Fig. 6. Panicle number of seven genotypes as affected by water stress at reproductive phase.

Table 1. Panicle length, panicle exertion, last leaf sheath and internode length of tested seven genotypes as affected by water stress at reproductive phase.

Designation	Panicle length (cm)		Panicle exertion (%)		Last leaf sheath length (cm)		Last internode length (cm)	
	Control	Stress	Control	Stress	Control	Stress	Cont-rol	Stress
CR Boro Dhan 2 (CR-898)	24.1	22.4	97.3	79.5	28.8	30.1	29.1	25.7
CR Dhan 300	21.4	20.4	97.6	69.5	28.3	30.4	30.9	26.3
CR Dhan 10	19.5	18.6	95.9	84.7	28.2	26.9	28.9	24.1
Naveen	23.3	22.5	99.4	79.5	32.5	31.5	35.1	26.3
CR Sugangh Dhan 907	18.3	17.2	98.1	91.7	24.5	22.8	26.9	22.5
Geetanjali	23.2	21.8	94.1	68.0	32.4	33.5	32.5	30.2
DRR Dhan 44	20.1	19.4	99.4	93.6	29.2	33.9	32.7	30.2
BRRI dhan56	25.5	23.0	97.2	96.8	34.5	32.7	35.3	29.3
BRRI dhan71	25.5	24.1	96.6	94.4	35.9	36.2	36.9	32.7
IR64	24.1	23.9	98.3	69.3	28.4	29.1	29.1	26.7
LSD (5%)	2.4		6.4		4.3		4.6	
CV (%)	6.6		4.3		8.5		9.4	

Yield and yield component

A significant reduction was found in the grain yield of all the genotypes under stress conditions compared to the control condition (Table 2). The grain yield varied from 31.34 to 47.10 g plant^{-1} under control conditions while under stress conditions it varied from 8.33 to 24.98 g plant^{-1}. The exotic genotype Geetanjali has greater yield potential at the control condition but under stress conditions, BRRI dhan71 produced the highest grain yield followed by BRRI dhan56 and the exotic genotype DRR Dhan 44. Among the tested genotypes, the lowest percent yield reduction was found in DRR Dhan 44 (39.0%) followed by CR Sugangh Dhan 907 (44.1%). Regarding filled grain number, the highest number of filled grain was found in CR Sugangh Dhan 907 both under control and stress conditions. The genotype DRR Dhan 44 also produced a statistically similar number of filled grains, which also showed less than 50% sterility. HI was reduced significantly due to water stress. However, the genotype DRR Dhan 44 showed the highest HI (0.32) under drought stress compared to other exotic genotypes. In all the genotypes the filled grain number was decreased concomitant increase of the per cent sterility, which indicates the per cent sterility was very sensitive to reproductive phase water deficit, which is attributed to poor panicle exertion in which anthesis is inhibited in the unexerted portion (O'Toole and Namuco, 1983). In rice, low water potential around the time of anthesis may lead to a failure of anther dehiscence, which leads to male sterility (Saini and Westgate, 2000). Islam and Islam (2010) reported that the yield of T. Aman was reduced by 30 and 55.2% for five days of drought at the reproductive and ripening phases respectively. Yue *et al.* (2006) suggested that the yield loss and harvest index reduction under drought stress in the late season were associated with the reduction of spikelet fertility, biomass and grain weight.

Table 2. Grain yield, filled grain no., % sterility and HI of 7 genotypes as affected by water stress at reproductive phase.

Designation	Grain yield (g plant^{-1})			Grain no. plant^{-1}		% Sterility		HI	
	Control	Stress	% Reduction	Control	Stress	Control	Stress	Control	Stress
CR Boro Dhan 2 (CR-898)	39.87	12.07	69.7	1918.8	682.4	26.0	66.9	0.47	0.23
CR Dhan 300	41.30	10.31	75.0	1812.1	576.5	25.3	74.6	0.36	0.15
CR Dhan 10	33.71	16.57	50.8	1508.2	855.7	32.0	60.2	0.38	0.27
Naveen	31.34	13.22	57.8	1754.7	876.4	34.0	66.1	0.35	0.23
CR Sugangh Dhan 907	33.08	18.48	44.1	1863.6	1262.5	28.5	41.4	0.39	0.27
Geetanjali	47.10	8.33	82.3	2202.5	429.8	32.6	75.1	0.45	0.15
DRR Dhan 44	36.56	22.32	39.0	1737.7	1176.6	26.5	33.4	0.40	0.32
BRRI dhan56	38.21	23.73	37.9	1785.3	1240.8	28.3	35.7	0.41	0.34
BRRI dhan71	41.68	24.98	40.0	1857.8	1230.8	17.7	29.8	0.41	0.31
IR64	42.49	9.08	78.6	1917.7	426.4	25.5	72.4	0.48	0.19
LSD (5%)	11.2			548.6		15.8		0.10	
CV (%)	24.9			24.5		23.0		18.2	

Root characteristics

The deep rooting ability of a genotype is assumed to be related to drought resistance or tolerance of a genotype. Deep root helps plants to utilize sub-surface water for the maintenance of high water potential to maintain normal panicle development and growth. Plants first draw water from the surface layers, and subsequently, the area of water extraction gradually shifts downward through the soil profile (Araki *et al*., 2006; Luo *et al*., 2023). Genotypic variation was observed for all the parameters. All the tested genotypes produced more than 50 cm long roots (Fig.7). The check variety Morich Boti produced the longest root (71.3 cm) followed by BRRI dhan71 and BRRI dhan56. Among the exotic genotypes CR Dhan 10, Geetanjali and DRR Dhan 44 produced more than 60 cm long roots. The sum of the length of roots is called cumulative root length (CRL). The check variety Morich Boti always produced the highest CRL (Table 3). However, among the exotic genotypes CR Dhan 10 had the highest CRL up to 30 cm depth, but below 30 cm soil depth the highest CRL was found in CR Sugangh Dhan907 and DRR Dhan 44. The total CRL was maximum in DRR Dhan 44. The root length density (RLD) is the length of roots per unit volume of soil. The RLD of exotic genotypes CR Dhan 10, CR Sugundh Dhan 907, and DRR Dhan 44 were comparable with the check variety Morich Boti. Root dry weight was also highest in DRR Dhan 44 among the exotic genotypes. Root weight density (RWD) is one of the most important parameters used for the evaluation of roots. Maximum RWD value was observed in deep-rooted check variety Morich Boti (0.49 mg cm^{-3}). Among the tested exotic genotypes the highest RWD value was found in DRR Dhan 44 (0.44 mg cm-3) which was statistically similar with check variety Morich Boti. The other most important character rooting ability is the ratio of root and shoot and it expresses the amount of root (mg) produced per gram of shoot. Among the tested genotypes, the highest amount of root produced by the check variety Morich Boti (693.9 mg/g of shoot) followed by the exotic genotype DRR Dhan 44 (572.7 mg/g of shoot). Genotypic variations in root traits have been reported in rice (Yu *et al*., 1995: Nguyen *et al*., 1997). Under drought conditions, the soil starts drying from the surface but deep soil horizons may remain wet and able to supply water to the plant's roots. Consequently, deep root portions may be more important than shallow root portions when a variety is to be examined for drought tolerance. Abd Allah *et al.* (2010) showed that root depth, root thickness, root volume, and dry root: shoot ratio were associated with drought tolerance. Genotypes or cultivars with deep root development will maintain higher leaf water potential under water limited condition. Well-developed root system will help the plant in maintaining plant water status (Kato *et al*., 2007). The deeper root system would significantly increase the total biomass as well as yield (Mohankumar *et al*., 2011).

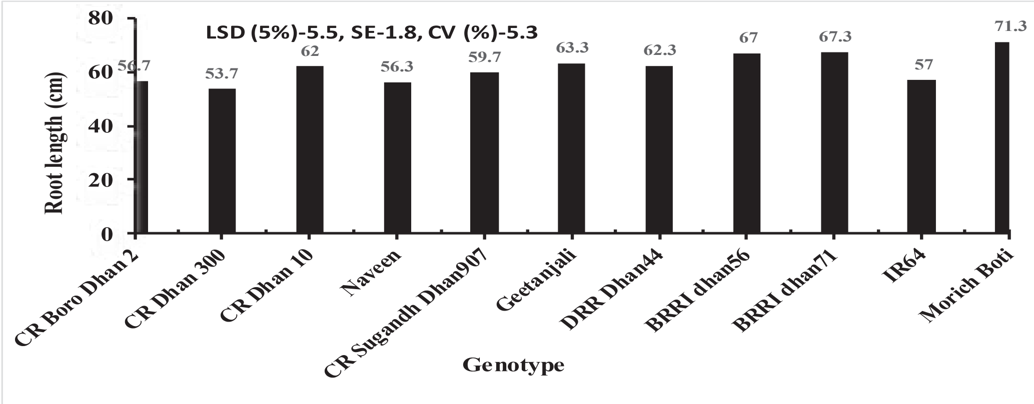

Fig. 7. Root length of seven tested genotypes with check variety Morich Boti.

Table 3. Cumulative root length (CRL), root length density (RLD), root weight, root weight density (RWD) and root shoot ratio of seven tested genotypes with the check variety Morich Boti.

Designation	CRL upto 30 cm depth (cm)	CRL below 30 cm depth (cm)	Total CRL (cm)	RLD (cm cm^{-3})	Root weight (mg)	RWD (mg cm^{-3})	Root shoot ratio (mg/g)
CR Boro Dhan2	2496.7	845.7	3342.3	0.67	1360.0	0.27	323.3
CR Dhan 300	2728.0	459.0	3187.0	0.64	1036.7	0.21	227.3
CR Dhan 10	2772.7	821.7	3594.3	0.72	1550.0	0.31	285.3
Naveen	2622.7	534.3	3157.0	0.64	1173.3	0.24	220.8
CR Sugandh Dhan 907	2532.0	998.0	3530.0	0.71	1393.3	0.28	345.7
Geetanjali	2085.7	521.3	2607.0	0.53	1210.0	0.24	363.0
DRR Dhan 44	2659.7	973.0	3632.7	0.73	2193.3	0.44	572.7
BRRI dhan56	2516.3	746.0	3262.3	0.66	1223.3	0.25	290.1
BRRI dhan71	2350.3	1222.7	3573.0	0.72	1610.0	0.32	341.6
IR 64	2526.7	783.3	3310.0	0.67	1243.3	0.25	294.6
Morich Boti (CK)	2877.3	1033.0	3910.3	0.79	2410.0	0.49	693.9
LSD (5%)	420.1	196.3	564.6	0.11	223.6	0.45	103.4
CV (%)	9.6	14.2	9.8	9.8	8.8	8.8	16.9

CONCLUSION

Among the seven exotic genotypes collected from India DRR Dhan 44 showed better performance under drought conditions followed by CR Sugandh Dhan 907 considering yield reduction, percent sterility and root characteristics, which could be used as donor parent in the hybridization programme.

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