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Evaluation of root characters and its relation to drought tolerance in rice

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ABSTRACT

The present experiment was conducted on ten genotypes viz. Dular, IET 826, Aditya, Browngora, IR 64, IR 30, Satabdi, Bandana, Rasi and Panke during wet season of 2008, 2009 and 2010. The experiment was conducted with an objective to identify genotypes with favourable root architecture to reduce yield loss under water stress conditions and to study the genetics of tolerance followed by identification of hybrids with high heterosis for yield and important root characters. On the basis of evaluation for root characters Dular and Browngora proved their efficiency to maintain yield under water stress condition and root volume and root shoot ratio were predominantly controlled by additive gene effect.

Key words: *rice, genotype, root character, drought*

Rice is by far the most economically important food crop in many developing countries, providing two thirds of the calorie intake of more than 3 billion people in Asia (Nanda, 2000). The production therefore, should be increased to a level so as to match the rate of increasing population to maintain the food-population balance. This increase in rice production must be achieved through utilisation of minimal land, less water, few agrochemicals and other inputs. Rice is generally favourably grown in regions with irrigation facilities. But due to global climatic change water becomes a limiting factor .Water is an important natural resources which supports life system in the biosphere. Unfortunately global climatic change has made this important resource as a most limiting factor against expression of yield potentiality of any crop including rice which is considered as the most important staple food in eastern zone of India. Drought had long been considered as the primary constraint to rainfed rice production. Ingram *et al., (*1990) suggested that about half of all rainfed lowland rice is prone to frequent drought. At this critical juncture, efforts should be made to develop lines in rice which may efficiently maintain sustainable yield under water-stress environment being least affected in its metabolic activities throughout its growth period. Evaluation of number of rice genotypes for identification of the genotypes with favourable root traits may provide appreciable resistance to water stress to maintain their yield potentiality (Liley *et al*, 1994a, 1985 b and Muhammad Farooq *et al* 2009). With this background the present investigation was conducted to identify various root characters which may influence on sustainable growth of rice with minimum predictable loss in productivity.

MATERIALS AND METHODS

Ten genotypes of rice were considered for the experiment *viz.,* Dular, IET 826, Aditya, Browngora, IR 64, IR 30, Satabdi, Bandana, Rasi and Panke collected from RRS, Chinsurah. The experiment was conducted in B.C.K.V, Mohanpur, Nadia, West Bengal during wet season of 2008, 2009 and 2010. The collected germplasms were raised in pots with three replication under water stress condition for 10 days at tillering stage and 15 days at flowering stage to evaluate ten genotypes for root characters and yield. Similarly the genotypes were grown under normal condition to record yield plant^{-1}. The different root characters considered were maximum root length, root volume, dry shoot weight, dry root weight and dry root shoot ratio, yield under stress condition, yield under normal condition and percentage yield reduction. The root and

shoot portions were oven dried at 65°C for 72 hours to measure the dry weight. On the basis of evaluation six genotypes were selected of which two proved tolerant like Dular and Browgora but with low *per se* performance for yield and four genotypes namely IET 826, Aditya, IR 30 and IR 64 showed low tolerance but with high *per se* performance for yield under normal conditions. These genotypes were crossed following 6 X 6 diallel mating systems in 2009 and the parents with hybrids were grown in 2010 for studies on inheritance, combining abilities and heterosis of root characters and yield. Combining ability was estimated following Griffing (1956) Model I method II and Heterosis following Matzinger *et al*., (1962). The data collected from the field trials were subjected to statistical analysis and the treatment variance due to genotypes variations was tested for significance, Ekanayake *et al.*, (1985a). The standard errors of mean and critical difference (CD) are indicated in the respective tables (Table 2 and Table 4). For estimation of genetic parameters of different root characters, the data were analysed (Panse *et al.*, 1984). Genotypic coefficients of variation (GCV) and Phenotypic coefficients of variation (PCV) were calculated by the formulae given by Burton (1952). The percentage of heritability (H) was estimated by the formula suggested by Hanson *et al*., (1956). The expected genetic advance (GA) as percentage of mean and phenotypic and genotypic correlation coefficients was computed (Johnson *et al.*, 1995).

RESULTS AND DISCUSSIONS

Analysis of variance revealed highly significant varietal differences for all the characters studied (Table 1), so there is enough scope for selection among the varieties. Maximum root length ranged from (26.85-40.39). The variety Dular was found to exhibit maximum value for root length (40.39cm) followed by Browngora (38.50 cm) and IET 826 (36.75 cm). Root volume (cc) ranged from (4.25-11.62) maximum being 11.62 cc found in

Table 1. ANOVA for different root characters and yield in ten rice genotypes

Source	d.f.	Mean sum of squares							
		MRL (cm)	RV (cc)	DSW (g)	DRW (g)	RSR	Y1 (g plant^{-1})	Y2 (g plant^{-1})	% RDT
Replication	2	1.155	.731	0.006	0.0054	0.00035	1.446	0.073	0.381
Variety	9	61.56**	12.24**	0.253	0.253**	0.00261**	94.240	4.44**	8.161
Error	18	1.353	0.251	0.143	0.0028	0.000287	0.552	0.0521	0.221

** Significant at 1% level, MRL=Maximum root length, RV=Root volume, DSW=Dry shoot weight, DRW=Dry root weight, RSW=Root shoot weight, Y1=Yield stress condition, Y2=Yield normal condition, %RDT=Percentage yield reduction

Table 2. Mean performance of ten genotypes for different root characters related to drought resistance

Variety	MRL(cm)	RV (cc)	DSW (g)	DRW (g)	RSR	Y1(g plant^{1})	Y2 (g plant^{-1})	% RDT
Dular	40.39	11.62	7.76	1.52	0.19	8.75	6.25	6.85
IET 826	36.75	6.50	7.25	1.08	0.14	14.25	8.66	10.10
Aditya	34.40	6.30	6.18	0.83	0.13	19.27	8.51	10.60
Browngora	38.50	5.95	7.46	0.95	0.13	15.04	4.80	5.65
IR 64	29.50	4.25	5.65	0.55	0.12	27.31	8.18	10.82
IR 30	31.85	5.25	6.50	0.71	0.11	21.32	7.55	9.60
Satabdi	33.50	6.10	6.20	0.79	0.13	20.63	7.50	9.45
Bandana	30.41	5.85	5.75	0.65	0.11	21.28	7.40	9.40
Rasi	27.95	6.35	7.37	0.85	0.12	16.60	8.25	9.90
Panke	26.85	4.65	6.85	0.55	0.08	26.16	6.35	8.63
Mean	33.01	6.28	6.69	0.84	0.12	19.06	7.34	9.09
SE	1.53	0.40	0.31	0.04	0.01	0.60	0.18	0.38
CD (P< 0.05)	3.227	0.859	0.64	0.09	0.02	1.27	0.39	0.81

MRL=Maximum root length, RV=Root volume, DSW=Dry shoot weight, DRW=Dry root weight, RSW=Root shoot weight, Y1=Yield stress condition, Y2=Yield normal condition, %RDT=Percentage yield reduction

Dular. Dry shoot weight ranged from (5.65-7.76g) and Dular occupied top rank (7.76 g) followed by Rasi and IET 826. Dry root weight ranged from (0.55-1.52g) and the variety Dular recorded maximum value for dry root weight followed by IET 826 and Browngora. The root shoot ratio ranged from (0.08-0.19) and maximum value was recorded in Dular (0.19) (Table 2). On the basis of root studies Dular and Browngora were identified as promising genotypes with respect to root architecture. These two genotypes were also found to exhibit minimum percentage of yield reduction and hence they could be utilised for improvement of high yielding genotypes being resilient to water stress conditions (Amelia Henry *etal.,* 2011).

The difference between GCV and PCV was found to be very minimum for most of the characters which suggested least environmental influence on expression of these characters. High heritability with moderate to high genetic advance was noticed for all the characters (Table 3). The characters exhibited moderate to high heritability. High heritability coupled with high genetic advance was noticed for dry root

Table 3. Variability, heritability and genetic advance for eight characters in ten rice genotypes

Characters	Mean ± SE	Co-efficient of variance		Heritability (broad sense)	Genetic advance (GA)	Genetic advance as percent of mean
		GCV	PCV			
MRL (cm)	33.01±1.53	13.32	14.49	84.5	8.33	25.24
RV (cc)	6.28±0.40	31.83	32.81	94.1	4.00	63.69
DSW (g)	6.69±0.31	10.68	12.09	78.1	1.30	19.43
DRW (g)	0.84±0.04	34.06	34.63	96.7	0.59	64.57
RSR	0.126±0.01	22.08	25.83	73.1	0.05	39.68
Y1 (g plant^{-1})	19.06±2.10	29.31	29.57	98.3	11.41	59.89
Y2 (g plant^{-1})	7.34±0.18	16.48	16.77	96.6	2.45	32.97
% RDT	9.09±0.38	17.88	18.61	92.3	3.22	35.42

Table 4. Mean performance of the parents and crosses for different characters and grain yield plant^{-1} (in pot)

	MRL (cm)	RV (cc)	DSW (g)	DRW (g)	RSR	Y1 (g plant^{-1})
Dular	40.91	12.01	6.52	1.12	0.17	6.36
IET 826	38.47	5.48	7.63	1.08	0.14	8.54
Aditya	35.64	4.98	5.98	0.79	0.14	8.62
Browngora	40.21	6.12	7.23	0.86	0.12	4.96
IR 64	28.46	4.55	5.88	0.59	0.10	7.43
IR 30	31.85	4.82	6.78	0.74	0.11	7.95
Dular X IET 826	40.50	8.42	7.77	1.49	0.19	8.42
Dular X Aditya	44.66	10.26	9.36	1.41	0.15	6.71
Dular X Browngora	39.58	6.95	6.40	1.09	0.17	5.80
Dular X IR 64	37.80	7.93	8.46	0.82	0.10	4.80
Dular X IR 30	39.18	6.87	9.00	1.24	0.14	6.22
IET 826 X Aditya	37.22	7.45	12.90	1.26	0.10	5.99
IET 826 X Browngora	38.85	6.96	13.49	1.34	0.10	4.92
IET 826 X IR 64	43.63	6.85	8.14	1.03	0.13	8.96
IET826 X IR 30	39.09	6.87	9.01	1.17	0.12	7.69
Aditya X Browngora	32.03	6.12	9.12	1.09	0.12	6.07
Aditya X IR 64	28.96	6.60	6.56	1.07	0.16	11.32
Aditya X IR 30	32.37	5.78	8.12	0.89	0.11	7.27
Browngora X IR 64	42.22	7.25	8.40	1.18	0.12	6.88
Browngora X IR 30	44.39	6.85	7.41	1.12	0.15	7.85
IR 64 X IR 30	36.54	4.50	8.43	0.65	0.08	7.08
SEm(±)	1.30	0.55	0.92	0.11	0.015	0.61
CD (P<0.05)	2.629	1.129	1.871	0.234	2.021	1.232

MRL=Maximum root length, RV=Root volume, DSW=Dry shoot weight, DRW=Dry root weight, RSW=Root shoot weight, Y1=Yield stress condition

weight and root volume. These traits are highly responsive to improvement for selection as they are influenced by high degree of additive genetic effects (Panse 1957) and can be improved following simple breeding methods like Pedigree method. High heritability with low genetic advance for maximum root length and root shoot ratio was an indication of non-additive gene action and to achieve desirable results a complex breeding strategy may be advocated accompanied by recurrent selection. High *per se* performance for yield under water stress condition was noticed in [Aditya X IR 64] followed by [IET 826X IR 64] and [Dular X IET 826] with one or more superior root characters (Table 4). The analysis of variance for combining ability and estimates of genetic components for different characters are shown in (Table 5). Most of root, shoot and yield characters showed significant variance for gca and sca which indicated influence of both additive and non-additive gene actions on the characters. The estimation of gca effects of six parents for six characters are presented in Table 6 and considering the trait Dular may be considered as the best general combiner followed by Browngora.

Dular was found to be best general combiners for root length, root volume, root shoot ratio, IET 826 for dry shoot weight and dry root weight and Aditya followed by IET 826 for yield plant^{-1}. Significantly highest specific combining abilities were noticed in [Dular X Aditya] followed by [IET 826 X IR 64] for root length, [Dular X Aditya] followed by [Browngora X IR 64] for root volume,[IET 826 X Browngora] followed by [IET 826XAditya] for dry shoot weight, [Dular X Aditya] for dry root weight, [DularX IET 826] and [Aditya X IR64] for root shoot ratio, [Aditya X IR 64] followed by [Dular X IET 826] for yield plant^{-1} as depicted in Table 7. Significantly high relative heterosis and heterobeltiosis for yield per plant was observed in [Aditya X IR 64] which also showed significant heterobeltiosis for most of the root and shoot characters (Table 8).Ekanayake *et al* (1985a) found significant

Table 5. Analysis of variance for combining ability and estimates of genetic components for different characters

Source	d.f	Mean sum of squares					
		MRL(cm)	RV(cm)	DSW(g)	DRW(g)	RSR	Y1(g plant^{-1})
Gca	5	35.374**	9.158**	3.363**	0.118	0.00147	3.788**
Sca	15	17.882**	1.281	4.005**	0.0384	0.000626	2.023
Error	40	0.846	0.156	0.429	0.00684	0.000113	0.188
Genetic components							
$\sigma\hat{}^2g$		4.316**	11.25**	0.366	0.0111	0.000136	0.36
$\sigma\hat{}^2s = \sigma\hat{}^2D$		17.036**	1.125	3.576**	0.031	0.000513	1.835
$\sigma\hat{}^2A$		8.632**	22.5**	0.732	0.0222	0.000272	0.72
Predictability ratio		0.336	0.952	0.169	0.4172	0.8421	0.2818

** Significant at 1% level, MRL=Maximum root length, RV=Root volume, DSW=Dry shoot weight, DRW=Dry root weight, RSW=Root shoot weight, Y1=Yield stress condition

Table 6. Estimates of general combining ability effects of the parents for different characters

Parents	MRL	RV	RSW	DRW	RSR	YI
Dular	2.42**	2.07*	-0.44	0.12	0.02	-0.66
IET 826	1.50	-0.05	1.13	0.14	0.00	0.39
Aditya	-2.21	-0.21	0.07	-0.01	0.00	0.58
Browngora	1.66*	-0.19	0.22	0.02	0.00	-1.06
IR 64	-2.26	-0.70	-0.72	-0.17	-0.02	0.49
IR30	-1.11	-0.92	-0.25	-0.10	-0.01	0.26
SE(gi)	0.265	0.93	0.188	0.022	0.00028	0.125
SE (gi-gj)	0.459	0.197	0.327	0.041	0.00053	0.216

** Significant at 1% level * Significant at 5% level Y1=Yield stress condition
MRL=Maximum root length, RV=Root volume, DRW=Dry root weight, RSW=Root shoot weight, Y1=Yield stress condition

Table 7. Estimates of specific combining ability effects of the crosses for different characters

Crosses	MRL(cm)	RV(cc)	DSW(g)	DRW(g)	RSR	YI (g plant^{-1})
Dular x IET 826	-1.17	0.44	-1.14	0.18	0.04	1.56
Dular x Aditya	6.71**	1.56*	1.54	0.25	0.00	-0.35
Dular x Browngora	-2.24	-1.77	-1.60	-0.10	0.02	0.39
Dular x IR 64	-0.09	-0.27	1.40	-0.17	-0.04	-2.17
Dular x IR 30	0.13	-1.12	1.46	0.17	0.00	-0.51
IET 826 x Aditya	0.18	0.87	3.49**	0.07	-0.03	-2.12
IET 826 x Browngora	-2.06	0.35	3.92**	0.13	-0.03	-1.54
IET 826 xIR 64	6.65**	0.76	-0.49	0.02	0.01	0.94
IET 826 x IR 30	0.96	1.00	-0.08	0.08	0.00	-0.09
Aditya x Browngora	5.17**	-0.31	0.62	-0.02	-0.01	-0.58
Aditya x IR 64	-4.31	0.68	-1.00	0.20	0.04	3.11**
Aditya x IR 30	-2.05	0.07	0.09	-0.05	-0.01	-0.71
Browngora x IR 64	5.08**	1.30*	0.68	0.28	0.01	0.31
Browngora x IR 30	6.10**	1.12	-0.78	0.14	0.03	1.52
IR 64 x IR 30	2.18*	-0.71	1.18	-0.12	-0.03	-0.81
SE (Sij)	0.665	0.122	0.337	0.0025	0.00008	0.148
SE (Sij-Sik)	1.482	0.273	0.751	0.0119	0.000198	0.329
SE (Sij-Skl)	1.270	0.234	0.643	0,0102	0.00016	0.282

** Significant at 1% level, * Significant at 5% level, MRL=Maximum root length, RV=Root volume, DSW=Dry shoot weight, DRW=Dry root weight, RSW=Root shoot weight, Y1=Yield stress condition

and positive heterosis in the F_1 for six root characters of rice indicating that in general, the F_1 plants had good root system.

On the basis of evaluation for root characters Dular and Browngora proved their efficiency to maintain yield under water stress condition and root volume and root shoot ratio were predominantly controlled by additive gene effect and simple breeding method like pedigree method of selection may be proved suitable to bring tolerance in high yielding varieties following hybridization with these genotypes and hybrids with significant positive sca effect for all the characters were evolved on combination of (high X poor), (poor X

Table 8. Percent heterosis over mid parent (relative heterosis) and better parent heterobeltiosis for different characters

	MRL(cm)		RV(cc)		DSW(g)		DRW(g)		RSR		Y1(g/plant)	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Dular X IET 826	2.04	5.27*	-3.69	53.70	9.80	1.81	35.27	37.78	20.89	32.95**	13.01**	-1.42
Dular X Aditya	16.69**	25.31**	20.78	106.02*8	50.14	56.87**	47.64**	78.48**	-2.81	10.02	-10.43	-22.17
Dular X Browngora	-2.41	-1.57	-23.33	13.56	-6.87	-11.44	9.85	26.18	15.89	41.62**	2.46	16.92
Dular X IR 64	8.99**	32.82**	-4.19*	74.27	36.47	43.89	-3.63	39.66	-28.94	-3.64	-30.41	-35.42
Dular X IR 30	7.69**	23.00**	-18.36	42.53	35.29	32.70	32.90	67.03	-2.95	24.55**	-13.08	-21.77
IET 826 X Aditya	0.44	4.43*	42.45**	49.60	89.51**	115.58**	34.33	58.99	-30.71	-28.85	-30.19	-30.51
IET 826 X Browngora	-1.25	-3.39*	19.93	13.66	81.56	86.58**	37.70	54.98	-24.7	-17.0	-27.1	-0.87
IET 826 X IR 64	30.38**	53.31**	36.54	50.44**	20.44	38.37	23.95	75.42	3.96*	26.16	12.21	20.59
IET826 X IR 30	11.17**	22.72**	33.40	42.53	25.08	32.92	28.13	57.57	-5.39*	9.09	-6.76	-3.30
Aditya X Browngora	-15.54	-20.34	10.36	0.08	38.12	26.21	31.37	25.79	-6.91	-0.28	-10.63	22.34
Aditya X IR 64	-9.63	1.77	38.46	44.95	10.64	11.62	55.36**	81.69	30.80**	53.97	41.06**	52.36
Aditya X IR 30	-4.07*	1.64	17.86	19.81	27.29	19.81	16.86	20.81	-10.69	0.01	-12.26	-8.57
Browngora X IR 64	22.98**	48.36**	35.85**	59.22	28.13	42.84	62.20	99.77	7.27	17.22	11.03	-7.43
Browngora X IR 30	23.21**	39.38	25.23	42.12	5.80	9.31	39.21	50.81	30.81**	36.36	21.60	-1.27
IR 64 X IR 30	21.18**	14.71**	-3.98	-6.64	33.13	24.29	-1.95	-11.89	-26.90	-30.00	-7.93	-10.94
SEm(±)	1.13	1.36	0.44	0.51	0.76	0.82	0.10	0.10	0.01	0.01	0.52	0.57

*Significant at 5% level, ** Significant at 1% level

MRL=Maximum root length, RV=Root volume, DSW=Dry shoot weight, DRW=Dry root weight, RSW=Root shoot weight, Y1=Yield stress condition, Y2=Yield normal condition, %RDT=Percentage yield reduction

Average) and (high X average) parents which predicted the presence of various allelic and non allelic interactions in controlling the characters within hybrids. Two hybrids [Dular X IET 826] and [Aditya X IR 64] should be grown in successive generation following pedigree method of selection to generate elite lines with stable yield under water stress environment. The gca, sca and heterosis estimates predicted the feasibility of further upgrading of root characters from certain cross combinations which would include genotypes like Dular, Browngora, IET 826, Aditya and IR 64.

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