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Influence of root characters on drought resistance in rice (*Oryza sativa* L.)

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Abstract

Thirteen genotypes of rice (*Oryza sativa* L.) *viz*., Bandana, Browngora, Rasi, IET 826, Satabdi, Pusa 312, Panke, Aditya, IR 36, IR64, IR 50, IR 30and Dular were evaluated for root characters namely, maximum root length (cm), root volume (cc), fresh and dry root weight (g), dry shoot weight (g) and root shoot ratio. The study revealed greater relative variability for all the root characters under irrigated and water stress (rainfed) regimes. The genotypes, Dular, Aditya, IR 36 and Browngora were found to be superior to other genotypes with respect to ideal root architecture. Phenotypic coefficient of variation was higher than genotypic coefficient of variation indicating greater influence of the environment on these characters. High heritability accompanied by high genetic advance was observed for root dry weight followed by root volume and dry shoot weight indicating importance of additive gene effects, which may facilitate the adoption of simple breeding strategies to obtain desirable changes with respect to these characters.

Key words: *Oryza sativa*, root architecture, heritability, genetic advance, additive gene effect

Introduction

Rice (*Oryza sativa* L.) is one of the major cereal food crops of the world and it is grown in a wide range of ecological conditions. Asia is considered the home continent of rice where 90% of rice is produced and consumed. Rice alone provides two thirds of the calorie intake of more than 3 billion people in Asia [1]. It is reported that by the year 2025 the global demand of rice is projected to grow at least equal to population growth, thus requiring a 70 % increase in supply i.e. 765 million tonnes of rice [2]. Therefore, in order to meet the future demand of rice, its production must be increased to a level so that it at least match the rate of increase in population growth to maintain a desired balance between population growth and food demand. This increase in rice production must be achieved through utilisation of less land, less water, few agrochemicals and other inputs. Unfortunately global climatic changes has made water as a most limiting factor to affect growth and productivity of rice which is considered an important staple food in India but more particular the eastern zone. Drought had long been considered as the primary constraint to rainfed rice production. Babu *et al.* [3] reported that drought stress is the major constraint to rice production and yield stability in rainfed ecosystem giving less than one third yield of world average. At this critical juncture, the challenge to plant breeders is to develop genotypes being sustainable in water limited environment. It is already identified that the root architecture in many crops play a crucial role to production and productivity with minimum effect on various metabolic activities throughout the growth period [4]. Rice root system plays an important role in adaptation of rice to drought prone environment and it has a wide range of genetic variability [5-7]. In the present investigation attempts have been made to identify various root characters, which may influence the sustainable growth of rice with minimum predictable loss in productivity.

Materials and methods

The experimental materials consisted thirteen varieties of rice *viz*., Browngora, Bandana which were collected from RRS Bankura; Dular, Panke, Pusa 312, IR36 and IR 64 collected from RRS, Chinsurah and Satabdi, Rasi, Aditya, IET 826, IR 30 and IR 50 collected from RRS Chakdah. The experiment was conducted at the Instructional Farm, Jaguli, B.C.K.V., Mohanpur during *kharif* 2008 and 2009. The material was planted Randomized Block Design with 3 replications under two regimes (i) irrigated and (ii) water stress conditions (rainfed). The total rainfall during the crop season was 5.62 m distributed over the months of August (3.07 mm),

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September (2 mm) and October (0.55 mm).The seedlings were raised at nursery bed following normal cultural practices and transplanted after 21 days of sowing. The row to row distance was 15-20 cm whereas plant to plant distance was 10-12 cm. Recommended dose of major nutrients (N, P and K) was applied. The different root characters considered were (i) maximum root length (cm), (ii) root volume (cc), (iii) fresh root weight (g) (iv) dry root weight (g) (v) dry shoot weight (g) and (vi) dry root shoot ratio. The data were recorded at harvest from 10 plants from the middle row in each replication for each variety. The root and shoot portions were oven dried at 65°C for 72 hours to measure the dry weight. The percentage of water loss was calculated by growing the genotypes in two water regimes, one in irrigated and another in water stress condition. Sterility percentage and grain yield per plant was also calculated. The data collected from the field trials were subjected to statistical analysis appropriate to the design and the treatment variations were tested for significance by 'F' test [8]. The standard errors of mean and critical difference (C.D) are indicated in the respective tables. For estimation of genetic parameters of different root characters, the data were analysed as per standard procedure [9]. Genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV) were calculated by the formulae [10]. The percentage of heritability (h^2) was also estimated as per the standard formula [11]. The expected genetic advance (GA) as percentage of mean and phenotypic and genotypic correlation coefficients was also computed [12].

Results and discussion

Performance of genotypes with respect to yield and floret sterility under irrigated and water stress conditions is presented in Table 1. Sgnificant variation was observed among the genotypes for yield and floret sterility. Significant interaction effect between genotypes and moisture treatment was observed only for yield but not for floret sterility. Minimum reduction in yield over control was observed in IR 36 (4.16%) followed by Dular (9.38%) and Browngora (17%). Sterility percentage in Dular was found to be comparatively low and in IR 36 high, which may be due to development of unproductive tillers in the genotype during water stress condition as compared to other genotypes with higher yield loss. The mean performance of thirteen genotypes for different root characters has been presented in Table 2. The root length ranged from 28.1-51.2 (cm), with mean being

Table 1. Mean grain yield per plant (g) and per cent sterility

Variety		Yield per plant (g)% of yield loss		Sterility (%)	
		Control	Water stress	Control	Water stress
Bandana		18.44	27.39	22.23	32.65
Browngora		12.82	17.00	5.28	111
Satabdi		25.6	27.50	23.49	10.90
Aditya		25.74	24.51	13.61	161.35
IR 36		20.21	4.16	12.44	193.32
IR 30		23.42	20.81	24.56	46.33
IR 50		23.73	16.47	13.00	86.38
IR 64		28.57	38.25	18.26	69.06
Pusa 312		30.69	46.52	7.97	118.06
Panke		19.44	35.13	21.43	60.87
Rasi		25.38	20.21	24.79	39.53
IET 826		22.80	17.61	12.77	145.18
Dular		15.02	9.38	13.82	56
Mean		22.45	16.75	16.43	28.68
Parent	SE(m)	0.5880		1.5981	
	CD 5%	1.6840		4.5766	
Treatment	SE(m)	0.2825		0.7677	
	CD 5%	0.8090		2.1985	
Parent x Treatment	SE (m)	1.0185		2.7680	
	CD 5%	2.9167		NS	

37.4 cm. The variety Dular was found to exhibit maximum value for root length (51.3 cm) followed by Aditya (46.2 cm) and Browngora (44.6 cm). Root volume (cc) ranged from (28.1-51.2) cc, maximum being 14.360 cc found at Dular. Fresh root weight ranged from 4.0-12.0 (g) and Dular showed maximum value (12.08 g) followed by Aditya and Browngora. The range of dry root weight (g) was found from (0.42-1.86 g). The maximum value (1.86 g) was recorded in Dular followed by Browngora (1.34 g) and IR 36 (1.29 g). Dry shoot weight (g) ranged from (3.8-9.53 g) and the maximum value was recorded by Dular (9.53 g) which was followed by Browngora (9.27 g) and Bandana (6.76 g). The range for root shoot ratio recorded was from 0.102 to 0.195 for which Dular recorded the highest value (0.195) followed by Aditya (0.192) and IR36 (0.191). On the basis of root studies, Dular, Aditya, IR36 and Browngora were found superior to other genotypes with respect to ideal root architecture. These genotypes also showed minimum water loss under water stress conditions and the efficiency of these genotypes to withstand water stress may be attributable to inherent superiority in their various root characters. The above mentioned genotypes exhibited optimum and excellent values for root traits and hence these could be utilised for improvement of high yielding genotypes being resilient to water stress conditions [13]. The genetic parameters for different characters are given in Table 3. Varietal differences for all the characters were highlighted from range and variance data. The GCV was maximum for dry root weight (53.15%) followed by root volume (38.82%) and dry shoot weight (35.93%). Minimum difference between PCV and GCV were recorded for most of the characters, which suggested least influence of environment on expression of these characters. High heritability (98.1%) accompanied by high genetic advance as percentage of mean (108) was observed for root dry weight followed by root volume and dry shoot weight and these characters may be influenced by additive genetic effects and with adoption of simple breeding strategies desirable changes with respect to these characters may be obtained through selection[14]. For development of lines suitable for moisture stress condition root volume and root length was also reported as better combinations for selection. High heritability accompanied with low genetic advance for maximum root length and root to shoot ratio was an indication of non-additive gene action for these characters. The high heritability may be due to favourable influence of the environment rather than genotype and selection for such traits may not be rewarding and to achieve desirable results a complex breeding strategy accompanied by recurrent selection may be advocated. The genotypic correlation co-efficient were higher than the corresponding phenotypic one in majority of the cases. Table 4 revealed the scope of achieving desirable results from selection based on the phenotypic performances of the genotypes. Root volume showed

Table 2. Mean performance of thirteen rice varieties for different root characters related to drought

Genotypes	Maximum root length (cm)	Root volume (cc)	Fresh root weight (g)	Dry root weight (g)	Dry shoot weight (g)	Root shoot ratio	Percentage yield loss
Bandana	35.54	9.40	8.72	1.29	6.76	0.191	27.38
Browngora	44.64	6.89	8.81	1.34	9.27	0.144	17.00
Rasi	34.20	5.91	5.29	0.60	5.11	0.117	18.24
IET 826	33.25	5.45	5.01	0.48	3.88	0.124	17.67
Satabdi	36.30	6.20	6.73	0.58	3.80	0.153	27.50
Pusa 312	38.93	4.10	5.79	0.55	4.38	0.125	46.52
Panke	32.45	6.92	6.48	0.63	4.55	0.138	35.13
Aditya	46.24	9.99	9.52	1.00	5.20	0.192	24.51
IR 36	37.39	5.63	4.90	0.44	3.46	0.127	4.10
IR 64	30.65	5.41	6.12	0.59	5.22	0.113	38.25
IR 50	36.92	8.90	8.78	0.89	6.74	0.132	16.47
IR 30	28.13	4.65	4.02	0.42	4.12	0.102	28.01
Dular	51.25	14.36	12.08	1.86	9.53	0.195	9.38
Grand mean	**37.376**	**7.216**	**7.096**	**0.821**	**5.540**	**0.143**	**23.858**
SE(m)	**0.187**	**0.157**	**0.124**	**0.035**	**0.080**	**0.006**	**0.081**
CD 5%	**0.545**	**0.460**	**0.361**	**0.103**	**0.233**	**0.018**	**0.167**

Table 3. Genetic parameters of different characters

Characters	Grand mean	Range	Variance			GCV	PCV	Heri-tability (%)	GA% of means
			Pheno-typic	Geno-typic	Environ-ment				
Maximum root length (cm)	37.376	28.130-51.250	42.826	42.722	0.105	17.487	17.509	99.76	35.98
Root volume (cc)	7.216	4.100-14.360	7.921	7.847	0.074	38.818	39.002	99.06	79.59
Fresh root weight (g)	7.096	4.020-12.080	5.380	5.334	0.046	32.547	32.687	99.15	66.76
Dry root weight (g)	0.821	0.420-1.860	0.194	0.190	0.004	53.145	53.660	98.09	108.42
Dry shoot weight (g)	5.540	3.800-9.530	3.981	3.962	0.019	35.927	36.014	99.52	73.83
Root shoot ratio	0.143	0.102-0.195	0.001	0.001	0.000	21.600	22.886	89.08	41.99
Percentage yield loss	24.279	4.993-45.813	187.889	187.516	0.373	56.401	56.457	99.80	116.07

significant negative correlation with respect to yield loss both at genotypic and phenotypic levels respectively followed by root length and dry root weight. This indicated that the yield loss can be checked with the lines bearing high root volume, longer root with high dry root weight. It was also observed that significant positive correlation was observed among the characters *viz*., root volume, fresh root weight, dry root weight, dry shoot weight and root shoot ratio. The positive association between two different desirable characters will help in simultaneous improvement of both the characters. Interrelationship between root length, root volume and root thickness [15] has been previously recorded.

Table 5 shows various direct and indirect effects attributing to percentage yield loss. Dry root weight (9.696) followed by fresh root weight (5.757) showed maximum direct effect on yield loss due to water stress which was substantially minimized by dry shoot weight, root to shoot ratio, root volume and root length which indicated that yield loss may be checked through manipulation on improvement on these characters and to develop water stress resistant lines and such ideal lines should be well balanced root: shoot ratio, high root volume and preferably with extended root length.

It can be concluded that Dular, Browngora, Aditya and IR36 are ideal genotypes in drought prone areas

Table 4. The genotypic (G) and phenotypic (P) correlation coefficients for pair of characters attributing to percent yield loss

Characters		Root volume(cc)	Fresh root weight(g)	Dry root weight(g)	Dry shoot weight(g)	Root shoot ratio	Percentage yield loss (%)
Maximum root length(cm)	G	0.735	0.829	0.790	0.673	0.753	-0.395
	P	0.732**	0.823**	0.780	0.671	0.705	-0.394*
Root volume(cc)	G		0.927	0.887	0.713	0.868	-427
	P		0.917**	0.868	0.709	0.801	-425*
Fresh root weight(g)	G			0.939	0.829	0.868	-0.268
	P			0.925	0.822	0.813	-0.266
Dry root weight(g)	G				0.930	0.793	-0.335
	P				0.921	0.784	-0.332*
Dry shoot weight(g)	G					0.535	-0.315*
	P					0.503	-0.315*
Root shoot ratio	G						-0.212
	P						-0.200

*=significant at 5% level**=significant at 1% level

Table 5. Path analysis of characters with percent yield loss

Characters	Maximum root length (cm)	Root volume (cc)	Fresh root weight (g)	Dry root weight (g)	Dry shoot weight (g)	Root shoot ratio	Percentage yield loss (%)
Maximum root length(cm)	–1.35320	–3.13928	4.77014	7.66499	–5.44373	–2.89359	–0.395
Root volume(cc)	–0.99418	–4.27295	5.33945	8.60349	–5.76715	–3.33535	–0.427
Fresh root weight(g)	–1.12126	–3.96312	5.75688	9.10225	–6.70636	–3.33600	0.268
Dry root weight(g)	–1.06967	–3.79122	5.40395	9.69671	–7.52400	–3.05050	–0335
Dry shoot weight(g)	–0.91051	–3.04591	4.77201	9.01780	–8.09045	–2.05816	–0.315
Root shoot ratio	–1.01851	–3.70709	4.99547	7.69413	–4.33128	–3.84447	–0.212

Residual effect = 0.300438

as they possess elaborate root system, reduced yield loss and high floret fertility. Selection of characters like dry root weight and root volume would be effective as these characters exhibited high heritability coupled with high genetic advance, which indicated additive gene action on expression of these characters. Simple breeding methods like pedigree selection in early segregating generation could be a dependable breeding procedure for improvement of rice showing tolerance to water stress through exploitation or influence of additive gene action as suggested earlier [16].

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