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Aerobic response index and diversity analysis for identification of aerobic rice donors

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ABSTRACT

Thirty six rice genotypes were evaluated to identify promising aerobic donors for eight quantitative characters. The analysis of variance revealed significant differences among the genotypes, environments and genotypes x environments. High phenotypic (PCV), genotypic (GCV) coefficient of variation and high heritability along with high expected genetic advance were recorded for grain yield and biological yield. Grain yield and biological yield had positive correlation for all the characters except days to fifty per cent flowering. Higher and positive direct effect on grain yield was exerted by biological yield, tillers hill^{-1} and grains panicle^{-1}. The D^2 analysis revealed that genotypes exhibited considerable diversity and were grouped in to six clusters. Based on clustering pattern, aerobic response index and stability factor of the genotypes, eight genotypes would be served as donors and can be include in combination breeding to improve drought tolerance of existing rice varieties.

Key words: *rice, variability, D^2 analysis, aerobic response index, stability factor*

In the rainfed lowland system, rice is generally transplanted in puddled soil, like in irrigated low land systems, though direct seeding is used in some places (Mackill *et al*., 1996). Aerobic rice systems, wherein the crop is established via direct seeding in non-puddled, non-flooded fields and managed intensively as an upland crop, are among the most promising approaches to water saving (Tuong and Bouman, 2003). Aerobic rice has traditionally been grown in low-input systems, but as fresh water for irrigation becomes increasingly scare, aerobic rice cultivation is expected to expand in regions with more intensive cropping. About half of the world's rice area is grown under rainfed conditions, either in fully aerobic soils or where the soil is saturated for only part of the season in some years (Lafitte *et al*., 2002). Because of the much greater risk of crop failure in these areas, farmers apply minimum levels of inputs. Genetic improvement of rice for aerobic environments has received lesser attention than breeding for lowland production system. Yield penalty and yield stability of aerobic rice have to be considered before promoting this water saving technology under favourable upland condition. Keeping the above facts in view, the present investigation was conducted to identify genotypes for aerobic situation and to work out exploitable variability in yield and yield attributes for further improvements.

MATERIALS AND METHODS

The field experiment was conducted at Central Rice Research Institute regional farm Koderma during wet season, 2007-08 under aerobic (E_1) and irrigated situation (E_2). The experiment was conducted taking 36 genotypes from different part of the country along with three checks *viz*., Anjali, Vandana and Khandagiri in randomized complete block design with three replications. The two water regimes were always kept apart to avoid water interference. Peizometers were installed in all the treatments to monitor the ground water fluctuation and guide the timing of irrigation. Each plot was 5 m long and 3.0 m wide, row to row distance was 15 cm and plant to plant distance was 10 cm in each plot in E_1 and 20 x 15 cm in E_2. Rice varieties under aerobic condition were directly sown at 2-3 cm soil depth in dry and well pulverized soil by hand plough with the seed rate of 60 Kg ha^{-1} to maintain 3-4 seeds $hill^{-1}$. Experimental plots were maintained at near saturation and re-watered only when soil moisture reached below 15 cm. Standard cultural procedures were adopted. Phosphorus (40 kg ha^{-1} P_2O_5) and potassium (40 kg ha^{-1} K_2O) were applied as recommended before sowing/planting in aerobic and transplanted conditions. Urea was used as source of N in three split doses. The first application was made at 21 days after sowing, the second at active tiller initiation and the third at panicle initiation stages. The total nitrogen amount applied was 80 kg ha^{-1}. All plant protection measures were taken. Weeds were controlled by treating plot by pre-emergence herbicide (Petrilachlor) after three days of sowing followed by one hand weeding. Plant samples above the ground were collected at maturity. Observations were recorded on days to 50 per cent flowering (DFF), plant height (PH), tiller $hill^{-1}$ (T/H), panicle length (PL), grains $panicle^{-1}$, filled grain $panicle^{-1}$, grain yield (GY) and straw yield (BY).

The effect of stress was assessed as percentage reduction in mean performance of a trait under aerobic condition relatively to the performance of the same trait under continuously saturated soil moisture condition. Aerobic response index (ARI) for each trait was calculated on the basis of mean data, following Fischer and Maurer (1978) as used for drought susceptibility index (DRI). The data were analyzed by appropriate statistical analysis (Gomez and Gomez, 1984) using CropStat 7.2 (IRRI, 2009) programme. The genetic parameters, correlation coefficients and path coefficient at genotypic and phenotypic levels were computed following Singh and Chaudhury (1985) and stability factor following Lewis (1954). Multivariate analysis of genetic divergence among varieties was done using Mahalanobis D^2 statistics (1936) and grouping of varieties into clusters by Tochers method (Rao, 1952).

RESULTS AND DISCUSSION

The analysis of variance for pooled data revealed significant differences among the environments, genotypes and genotype x environment for all the characters (Table 1). The estimation of mean of all eight characters for two environments showed lower value under aerobic as compared to irrigated condition. However, differences in mean values of DFF, GY, FG/P and BY were higher and rest of other characters showed marginal differences. High values of PCV closely followed by GCV for PL, FG/P, GY and BY indicated greater opportunities for desired gain through phenotypic selection and rest of the characters showed moderate to low PCV and GCV values (Table 2). Small differences between estimates of PCV and GCV for most of the traits indicated that lesser influence of environment towards expression of these traits. Similar findings were reported by Karad and Pol (2008) and Ubarhande *et al*. (2009). In the present study, genetic advance showed a wide range in its magnitude and in general, high h^2_b estimate were associated with the high Gs per cent (Table 2). The grain yield and biological yield demonstrated high estimates of Gs per cent coupled with high heritability values (Iftekharuddaula *et al*., 2001 and Kole *et al*., 2008) while, rest of the characters

Table 1. Pooled analysis of variance for quantitative traits in rice genotypes

Characters	Pooled analysis			
	Replications (2)	Environments (1)	Genotypes (35)	Genotype x Environment (35)
DFF	1.77	2350.26**	532.64**	8.89**
PH	5.81*	523.91**	2764.94**	11.79**
T/H	0.58	69.25**	13.73**	1.26**
PL	4.43*	895.08**	444.06**	418.92**
G/P	0.19	545.31**	4682.75**	25.20**
FG/P	2.54	99.63**	5790.59**	379.78**
GY	19146.30	940500.00**	1192790.00**	44859.60**
BY	5145.23**	169176.00**	3813320.00**	216081.00**

*, **, Significant at 5 per cent and 1 per cent levels, respectively.
DFF: Days to 50 per cent flowering; PH: Plant Height (cm); T/H: Tillers $hill^{-1}$; PL: Panicle Length (cm); G/P: Grains $panicle^{-1}$; FG/P: Filled grains $panicle^{-1}$; GY: Grain Yield (Kg ha^{-1}) and BY: Biological Yield (Kg ha^{-1})

showed moderate estimates for both the parameters except T/H and PL. But panicle length expressed high estimate of genetic advance with low heritability may be under the control of non additive type of gene action and G x E interaction plays a significant role in the expression of the traits (Iftekharuddaula *et al*., 2001).

Genotypic correlation coefficient was higher than their corresponding phenotypic correlation coefficient for most of the characters (Table 3). Interestingly, GY and BY had positive correlation for all the characters under study except tiller hill^{-1} at both phenotypic and genotypic level. This indicates that phenotypic selection based on these characters could result in an appreciable improvement of GY (Kole *et al*., 2008). Biological yield followed by T/H and G/P at both the levels and PH at phenotypic level exerted very high positive direct effects on GY (Fig. 1). Therefore, BY, T/H and G/P emerged as most important direct contributors of GY and can be used as selection parameters under aerobic situation (Venkataramana and

Table 2. Estimates of mean, range, coefficient of variation, heritability and genetic advance for quantitative characters under aerobic condition

Characters	Mean± SE m	Range		Coefficient of Variation		Heritability (h^2b)	Genetic advance in per cent of mean
		Min.	Max.	GCV	PCV		
DFF	84.31 ±0.48	69.00	110.83	08.98	11.94	56.7	17.85
PH	93.49 ±0.56	62.07	136.97	16.26	23.08	49.6	30.23
T/H	8.74 ±0.22	06.90	16.17	11.36	19.52	33.8	17.44
PL	23.87 ±0.43	17.05	28.88	31.52	50.75	38.6	51.70
G/P	122.36 ±0.49	82.40	181.68	15.55	21.94	50.2	29.07
FG/P	104.48 ±0.71	63.07	169.17	21.07	29.42	51.3	39.83
GY	1778.42 ±45.73	1230.00	2929.33	25.07	26.31	90.7	63.01
BY	3488.26 ±9.40	2498.50	6093.00	21.00	23.45	80.2	49.64

DFF: Days to 50 per cent flowering; PH: Plant Height (cm); T/H: Tillers hill^{-1}; PL: Panicle Length (cm); G/P: Grains panicle^{-1}; FG/P: Filled grains panicle^{-1}; GY: Grain Yield (Kg ha^{-1}) and BY: Biological Yield (Kg ha^{-1})

Table 3. Estimates of Genotypic (upper) and phenotypic () correlation coefficients between different characters in rice genotypes under aerobic condition

	DFF	PH	T/H	PL	G/P	FG/P	BY	GY
DFF	1.00	0.294**	0.134*	0.214**	0.036	-0.112	0.276**	0.203**
	1.00	0.106	0.158*	0.124	0.093	0.060	0.243**	0.113
PH		1.00	0.452**	0.321**	0.121	0.092	0.255**	0.354**
		1.00	-0.027	0.224**	0.387**	0.305**	0.231**	0.255**
T/H			1.00	0.132	0.180**	0.299**	-0.403**	-0.197**
			1.00	-0.0.13	-0.069	0.015	-0.223**	-0.153*
PL				1.00	-0.091	-0.408**	0.304**	0.330**
				1.00	0.093	-0.223**	0.223**	0.231**
G/P					1.00	0.898**	0.434**	0.401**
					1.00	0.884**	0.385**	0.279**
FG/P						1.00	0.199**	0.208**
						1.00	0.264**	0.147**
BY							1.00	0.919**
							1.00	0.811**
GY								1.00

DFF: Days to 50 per cent flowering; PH: Plant Height (cm); T/H: Tillers hill^{-1}; PL: Panicle Length (cm); G/P: Grains panicle^{-1}; FG/P: Filled grains panicle^{-1}; BY: Biological Yield (Kg ha^{-1}) and GY: Grain Yield (Kg ha^{-1})

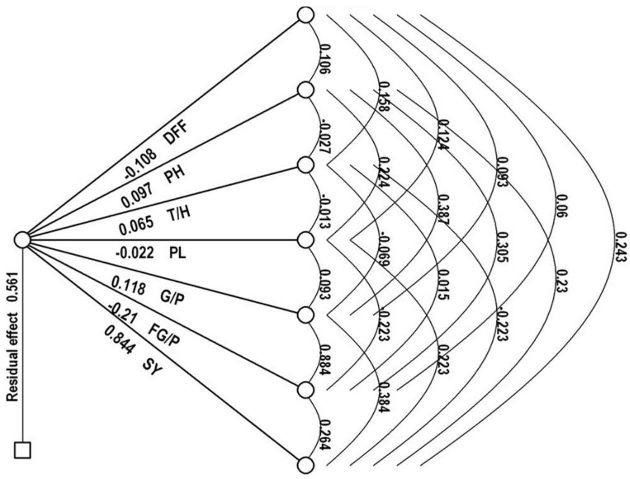


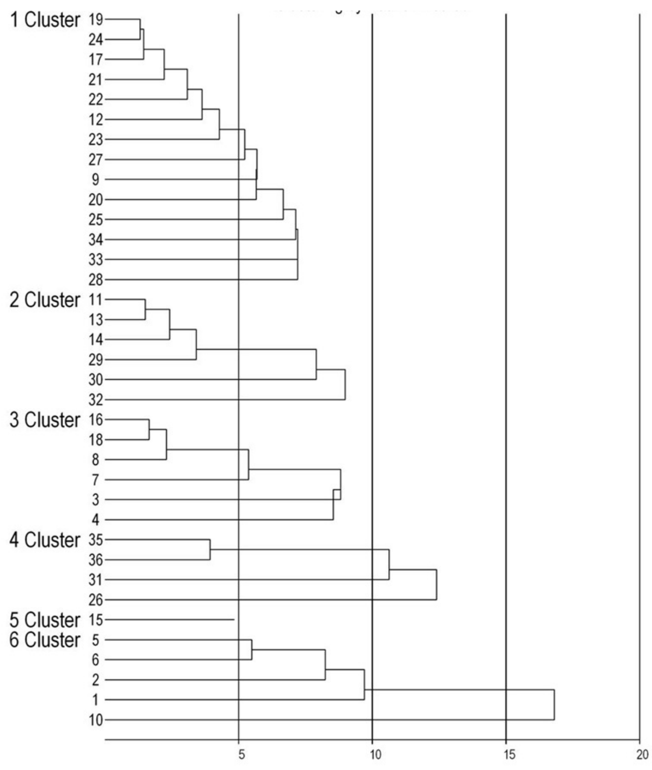
Fig. 1. **Phenotypical diagram for grain yield**

Hittalmani, 2000 and Mishra and Verma, 2002). In case of indirect effects, BY exhibited substantial positive indirect effects on GY at both the levels *via* all the characters except T/H. Thus, BY was identified as most important indirect yield component and can be used as parameters for yield component. The estimates of residual factors were also very low in the path analyses carried out at both the levels.

Thirty six genotypes in the present study could be divided in to six distinct clusters (Fig. 2). Cluster I with 14 entries had maximum number of genotypes followed by clusters II and III with six genotypes representing different eco-geographical regions. On the other hand, cluster V comprised single genotype i.e. CR2341-46-342-31-29-1-1. Further, cluster IV had 4 genotypes while cluster VI comprised 5 genotypes. Interestingly, the genotypes that originated in one region had been distributed into different clusters. The absence of correlation between genetic diversity and geographic diversity suggests that forces other than geographic origin, such as exchange of breeding material, genetic drift, variation, selection are responsible for diversity, as reported earlier (Murthy and Arunachalam, 1966 and Maurya and Singh , 1977). Bose and Pradhan (2007) have also reported similar findings in rice. The intra and inter cluster distances are presented in Table 4. The highest inter cluster distance (7.39) was found between cluster IV and VI followed by cluster III and VI (6.46) and between cluster I and VI (5.75). The members of these clusters are to be given importance in hybridization programme. The genotypes of the most distant cluster were quite contrasting in performance with respect to GY and BY (Table 5). The cluster means of genotypes revealed considerable genetic differences between the groups. The cluster II registered the highest mean value for PH and PL, whereas the highest

Table 4. Intra and inter-cluster D^2 among seven clusters under aerobic condition

Clusters	I	II	III	IV	V	VI
I	2.53	3.45	3.94	3.40	3.95	5.75
II		2.78	5.01	4.06	5.52	4.77
III			2.89	5.17	4.21	6.46
IV				3.77	5.43	7.39
V					0.00	4.23
VI						3.91



1.Anjali; 2. Vanaprava; 3. VL Dhan; 4. Khandagiri; 5. VL dhan 16; 6. Himalaya 2216; 7. ASD 17; 8. Himalaya 741; 9. Himalaya 799; 10. IET 18665; 11. Vandana; 12. Sneha; 13. Kalinga III; 14. Himalaya; 15. CR 2341-46-342-31-29-11; 16. GR 9; 17. Kalyani; 18. Hazaridhan; 19. Dhala Heera; 20. WR 3-2-6-1; 21. Richaria; 22. CR 876-6; 23. Himalaya 1; 24. Himdhan; 25. Hasan Sarai; 26. Annada; 27. Anapurna; 28. Aswini; 29. PTB 7; 30. PTB 28; 31. JD 13; 32. PTB 22; 33. JD 15; 34. JD 12; 35. JD 6 and 36. Heera

Fig. 2. **Clustering of thirty six rice genotypes studied**

average cluster mean was reported for yield components like G/P and FG/P in cluster III followed by cluster IV for T/H. The hybridization between genotypes of different clusters is necessary for the development of desirable genotypes (Sinha *et al*., 1991). Bose and Pradhan (2005) and Rahman *et al*. (1997) have also reported that selection of parents for hybridization should be from two clusters having wider cluster distance to get maximum variability in the segregating generation. The clusters contributing maximum to D^2 values are to be given greater emphasis for deciding the clusters for the purpose of further selection and hybridization (Table 5). Percentage contribution of the individual character towards divergence was maximum through GY (43.81%) followed by G/P (18.25%) and BY (12.06%). These results were not in agreement with Bose and Pradhan (2005) who observed PH, DFF and T/H as maximum contributors towards divergence low land situation.

Table 5. Cluster mean for eight characters under aerobic condition

Cluster No.	DFF	PH	T/H	PL	G/P	FG/P	BY	GY
I	78.10*	82.46	8.03	21.01	109.21	91.59	3293.43	1525.71
II	80.44	120.44+	8.56	23.50+	117.65	103.03	2805.33*	1489.28
III	79.89	89.04	8.00	22.89	154.72+	140.59+	3911.44	2110.00
IV	81.08	67.28*	9.31+	21.41	108.03*	96.43	2822.58	1195.25*
V	87.00	80.87	8.60	23.13	118.33	79.30*	4566.00	1725.00
VI	89.93+	109.66	7.32*	20.96*	126.81	105.55	4863.93+	2437.20+
No. of times ranked 1st	56	35	27	0	115	45	76	276
Contribution (%)	8.89	5.56	4.29	0.00	18.25	7.14	12.06	43.81

DFF: Days to 50 per cent flowering; PH: Plant Height (cm); T/H: Tillers hill^{-1}; PL: Panicle Length (cm); G/P: Grains panicle^{-1}; FG/P: Filled grains panicle^{-1}; BY: Biological Yield (Kg ha^{-1}) and GY: Grain Yield (Kg ha^{-1})

Yield is a function of yield potential, escape, and aerobic response. Therefore, the use of the aerobic response index can help to distinguish suitable variety for aerobic adaptation from phenology and yield potential. Large ARI values indicate greater drought susceptibility (Chauhan *et al*., 2007). Higher mean ARI values observed for FG/P and GY indicated that this character is relatively more prone to stress. Approximately, 55.56 per cent genotypes under study were recorded low ARI (ARI<1) values for G/Y; three genotypes near to one ARI value and two genotypes *viz*., GR 9 and Himalaya 1 recorded one ARI values thereby indicating that the genotypes were tolerant to water limiting condition (Table 6). Further more tolerant genotypes also showed relatively low ARI mean value of one or two characteristics. None of the genotypes gave higher yield in aerobic as compared to irrigated condition. Much larger gains should be expected by uses of genotypes with below average ARI in future aerobic rice breeding programmes.

Genotype and environment interaction is of immense value in plant breeding programme. It plays an important role in the performance of genotype. This arises from lack of correspondence between genetic and non-genetic factors. Low ARI values (<1.00) for seed yield in respect of most of the genotypes was imparted by stability on FG/P and BY. For instance the genotypes namely Anjali, VL Dhan and VL Dhan 16 recorded low ARI and good stability in performance for FG/P and BY, especially for GY and above said genotypes produced more than 2 t ha^{-1} in both the conditions. The low ARI value performer for GY and BY *viz*., Vanaprava, Khandagiri, Himalaya 2216, ASD 17 and Himalaya 741 showed near unity ratio of stability factor for FG/P, GY and BY where as these genotypes showed high ARI values for FG/P, indicted that these genotypes were susceptible to water limited condition for FG/P. Furthermore, these genotypes grouped in to two different maximum statistical distance clusters (Cluster III & VI). Interestingly these genotypes also produced above 1.9 t ha^{-1} under aerobic situation. This superior performance of such genotypes for low ARI value and stability could possible is attributed to the pre

Table 6. Estimates of Aerobic Response Index (ARI) and Stability Factor (SF) for filled grains panicle^{-1}, Grain Yield (Kg ha^{-1}) and Biological Yield (Kg ha^{-1}) in rice genotypes

Genotypes	FG/P		BY		GY	
	ARI	SF	ARI	SF	ARI	SF
Anjali	0.85	0.82	0.25	0.97	0.63	0.80
Vanaprava	1.09	0.77	0.66	0.93	0.26	0.92
VL Dhan	0.87	0.82	0.66	0.93	0.56	0.83
Khandagiri	1.19	0.75	1.44	0.84	0.68	0.79
VL Dhan 16	0.90	0.81	0.58	0.94	0.75	0.77
Himalaya 2216	1.45	0.69	0.74	0.92	0.66	0.80
ASD 17	1.08	0.77	0.99	0.89	0.84	0.74
Himalaya 741	0.60	0.87	1.00	0.89	0.84	0.74
Himalaya 799	0.93	0.80	-0.11	1.01	0.86	0.73
IET 18665	0.77	0.84	1.15	0.87	0.82	0.74
Vandana	1.18	0.75	1.12	0.88	0.87	0.73
Sneha	0.93	0.80	0.78	0.91	0.85	0.74
Kalinga III	1.35	0.72	3.28	0.64	0.94	0.71
Himalaya	1.64	0.66	1.20	0.87	1.03	0.68
CR 2341-46-342-31-29-11	1.22	0.74	-1.42	1.16	0.84	0.74
GR 9	0.69	0.86	1.21	0.87	1.00	0.69
Kalyani	1.04	0.78	0.76	0.92	0.97	0.70
Hazaridhan	0.57	0.88	0.66	0.93	0.80	0.75
Dhala Heera	1.06	0.78	0.65	0.93	0.81	0.75
WR 3-2-6-1	1.34	0.72	0.20	0.98	0.98	0.70
Richaria	0.89	0.81	1.61	0.82	0.89	0.72
CR 876-6	1.15	0.76	3.91	0.57	1.65	0.49
Himalaya 1	1.65	0.65	1.11	0.88	1.00	0.69
Himdhan	0.89	0.81	1.00	0.89	1.09	0.66
Hasan Sarai	1.18	0.75	1.65	0.82	1.04	0.68
Annada	0.92	0.81	1.38	0.85	1.10	0.66
Anopurna	1.03	0.78	0.99	0.89	1.23	0.62
Aswini	1.38	0.71	-1.67	1.18	1.29	0.60
PTB 7	1.09	0.77	1.50	0.84	1.03	0.68
PTB 28	0.84	0.82	0.74	0.92	1.48	0.54
JD 13	0.97	0.80	1.15	0.87	1.17	0.64
PTB 22	0.68	0.86	1.34	0.85	1.59	0.51
JD 15	1.45	0.70	0.98	0.89	1.25	0.61
JD 12	1.29	0.73	1.20	0.87	1.69	0.48
JD 6	1.35	0.72	1.51	0.83	1.97	0.39
Heera	1.17	0.75	1.17	0.87	1.90	0.41
	1.07		0.98	-	1.04	-

FG/P: Filled grains panicle^{-1}; BY: Biological Yield (Kg ha^{-1}) and GY: Grain Yield (Kg ha^{-1})

dominance of fixable effects. Ouk *et al*. (2006) used drought susceptibility index values and seed yield under rainfed lowland condition as a selection criterion for drought tolerance in rice.

The impact of improved-plant type varieties and associated technologies in the favored localities put forward a new concept of upland rice, leading to new denomination-aerobic rice. There is a need to develop upland rice varieties that will produce acceptable yields in both water-limited and favorable environments (Bernier *et al*., 2008). In the view of above discussion, it is contemplated that the improvement in characters like PL, FG/P, G/P and BY will help in improving the grain yield in aerobic rice. In present study, Anjali, VL Dhan, VL Dhan-16, Vanaprava, Khandagiri, Himalaya-2216, ASD-17, Himalay-741 were found to be potential enough with low ARI, near unity stability, fell into different clusters and yielded substantial yield under water limiting condition would be serve as useful donor for improving tolerance of existing rice cultivars. Thus it can be concluded that their utilization in combination breeding may help in generating high yielding varieties by pyramiding multi-characteristics for drought tolerance.

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