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Research Article

Response of rice (*Oryza sativa* L.) genotypes under aerobic conditions

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Abstract:
A field experiment was conducted during wet season 2009 to study the response of rice genotypes under aerobic conditions. Variance studies revealed significant differences among the genotypes for the traits, days to flowering, plant height, harvest index, grain yield, panicle number, straw yield, panicle length, test weight and biomass. Higher values of heritability and genetic advance were observed for plant height and days to flowering. Grain yield per plot showed positive association with harvest index and total biomass. Correlation and path analysis revealed an ideal plant type of genotype under aerobic conditions should have high harvest index and biomass. Eight rice genotypes with increased yield advantage over checks have been identified as suitable entries for aerobic cultivation. Results also suggested that all rice genotypes are not suitable for aerobic method of cultivation and the genotypes which are able to acclimatize to the non-puddled aerobic conditions should be identified and released.

Keywords: Aerobic rice, fresh water, grain yield, correlation, path analysis

Introduction

Rice, the staple food of the country is cultivated predominantly under irrigated conditions. Being an extravagant consumer of water, rice uses around 5000 liters of fresh water to produce 1kg of rice (Bouman, 2009). The increase in depletion of fresh water resources (Gleick, 1993) is a major threat to the traditional way of rice cultivation. It has been estimated that 2 million hectares of Asia's irrigated dry-season rice is to be affected by water scarcity by 2025 (Tuong and Bouman, 2002). In Karnataka, rice is cultivated in an area of about 1.47 million hectares with average productivity of 3.4 tonnes/ha (www.decanet.com). Area wise rice productivity has remained same or rather decreased due to many constraints. Among them, non availability of water during certain stages of crop stand is a major constraint. To combat this problem water-saving rice production system like, aerobic rice cultivation is being popularized in dry zones of the state to obtain optimum yield with less amount of water consumption.

Aerobic rice is a production system in which input responsive rice varieties with aerobic adaptation are grown in non-puddled and non-saturated soils (Bouman *et al*. 2002). To obtain high grain yield under aerobic method of cultivation, there is a need to develop new rice varieties which are drought tolerant, weed competitive, better nutrient absorbers, disease and pest resistant. Several intensive breeding efforts to develop resistant aerobic rice cultivars are under progress with the formation of many drought consortiums. Such method of rice cultivation has been of great success in China and Brazil, where grain yield of some genotypes has been reported to be on par with irrigated yield levels in northern China (Vijayakumar *et al*., 2006). Meanwhile, in India, the method is at the infant stage and needs to be widely popularized with the development of new varieties. Under dry land situations an experiment was raised to test the response of 90 rice genotypes in dry non-rice soils and was surface irrigated whenever there was a dry period without rainfall.

Materials and Methods

Plant materials: Eighty eight rice genotypes collection from IRRI and two aerobic check varieties MAS 946-1 and MAS 26 (Table 1) were used in the study. Field experiment was conducted in wet season 2009 at University of Agricultural Sciences, Bangalore in randomized block design with three

replications. Soil type was sandy loam and shallow in texture with neutral pH 7.1. Field was thoroughly prepared and each genotype was raised in a 2 m^2 plot by direct seeding in the main field at a spacing of 30cm x 10cm. Package of practices and protection measures were followed as per recommendation (Hittalmani *et al*. 2008, unpublished) ensuring uniform and healthy crop stand. Surface irrigation was given once in 5-7 days at vegetative stage and once in 2-3 days at reproductive stage.

Observations: The observations were recorded on five randomly selected plants per genotype per replication for the traits, days to 50% flowering, plant height, panicle number, panicle length, 100 grain weight, biomass, harvest index, straw yield/plot and grain yield/plot.

Data analysis: Data for the above traits were collected from five randomly selected plants from each genotype. Data was subjected to statistical analysis Viz., Analysis of variance (ANOVA), mean, range, genetic variability components such as phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2) and genetic advance as percent mean (GAM), correlation analysis and path analysis. Statistical software GENRES was used for the analysis.

Results and Discussion:

Genetic variability in any crop is pre-requisite for selection of superior genotypes over the existing cultivars. Variance analysis for all the characters revealed significant variation among the genotypes studied (Table 2). All characters showed low genotypic coefficient of variation than phenotypic coefficient of variation indicating the influence of environment on these traits. Heritability estimate ranged from 17% in biomass to 76% in plant height and range of genetic advance was from 0.08 for harvest index and 21.19 for plant height. High values of heritability and genetic advance was observed for plant height and days to flowering. Since heritability is an estimate of the heritable portion of the variation, a higher heritability values for quantitative characters are useful as they provide the base of selection on the phenotypic performance. Similar findings were reported for plant height by Venkataramana *et al*. (1999), Girish *et al*. (2006) and Krishna and Hittalmani (2009). Panicle number and panicle length exhibited moderate heritability and genetic advance. Low heritability and genetic advance values were observed for grain yield, straw yield, test eight and biomass indicating high environmental influence for the characters.

Yield performance: Performance of rice genotypes under aerobic conditions in terms of mean grain yield (kg/plot & kg/ha) and rankings based on grain yield is presented in Table 1. Highest average yield of 3.19 kg was recorded for genotype, IR 80013-B-141-4-1 followed by IR-78937-B-4-B-B-B (3.09 kg) and IR 84899-B-183-CRA-19-1 (2.61 kg). The released aerobic rice variety, MAS 26 was fourth among rankings and mean grain yield of about 2.56 kg was recorded. Out of 90 genotypes evaluated, 8 were identified has suitable genotypes for cultivation under non flooded aerobic conditions. All these eight entries showed yield advantage over state aerobic check variety, MAS 946-1.

Correlation between characters: Complex inter-relationship among various traits in determining one depended variable exists for the character like yield. Such associations between morphological traits and yield can be determined by correlation studies. Grain yield per plot showed positive association with harvest index and biomass and negative association with straw yield (Table 3). Significant association was also reported between yield and plant height, panicle number and number of tillers (Yadav, 1992; Girish *et al*.,2006). But with respect to other characters there was no significant association.

Conclusion

Evaluation of rice genotypes under aerobic conditions revealed that biomass and harvest index exhibited high positive direct effect on grain yield. In the selection of genotypes, maximum importance should be given to these traits in order to obtain higher grain yield in rice under aerobic conditions. The results also suggested that all rice genotypes are not suitable for aerobic method of cultivation and genotypes which are able to acclimatize under non-puddled conditions should be identified and released.

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Table 1. Mean values of 91 Aerobic rice genotypes for nine morphological characters under aerobic condition

Genotypes	Days to Flowering	Plant Height (cm)	Panicle number	Panicle Length (cm)	Test weight (g)	Biomass (g)	Harvest Index	Straw yield/Plot (kg)	Grain yield/Plot (kg)	Plant Height (cm)
IR 72667-16-1-B-B-3	97.00	79.33	15.00	20.67	2.65	4.29	0.53	2.00	2.29	4580 [10]
IR 78908-193-B-3-B	90.00	103.00	13.67	26.33	3.05	3.94	0.48	2.04	1.91	3820
IR 78908-105-B-2-B	90.33	97.00	12.00	25.00	3.20	4.05	0.48	2.11	1.95	3900
IR 83614-281-B	91.33	91.00	19.00	22.00	2.69	4.08	0.48	2.13	1.95	3900
IR 78908-126-B-2-B	89.00	95.33	14.33	21.00	3.15	4.07	0.44	2.30	1.77	3540
IR 83614-673-B	94.33	95.33	12.67	24.00	2.85	3.84	0.41	2.26	1.57	3140
NDR 1119	96.67	79.67	13.33	25.00	2.75	3.79	0.44	2.13	1.66	3320
IR 83614-315-B	91.33	93.00	18.33	20.33	2.75	3.65	0.45	2.02	1.63	3260
IR 80013-B-141-4-1	102.67	91.67	13.33	22.67	2.70	5.17	0.61	1.98	3.19	6380 [1]
IR 70215-70-CPA-3-4-1-3	93.33	81.33	13.67	25.67	2.88	3.60	0.52	1.73	1.88	3760
IR 83614-203-B	93.00	100.00	13.33	23.67	2.75	4.05	0.48	2.11	1.94	3880
IR 83614-564-B	98.33	81.00	14.00	25.67	3.01	3.90	0.43	2.21	1.69	3380
IR 83614-349-B	95.00	96.67	13.00	24.00	2.88	4.26	0.51	2.11	2.14	4280
IR 80416-B-152-4	93.67	88.00	15.67	21.67	2.65	4.09	0.50	2.06	2.03	4060
IR 78908-142-B-3-B	90.67	95.33	13.33	26.33	2.70	3.58	0.24	2.73	0.85	1700
IR 79970-B-47-1	89.67	91.67	13.33	26.67	3.05	3.80	0.47	2.02	1.77	3540
IR 78937-B-4-B-B-B	102.67	87.67	13.00	24.67	2.88	4.33	0.71	1.24	3.09	6180 [2]
IR 79899-B-179-2-3	91.00	90.33	18.00	26.00	3.11	3.77	0.32	2.55	1.22	2440
IR 79913-B-221-B-2	89.33	86.33	14.33	26.67	3.15	4.11	0.48	2.13	1.99	3980
IR 83614-394-B	92.33	106.67	13.33	25.67	2.95	4.16	0.54	1.93	2.23	4460
IR 78908-80-B-3-B	91.00	108.33	11.33	24.33	2.88	4.09	0.50	2.05	2.05	4100
IR 79906-B-5-3-3	92.33	77.67	16.33	25.67	2.75	3.82	0.47	2.03	1.79	3580
IR 78878-53-2-2-2	92.00	93.67	10.00	22.67	2.90	3.74	0.41	2.19	1.54	3080
IR 83614-46-B	93.33	86.67	17.33	23.67	2.75	4.04	0.48	2.11	1.94	3880
IR 79913-B-399-B-2	97.67	89.67	14.33	27.67	3.20	3.99	0.52	1.93	2.06	4120
IR 83614-61-B	91.33	102.67	14.33	26.00	3.20	4.32	0.49	2.21	2.11	4220
IR 79956-B-60-2-3	91.00	97.33	14.00	22.00	3.00	3.96	0.50	1.97	1.98	3960
IR 79959-B-217-1-2	95.00	96.33	17.33	27.33	2.54	3.95	0.53	1.85	2.10	4200
IR 83614-513-B	94.67	91.33	12.67	25.33	2.63	4.01	0.49	2.06	1.95	3900
IR 83614-438-B	97.33	88.67	14.33	25.67	3.05	4.19	0.52	2.02	2.17	4340
IR 77298-14-1-2	90.33	90.67	13.33	21.00	2.90	3.85	0.52	1.81	2.05	4100
R-RF-60	95.00	60.67	16.67	24.33	2.87	3.80	0.43	2.13	1.68	3360
R-RF-65	93.33	66.33	11.33	21.00	3.15	3.92	0.44	2.18	1.74	3480
R-RF-66	97.33	67.67	12.67	20.00	2.16	4.09	0.42	2.37	1.73	3460
R-RF-45	92.67	86.00	12.33	21.00	2.50	3.83	0.49	1.97	1.87	3740
BAU 398-02	95.33	72.33	12.67	21.67	2.85	3.81	0.42	2.19	1.62	3240
IR 84891-B-112-CRA-15-1	89.33	85.33	12.33	24.67	2.78	3.95	0.46	2.11	1.84	3680
IR 84900-B-149-CRA-2-1	90.67	88.67	14.67	27.33	2.75	4.11	0.42	2.41	1.70	3400
IR 81039-B-173-U-3-3	89.67	89.00	12.33	25.33	2.55	3.66	0.45	1.98	1.68	3360
IR 81430-B-B-94	90.00	94.00	11.00	25.33	2.35	3.90	0.42	2.25	1.64	3280

Contd..

Table 1. Contd..

Genotypes	Days to Flowering	Plant Height (cm)	Panicle number	Panicle Length (cm)	Test weight (g)	Biomass (g)	Harvest Index	Straw yield/Plot (kg)	Grain yield/Plot (kg)	Plant Height (cm)
IR 79975-B-83-4-3	90.00	95.33	11.33	21.00	2.65	3.92	0.39	2.40	1.52	3040
IR 84896-159-CRA-12-1	87.33	89.33	15.33	23.33	2.85	4.17	0.45	2.27	1.89	3780
IR 84887-B-153-CRA-25-1	95.00	83.00	15.33	24.67	2.95	4.11	0.47	2.18	1.92	3840
IR 84894-B-143-CRA-17-1	96.00	90.00	11.00	25.33	3.01	3.92	0.50	1.95	1.97	3940
IR 84894-B-139-CRA-8-1	90.33	91.67	19.33	23.33	2.55	4.32	0.56	1.90	2.41	4820 [8]
IR 79971-B-148-3-1	92.00	104.33	13.67	20.67	2.65	4.03	0.48	2.09	1.94	3880
IR 78875-207-B-1-B	99.33	99.33	11.33	21.00	2.26	4.47	0.56	1.97	2.50	5000 [6]
IR 81044-B-112-U-4-2	92.00	96.67	15.67	24.67	3.15	3.93	0.52	1.90	2.03	4060
IR 84899-B-183-CRA-19-1	106.00	91.33	14.67	21.00	2.76	4.63	0.57	2.02	2.61	5220 [3]
IR 82870-58	92.33	72.33	14.00	22.67	3.20	3.76	0.38	2.32	1.44	2880
IR 80416-B-152-4	93.33	89.67	13.33	25.33	2.98	3.68	0.45	1.99	1.69	3380
IR 81063-B-94-U-3-2	108.67	80.33	16.67	27.00	2.65	4.41	0.48	2.28	2.13	4260
IR 81057-B-132-U-4-4	92.67	84.67	16.33	23.33	2.67	3.79	0.46	2.04	1.75	3500
IR 84899-B-182-CRA-12-1	100.00	83.00	15.67	21.33	2.75	4.08	0.62	1.54	2.54	5080 [5]
IR 80461-B-7-1	96.00	77.67	15.00	24.00	2.75	4.13	0.51	2.06	2.07	4140
IR 84899-B-185-CRA-5-1	92.00	101.33	13.67	24.33	2.67	4.06	0.46	2.18	1.88	3760
IR 74371-70-1-1	98.00	82.33	14.67	24.33	2.95	3.75	0.42	2.16	1.58	3160
NDR 1045-2	105.00	85.00	14.67	24.00	2.75	4.24	0.57	1.82	2.42	4840 [7]
IR 55419-04	96.00	80.00	14.00	25.00	2.95	4.25	0.48	2.24	2.02	4040
IR 80463-B-39-1	94.67	80.67	10.33	24.67	2.75	3.85	0.35	2.51	1.34	2680
IR 70210-39-CPA-7-1-1-4-2	102.00	100.33	12.33	23.00	2.55	4.51	0.46	2.35	2.16	4320
IR 80417-B-120-4	94.33	76.00	9.67	21.67	2.75	4.26	0.48	2.23	2.04	4080
IR 80461-B-7-1	91.33	77.33	12.00	23.33	2.65	4.13	0.43	2.34	1.79	3580
IR 82870-48	94.00	63.67	13.00	21.33	2.75	3.79	0.48	1.93	1.86	3720
IR 78875-207-B-B-13-14	94.67	93.00	10.67	23.67	2.95	3.79	0.40	2.26	1.53	3060
IR 72875-94-3-3-2	93.33	86.00	13.00	20.67	2.75	3.73	0.39	2.26	1.47	2940
IR 75417-R-R-R-R-267-3	96.67	66.00	8.00	23.00	2.65	3.82	0.31	2.63	1.19	2380
IR 64683-87-2-2-3-3	93.67	63.33	9.00	24.00	2.65	3.84	0.38	2.38	1.47	2940
IR 78875-207-B-3-B	94.00	96.67	10.00	25.67	3.35	3.83	0.42	2.20	1.63	3260
IR 70182-18-PMI-7-UBN-2-B-1-1-1	98.00	70.67	9.33	21.67	2.86	4.06	0.31	2.79	1.27	2540
IR 83614-338-B	93.33	74.33	10.00	27.33	2.65	3.98	0.36	2.57	1.42	2840
IR 78908-140-B-1-B-B	99.33	78.33	10.33	24.67	2.75	4.09	0.49	2.09	1.99	3980
IR 80408-B-43-3	91.33	97.33	9.00	23.33	2.75	4.03	0.34	2.62	1.41	2820
PM 6 18	95.00	73.67	11.00	24.67	2.75	4.09	0.38	2.55	1.54	3080
NDR 1135	94.00	81.67	11.00	26.33	3.02	3.65	0.32	2.50	1.15	2300
CB 5755	93.00	90.00	8.67	25.33	2.75	3.87	0.34	2.55	1.32	2640
IR 77080-B-34-3	95.33	80.33	10.67	21.33	3.03	4.18	0.33	2.82	1.36	2720
IR 82870-11	94.00	102.33	13.67	21.67	2.75	3.98	0.41	2.34	1.64	3280
IR 84894-B-138-CRA-6-1	99.67	72.33	12.33	24.33	1.65	4.34	0.37	2.75	1.59	3180

Contd..

Table 1. contd..

Genotypes	Days to Flowering	Plant Height (cm)	Panicle number	Panicle Length (cm)	Test weight (g)	Biomass (g)	Harvest Index	Straw yield/Plot (kg)	Grain yield/Plot (kg)	Plant Height (cm)
CB 5754	93.00	79.00	12.00	25.33	2.95	3.80	0.36	2.44	1.36	2720
IR 80463-B-39-3	101.33	62.33	13.00	22.00	2.95	3.80	0.35	2.49	1.31	2620
IR 80508-B-194-2-B	106.33	71.33	12.00	21.67	2.65	4.10	0.38	2.51	1.59	3180
IR 84882-B-121-CRA-3-1	96.67	69.33	9.33	24.33	1.68	3.56	0.34	2.36	1.20	2400
MTU 1010	100.00	74.33	14.67	22.67	2.95	3.81	0.48	1.97	1.84	3680
IR 64	103.33	58.00	17.33	22.67	3.05	4.27	0.52	2.03	2.24	4480
IR 36	101.00	58.33	13.00	20.33	2.75	3.47	0.37	2.18	1.29	2580
LALAT	104.00	73.33	16.00	26.67	2.75	4.23	0.53	1.98	2.25	4500
MAS 946-1	99.67	66.00	11.00	23.67	3.20	4.57	0.50	2.27	2.30	4600 [9]
MAS 26	94.00	80.33	9.67	24.33	3.05	4.98	0.51	2.42	2.56	5120 [4]
SWARNA	108.00	47.33	11.33	25.67	1.71	3.70	0.31	2.51	1.19	2380

Table 2. Variability parameters of different morphological traits under aerobic condition

Traits	Range		Mean	SEm	CD	CV	Variance	PCV (%)	GCV (%)	h^2 (%)	GA
	Min	Max									
Days to Flowering	87.0	108.0	95.16	1.69	6.17	3.08	7.47*	5.47	4.52	68	7.71
Plant Height (cm)	47.0	108.0	84.60	3.75	13.69	7.69	11.20*	16.02	14.08	77	25.51
Panicle number	8.0	19.0	13.00	1.37	5.02	18.13	3.10*	23.69	15.20	41	20.10
Panicle Length (cm)	20.0	27.7	23.82	0.70	2.56	5.12	7.98*	9.39	7.85	69	13.53
Test weight (g)	1.65	3.35	2.79	0.15	0.55	9.42	3.94*	11.97	8.43	49	12.25
Biomass (g)	3.46	5.16	3.99	0.24	0.88	10.57	1.19	10.83	2.65	6	1.34
Harvest Index	0.23	0.70	0.44	0.04	0.15	16.63	3.33*	22.06	14.60	43	19.90
Straw yield/Plot (kg)	1.20	2.80	2.18	0.18	0.67	14.68	2.13*	16.95	8.89	27	9.61
Grain yield/Plot (kg)	0.84	3.19	1.81	0.23	0.86	22.63	2.83*	28.73	17.70	37	22.47

* - Significant at 5%

Table 3. Correlation coefficients among the traits observed under aerobic condition

Characters	Plant Height (cm)	Panicle number	Panicle Length (cm)	Test weight (g)	Biomass (g)	Harvest Index	Straw yield/Plot (kg)	Grain yield/Plot (kg)
Days to Flowering	-0.467	0.004	-0.074	-0.322	0.331	0.157	-0.050	0.253
Plant Height (cm)		0.137	0.132	0.302	0.219	0.321	-0.259	0.318
Panicle number			0.025	0.129	0.125	0.446	-0.455	0.386
Panicle Length (cm)				0.108	-0.084	-0.047	0.014	-0.065*
Test weight (g)					-0.030	0.233	-0.288	0.173
Biomass (g)						0.539	-0.129	0.749*
Harvest Index							-0.898**	0.957**
Straw yield/Plot (kg)								-0.753*

* - Significant at 5% ** - Significant at 1%