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Stability of rice (*Oryza sativa* L.) varieties for *boro* season of eastern India

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Abstract

Twelve high yielding varieties (HYVs) of rice (*Oryza sativa* L.) were evaluated for their adaptive advantage to various dry season rice ecologies under direct seeded wetland condition for yield and its' consistency. Varieties interacted with time of seeding for duration, yield and its components, disease and pest reaction as well as for milling recovery. Knowledge on thermo-sensitivity and short day effect may be helpful for seed producers as well as for commercial purpose. Duration in different varieties got delayed due to cold stress in November and December seeding and it varied in between 14 to 34 days. It was minimum in case of Vandana (14 days) and maximum in Saket 4 (34 days) due to effect of cold during growing season. Medium late variety Pusa 44 registered the highest yield (about 10 t/ha) when seeded in mid-November. IR 64, CR 749-20-2 and Lalat, which are very popular in *boro* areas, performed equally well under mid-December seeding. The variety Vandana may be promising for Early *Ahu* areas of Assam or in the areas where rice is taken after mustard or potato as a direct seeded crop. Variety Tapaswini did not flower at all when sown in mid-February till the end of the season due to non-availability of appropriate short-day requirement. Desirable grain type and tolerance to blast of Khitish under mid-February seeding has made it popular in the late *boro* areas of West Bengal. Varieties varied greatly in milling recovery - it was the highest when sown in between mid-November to mid-December, except in Saket 4 and lowest in mid-January seeding and onwards, indicating grain-filling aspect for consideration as affected by weather conditions due to different times of seeding.

Key words: *Boro* rice, dry season, short day, thermo sensitivity, G × E interaction

Introduction

Dry season (DS) rice grown during October/November to May/June in the fallow areas after recession of rain or after the harvest of wet season rice or after rice-mustard/potato/vegetable crops, is popularly known as *boro* rice in West Bengal and *dalua* rice in Orissa [1, 2, 3]. In Assam, Tripura and Manipur, it is classified as *boro* and early *ahu* depending on the time of cultivation [4, 5]. In Bihar it is popular as summer rice [6]. Early *ahu* is of shorter duration and requires life-saving irrigation with minimum inputs of fertilisers and pesticides. *Ahu* rice is cultivated up to an elevation of 600m above mean sea level (D. N. Borthakur personal communication. Cultivars of varying duration groups are grown by the farmers depending upon their cropping schedule, appropriate utilization of resources, socio-economic condition etc. Dry season rice is the only source of income generation where excess soil moisture does not permit any other crop to be grown successfully [1].

Dry season rice yields are often higher due to availability of more solar radiation, less pest problems and better management practices. It has become the main-stay for food security in the flooded, flood-prone and cyclone-prone areas of Eastern India [2] and Bangladesh [7]. In the present investigation an attempt was made to identify the way for maximising productivity and characterize the suitability of popular HYVs of different duration groups for their adaptation to various DS season ecologies based on their performance, consistency, growth behaviour, and pest and disease reactions etc under different dates of seeding.

Materials and methods

Twelve popular varieties of different maturity groups *viz.* Heera and Vandana from very early group (<90 days); IR 64, Ratna, Saket 4, CR749-20-2, IR 36, Khitish and CR 679-2 of mid Early group (<130 d) and Pusa 44, Lalat and Tapaswani of mid Late group (130 d) were grown in a randomised complete block design with three replications on 4 successive dates (November 15/(D1), December 15/(D2), January 15 (D3) and February 15/(D4) under direct seeded irrigated wetland condition. The seeds were soaked for 24 hours followed by 36-48 hours of incubation for sprouting and were broadcasted in 18.25 m^2 experimental plots. Weed control was done using Butachlor @ 1.25 kg a. i./ha after 5-7 days of seeding in a thin film of water. Fertiliser @ 80: 40: 40 kg NPK/ha were applied. Total amount of P and K were applied as basal and N in 4 equal splits (15 DAS, 30 DAS, PI and heading). Need based pest control measures were taken as and when required. Observations on grain yield were recorded over the net plot size 15.04 m^2 leaving the borders. Number of ear bearing tillers was recorded over one m^2 area in each plot. Blast infestation and lodging characteristic were scored using SES scale [8]. For plant height, panicle length and number of fertile and sterile grains per panicle, observations were recorded on 5 plants collected randomly from the middle of each plot. Thousand grains were randomly chosen after threshing and cleaning from each replication to record the 1000 grain weight. Milling of the harvested grain was carried out at 14 % moisture content by using Satake Lab milling machines. The data were analysed for G × E interaction [9].

Results and discussion

ANOVA for grain yield and its components revealed significant differences among the varieties and the environments (Table 1). Highly significant mean squares due to genotype × environment (G × E) interaction for all the traits studied revealed that the genotypes interacted considerably with environmental conditions that existed in dates of seeding. These results were in conformity with the earlier reports [10] in rice. Both the linear and non linear components of G × E interaction were significant for grain yield and its components studied except ear bearing tillers/m^2, thereby indicating the importance of both regression coefficient (b_i) and deviation from regression (S^2di) in determining the stability of grain yield and its components except for plant height. Linear component was significant when tested against pooled error for grain yield and other traits indicating the possibility of prediction of performance of varieties in different growing ecologies during dry season.

Table 1. ANOVA for stability parameters of different traits in rice for *boro* season

Sources of variation	DF	Grain yield (t/ha)	Gains/ panicle	Sterility (%)	1000 grain weight (g)	Days to flower
Rep within environment	8	0.15	38.4	5.2	0.13	0.22
Genotypes	11	7.59**++	711.2**	35.4**	33.61**++	328.28**
Env. + Genotypes × Env.	36	4.54**++	362.6**	45.6**	9.15**++	353.68**
Environments	3	43.07**++	723.3**	96.6**	34.15**++	2384.40**++
G × E	33	1.04**++	329.8**	40.9**	6.79**++	169.0**
Env. (Lin.)	1	129.21**++	2169.8**	289.8**++	105.45**++	7153.15**++
G × E. (L.)	11	1.89**+	349.0**	37.3**	19.12**++	242.58**+
Pooled deviation	24	0.36**	349.0**	39.2**	0.57**	121.29**
Pooled error	88	0.10	35.2	3.5	0.18	0.12

*P = 0.05, **P = 0.01 (with pooled error); +P = 0.05, ++P = 0.01 (with pooled deviation)

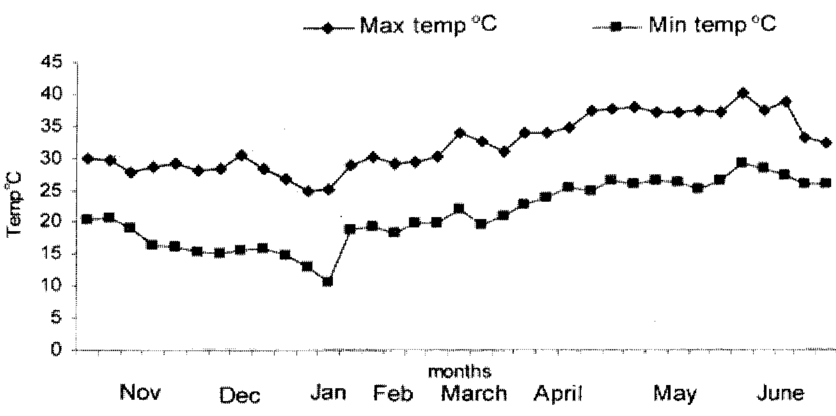

Fig. 1. Maximum and minimum temperature at CRRI farm during *rabi* season

The grain yield and duration of rice fluctuated considerably (Table 2) even though in none of the varieties showed severe symptoms of cold stress. Pusa 44 recorded the highest grain yield of about 10.2 t/ha in Nov 15 seeding. It also recorded highest yield over all the environments (7.5 t/ha) followed by IR 64, CR 749-20-2, Lalat and IR 36. Grain yield was the highest in December 15 seeding, followed by November 15 and January 15, February 15 seeding recorded the lowest yield due to reduced duration affecting stand establishment in most varieties due to high temperature (Fig. 1).

January 15 and February 15 seeded crop needed extra care for yellow stem borer as all the genotypes were infested. For blast, different disease intensity over varieties was recorded. Saket 4 registered severe blast infestation in all the four dates of seeding, while in Khitish blast problems were recorded in first three dates of sowing only. Blast infested plots registered reduced 1000 grain weight due to poor grain filling. On the other hand, in November and December sown crops, occurrence of yellow stem borer and weeds were less up to the third week of January. Duration was affected by sowing time in all the varieties. In all the varieties days to 50 % flowering (DF) was maximum in November 15 seeding and it successively reduced up to Jan 15 seeding. Tapaswani did not flower at all on January

Table 2. Stability parameters for grain yield, fertile grains/panicle, days to flower and 1000 grain weight in rice

Variety	Grain yield (t/ha)			Days to flower			Filled grains/panicle			1000 grain weight (g)		
	$\bar{X}$	bi	S^2di	$\bar{X}$	bi	S^2di	$\bar{X}$	bi	S^2di	$\bar{X}$	bi	S^2di
Heera	4.07	0.83	–0.08	72	0.80	16.20	50	0.89	-16.7	22.8	0.80	0.04
Vandana	5.84	0.73	0.42	67	0.39	9.10	51	–0.54	161.4	23.1	0.46	–0.12
CR 679-2	6.70	1.25	0.02	91	0.91	8.80	53	0.10	148.7	22.6	0.81	–0.15
Saket 4	2.50	0.28	0.13	89	1.09	26.70	34	–0.30	371.6	18.9	–0.74	–0.16
Ratna	5.35	0.80	0.41	89	1.01	20.30	50	0.15	146.8	20.7	0.92	0.11
CR 749	7.91	1.10	0.21	88	0.73	55.40	63	1.72	212.8	20.9	1.24	1.43
Lalat	5.2	1.18	–0.06	87	0.66	48.60	54	1.91	–20.6	22.0	1.18	–0.14
IR 64	6.20	1.37	0.53	89	1.01	20.30	52	53.0	61.3	24.8	1.12	0.28
IR 36	5.52	1.13	1.37	89	0.64	1.20	55	0.71	49.4	19.6	0.64	0.37
Tapaswani	6.08	1.61	2.42	97	2.92	12.34	72	2.29	26.55	13.4	5.22	3.29
Pusa 44	10.2	1.39	0.31	98	0.84	0.05	87	0.40	–8.25	22.26	0.90	–0.15
Khitish	4.88	0.29	–0.10	86	0.99	15.70	53	3.13	1.33	20.5	–0.57	–0.08
Mean	3.43	1.00		85	1.00		57	1.00		21.0	1.00	
SE (m)	0.03			3.61			5.71			0.44		
SE (bi)		0.23			0.45			1.39			0.22	

$\bar{X}$ = mean of observations, bi = Regression coefficient and S^2di = Deviation from regression co-efficient

15 seeding. This might be due to nonavailability of appropriate short day photo-period requirement (Fig. 2). Days to 50% flower (DF) was increased by 14 (Vandana) to 34 (Saket 4) days in different genotypes (Table 3). Genotypes interacted with environment for grain filling in terms of filled grains/panicle and 1000-grain weight (TGW). Genotypes differed in terms of number of filled grains/panicle. Thousand grain weights also fluctuated considerably over environments. Pusa 44 registered highest number of filled grains per panicle and IR 64 possessed highest TGW in D1. In the subsequent dates however only TGW declined in all the varieties except Khitish, indicating variation in grain filling among genotypes due to absorption in solar radiation. Severe blast infestation affecting surface leaf area in Saket 4 might be responsible for partial grain filling. In other genotypes also, decline in TGW might be attributed to low photo-synthate accumulation as high temperature

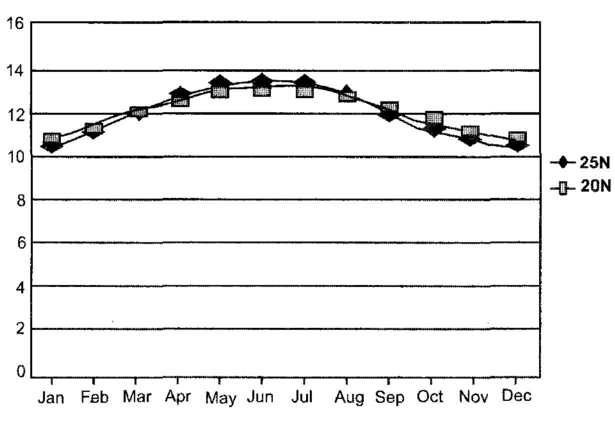

Fig. 2. Day length of different latitude

increases respiration rate (11). Milling recovery traits were also affected by the time of seeding. The estimated yield based on panicles/m^2 filled grains/panicle and TGW differed significantly from the observed yield (\$Echi sup 2 =10.5 at 45 df). The milling recovery was affected due to date of seeding as well. Vandana recorded the lowest milling recovery on all the dates of seeding, whereas Pusa 44 registered the highest milling recovery (Table 3). Among the dates of seeding, early sowing recorded the highest milling recovery as compared to later dates of sowings. Growth, flowering behaviour and other developmental aspects of grains, therefore, necessitate thorough understanding and categorization before recommending any variety for commercial cultivation [12]. Simple linear regression as a quantitative measure of phenotypic stability was used to describe the consistency in performance of genotypes in a wide range of environment [13]. In addition to mean ($\bar{X}$) and regression coefficient (bi), deviation from regression (S^2di) should be given weight age [9]. Use of deviation from regression alone as a measure of stability was emphasized; where as linear regression could be treated as varietal response [14]. A stable variety will, thus, have lowest deviation from regression and *vice versa*. Accordingly, the mean ($\bar{X}$) and deviation from regression (S^2di) of each genotype were considered for stability and linear regression (bj) was used for testing varietals response. Difference among varieties for panicles/m^2 was not significant in all the four environments. Number of spikelets did not differ for each variety (Table 3). Assessment of varieties based on individual parameters of adaptability ($\bar{X}$, bi, (S^2di) for grain yield revealed that all the 12 genotypes tested showed significant response to sowing dates by their significant values of regression coefficient from unity. Out of 12 varieties

Table 3. Mean performance of rice genotypes over environments

	Grain yield (t/ha)				Days to flower				Filled grains/panicle				Ear bearing tillers/m^2			
Variety	**D1**	**D2**	**D3**	**D4**	**D1**	**D2**	**D3**	**D4**	**D1**	**D2**	**D3**	**D4**	**D1**	**D2**	**D3**	**D4**
Heera	4.07	4.41	3.75	2.05	86	80	61	61	53	54	52	42	502	502	577	433
Vandana	5.84	5.28	4.56	3.58	75	72	61	61	55	54	51	45	512	563	576	417
CR 679-2	6.70	6.95	4.26	2.82	103	96	8.3	84	59	60	53	42	511	502	411	325
Saket-4	2.50	3.24	2.68	2.19	110	93	75	78	34	36	35	32	728	743	452	433
Ratna	5.35	5.47	3.27	2.13	108	92	76	80	53	52	50	48	530	510	414	532
CR 749-20-2	7.91	6.76	4.52	3.02	104	93	76	80	63	70	60	58	590	451	403	347
Lalat	5.90	7.51	5.09	3.92	100	95	75	80	50	62	53	52	545	515	488	448
IR 64	6.20	8.23	5.66	3.59	107	93	76	76	48	59	52	48	576	577	462	455
IR 36	5.52	6.07	4.20	3.20	99	94	82	80	61	55	54	51	445	582	445	472
Tapaswini	6.08	7.02	5.34	-	114	96	81	-	79	76	71	-	520	503	563	*
Pusa 44	10.70	7.02	6.53	4.47	113	104	90	87	90	89	86	82	554	486	374	355
Khitish	4.88	4.34	5.08	5.54	103	94	73	76	61	53	51	68	494	447	573	476
GM	5.99	6.10	4.66	3.43	101.8	91.8	75.8	70.2	58.9	59.2	54.0	47.3	542	523	477	427
CD	1.58	1.24	0.60	0.43	1.2	0.8	0.70	0.99	16.6	12.8	13.9	7.5				
CV	10.0	9.80	5.81	7.83	0.68	0.54	0.54	0.99	20.6	10.5	11.6	15.7				

	Blast score				Lodging score				1000 grain weight (g)				Head rice recovery (%)			
Variety	**D1**	**D2**	**D3**	**D4**	**D1**	**D2**	**D3**	**D4**	**D1**	**D2**	**D3**	**D4**	**D1**	**D2**	**D3**	**D4**
Heera	1	1	1	1	1	1	1	1	23.94	23.14	23.30	20.68	47.8	48.8	36.4	46.3
Vandana	1	1	1	1	5	7	7	7	23.63	23.83	22.94	22.80	45.2	40.4	42.9	37.0
CR 679-2	3	3	3	1	1	1	1	1	23.77	23.34	22.56	20.66	51.2	50.7	41.1	46.2
Saket-4	5	7	7	7	1	1	1	1	17.95	18.18	19.07	20.76	57.9	59.1	57.4	59.7
Ratna	1	3	3	1	1	1	1	1	21.73	21.40	21.52	18.27	55.6	57.3	49.6	55.1
CR 749-20-2	1	1	1	1	1	1	1	1	23.67	21.94	19.81	18.26	68.0	69.5	66.0	64.8
Lalat	1	1	1	1	1	1	1	1	24.80	23.06	22.08	19.12	51.8	53.5	48.3	40.4
IR 64	1	1	1	1	1	1	1	1	26.28	26.50	24.16	22.26	61.8	60.8	49.0	57.9
IR 36	3	3	3	1	1	1	1	1	21.08	20.23	18.92	18.32	60.2	60.9	61.3	53.1
Tapaswani	3	3	3	1	1	1	1	1	18.51	19.16	16.15	-	68.5	68.3	66.9	-
Pusa 44	1	1	1	1	1	1	1	1	24.80	24.12	23.00	20.76	64.7	60.8	50.0	47.3
Khitish	7	7	3	1	1	1	1	1	19.49	20.21	20.59	21.91	51.6	52.2	52.9	61.1
Mean	3.2	3.7	3.2	1.7	1.5	1.7	1.7	1.7	22.12	22.10	21.17	18.60	57.0	56.8	51.8	51.7
CD									1.00	1.54	1.49	0.87	2.68	2.88	3.62	4.73
CV									2.65	4.13	4.15	2.79	15.3	16.4	18.8	24.5

tested, 10 exhibited stable performance for grain yield. Pusa 44 and IR 64 registered as stable. Tapaswani was most unstable as it failed to flower during February 15 seeding. Stability in grain yield was also imparted by the stability for the yield components. As such the performance of Tapaswani for yield in the first three dates was consistent and it may find place for cultivation in November to December seeding.

Genotypes form one of the key components in the production and trade to provide profitability to the growers. Rice varieties generally yield in between 22-33 g day^{-1} m^2 grain [15]. However, dry season rice is mostly grown under intensive care and with very high input. Therefore, varieties need to have above 60g day^{-1} m^2 grain yields and these should be widely adapted, shorter in duration (100-125d) and of good grain quality. A greater deal of research is needed to protect and stabilize the grain yield and genetic improvement in nutritional quality. Medium late variety Pusa 44 registered the highest yield (about 10 t/ha) when seeded in mid-November. IR 64, CR 749-20-2 and Lalat, which are very popular in boro areas, performed well, under mid-December seeding. The variety Vandana may be promising for Early Ahu areas of Assam or in the areas where rice is taken after mustard or potato as a direct seeded crop. Variety Tapaswini did not flower at all when sown in mid-February till the end of the season due to non-availability of appropriate short-day requirement. Fig. 2 reveals that from August to March day length becomes shorter in between 20-25^{o} N. Wet season rice is exposed to short day from August to December while dry season rice meets the short day requirement in between March to May [16]. Desirable grain type and tolerance to blast of Khitish under mid-February seeding has made it popular in the late boro areas of West Bengal. Varieties varied greatly in milling recovery-head rice recovery was the highest when sown in between mid-November to mid-December, except in Saket 4 and lowest in mid-January seeding and onwards, indicating grain-filling aspect for consideration as affected by weather conditions due to different times of seeding.

Subsequent genetic improvements in the DS rice breeding programs in India should incorporate a variety of desirable traits such as better grain filling, quality, adaptation to cold during December-January, excess temperature at flowering and grain filling, tolerance to disease and insect resistances in to the leading varieties. The future strategy of dry season rice breeding in India should focus on the path breaking collaboration researches that raise the ceiling of grain yield through identification and breeding of varieties adaptive to organic recycling, marginal and judicial use of agro-chemicals and high dose of nutrients through bio-fortification, as breeding that impart not only greater yield and stability but desired quality too and also necessarily adaptive to proportional balanced nutrient support in the soil system keeping bio-safety of the environment.

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