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Phenotypic stability for grain yield in rice

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ABSTRACT

Twenty six rice genotypes were evaluated at the Rice Research Station, Orissa University of Agriculture & Technology, Bhubaneswar, over eight environments during wet season 2000 and dry season 2001 for the assessment of yield and yield stability. Pooled analysis of variance for grain yield over environments showed highly significant differences among genotypes, environments and genotype-environment (GxE) interaction indicating diverse and variable nature of cropping environments. The genotypes were classified into four adaptive groups based on regression co-efficient (b) and deviation from regression (S^2_d). Majority of the high yielding genotypes in both mid-early group (Daya, Lalat, Sebati, Konark and ORS 199-5) and medium maturity group (Bhuban, Birupa, Meher, Kharavela and Tapaswini) with high yield potential have either above average (b>1) or below average (b<1) responses. The genotypes Sarathi and IR 36 with low yield potential exhibited average stability with unit regression and S^2_d values not significantly different from zero.

Key words: *Rice, genotype- environment interaction, regression co-efficient*

The stability of performance of a genotype is as important as its inherent yield potential. It is one of the desired properties of a variety for its general cultivation over a wide range of environments, which relates to the interaction between genotype and environment. Adaptability in crop has been defined as the genetic ability of crop varieties to produce high stable yields in various environments. The genetic character of general adaptability is mainly comprised of two components like stability and productivity (Matsuo, 1975). The regression coefficient (b) of the yield of an individual variety on the mean yield of large number of varieties is considered to be an indicator of yield stability, provided the deviation from regression is negligibly small. Realizing the importance of high yield and greater stability an attempt has been made to evaluate 26 mid-early and medium maturity duration rice varieties in eight different environments, during the course of present investigation for the assessment of evaluation of yield and yield stability under variable environments based on the regression model of Eberhart and Russell (1966).

MATERIALS AND METHODS

The experimental material used in the present investigation consisted of 26 high yielding genotypes including 23 varieties and three elite cultures of rice. The genotypes belonged to two maturity durations groups viz. (i) mid-early group (Daya, Sarathi, Shrabani, Lalat, Ananga, Sebati, Bhoi, Konark, IR 36, IR 64, ORS 199-5 and CR 749-20-2) and (ii) medium group (Bhuban, Gouri, Birupa, Samanta, Bhanja, Meher, Kharavela, Gajapati, Surendra, Pratap, Tapaswini, Jaya, ORS 201-5 and Vijetha). The environments included two normal sowings (sowing date-1 and sowing date-2) and two late sowings (sowing date-3 and sowing date-4) during 2000 wet season and two normal sowings (sowing date-5 and sowing date-6) and two late sowings (sowing date-7 and sowing date-8) during 2001 dry season. Thus, the test genotypes were grown in 8 different environments representing four dates of sowings in each season.

The experiment was laid out in randomized complete block design with three replications at Rice Research Station, OUAT, Bhubaneswar. Thirty days old seedlings were transplanted as six-row plots of 3 m length with a row-to-row distance of 20 cm and plant-to-plant spacing of 15 cm. A fertilizer dose of 80 kg N, 40 kg P_2O_5 and 40 kg K_2O was applied as per scheduled management practices. The recommended crop management practices were followed including need based irrigation and plant protection to raise a normal crop in both the seasons. Grain yield was recorded for each plot in grams and converted to quintals per hectare. The data on grain yield was statistically analysed for stability parameters as suggested by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

Analysis of variance for grain yield pooled over eight environments showed highly significant difference among genotypes (G), environments (E) and genotype-environment (GxE) interaction (Table 1) indicating diverse and variable nature of cropping environments, thus fulfilling one of the requirements for validity of stability analysis.

The mean grain yield of 26 genotypes exhibited wide range of variation within and between environments (Table 2). The environmental means for grain yield ranged from 28.05 q/ha (environment-4) to 42.45 q/ha (environment-1) with a general mean of 34.88 q/ha, thus indicating wide variability of the test environments under study. The order of environment means for grain yield was environment-1> environment-7> environment-5> environment-2>environment-6>environment-3>enviroinment-8>environment-4, thus indicating most favourable and most unfavourable environments. Some of the top yielding genotypes were Konark, Sebati, Daya, OR 199-5 and Lalat in mid-early group whereas in medium maturity group Bhuban, Birupa, Tapaswini, Meher and Kharavela were found promising. It was also observed that no single genotype maintained the relative rank order in all the eight environments. The difference in performance of genotypes in different environments indicated the presence of significant genotype-environment (GxE) interaction for the expression of the character.

The estimates of stability parameters like mean, regression coefficient (b), deviation from regression (S^2_d) and the coefficient of determination (R^2) for grain yield are presented in Table 3. The mean square due to deviation from regression was significant in fourteen out of twenty six genotypes there by indicating its importance in assessment of predictability of genotypic performance under varied environmental conditions.

The estimates of regression coefficient (b) ranged from 0.291 in ORS 199-5 to 1.604 in Jaya indicating fluctuating response of genotypes in different environments. The deviation from regression (S^2_d) ranged from 0 to 126.475. The S^2_d value was significantly different from zero in 12 genotypes like Shrabani, Ananga, Bhoi, CR 749-20-2, Gouri, Bhanja, Meher, Kharavela, Pratap, Tapaswini, Jaya and ORS 201-5 indicating unpredictability in respect of grain yield.

The coefficient of determination (R^2) showed that the regression response accounted for more than 80 percent of total variation in case of Daya, Sarathi, IR36, Gajapati and Vijetha; 50-79 percent of total variation in case of Lalat, Sebati, Bhuban, Birupa, Samanta, Surendra, Pratap and ORS 201-5 and the remaining 13 genotypes had 10.7 to <50 per cent of total variation. Thus the co-efficient of determination ranged from 10.7 per cent (Bhoi) to 92.7 per cent (Daya) and it indicated that the linear regression accounted for major part of the variation. High R^2 values show that the regression lines give nearly perfect fit to actual yield of varieties in different environments. Thus the coefficient of determination is considered as a conformation of variety's linear response to change in growth condition. According to Langer *et al.* (1979) and Nguyan *et al.* (1980) the three stability parameters like 'b', 'S^2_d' and 'R^2' are equally effective in assessing stability of performance. However, preference can be given on coefficient of determination (R^2) over deviation

Table 1. Pooled analysis of variance for grain yield over environments (sowing dates)

Source	DF	SS	MS	F
Replications in Environments	16	3759.79	234.99	9.93**
Genotypes (G)	25	11922.77	476.91	20.15**
Environments (E)	7	14803.44	2114.78	89.34**
G x E	175	16415.56	93.80	3.96**
Error	400	9469.91	23.67	

** Significant at 1% level of significance

Table 2. Mean grain yield of genotypes ($t\ ha^{-1}$) in different environments

Environment/Genotype	Env-1	Env-2	Env-3	Env-4	Env-5	Env-6	Env-7	Env-8	Mean
Mid-early group									
Daya	4.30	3.72	3.09	2.43	4.44	3.28	4.35	2.54	3.52
Sarathi	3.74	3.15	2.61	2.37	3.20	2.80	3.43	2.07	2.92
Shrabani	4.20	3.07	2.48	2.57	2.69	2.52	2.32	1.53	2.67
Lalat	4.66	3.32	2.91	2.72	4.13	4.15	3.56	2.46	3.46
Ananga	3.89	3.57	2.83	2.44	2.83	3.32	2.28	1.85	2.88
Sebati	3.80	3.76	3.00	2.74	3.48	3.46	3.65	3.02	3.36
Bhoi	4.02	3.53	2.80	2.98	3.09	2.94	2.33	3.02	3.09
Konark	4.35	3.72	2.87	3.00	3.69	3.59	3.17	3.40	3.47
IR 36	3.87	3.50	2.35	2.48	3.67	3.30	3.37	2.76	3.16
IR 64	2.74	2.65	2.11	2.50	3.28	2.52	2.43	1.74	2.50
ORS 199-5	4.13	3.70	3.37	3.41	3.44	3.82	2.93	3.02	3.48
CR 749-20-2	4.04	3.41	2.89	2.94	2.70	2.52	3.09	1.81	2.93
Medium group									
Bhuban	4.89	4.33	3.74	3.04	4.74	4.06	3.84	2.86	3.94
Gouri	3.76	3.70	3.98	3.11	4.96	2.74	5.11	2.87	3.78
Birupa	5.04	3.89	3.94	3.06	5.06	3.11	4.44	3.21	39.7
Samanta	4.41	3.80	3.52	3.37	4.83	3.67	4.26	2.53	3.80
Bhanja	4.20	3.19	3.56	3.56	4.41	2.82	4.83	3.39	3.74
Meher	4.44	3.83	3.61	3.17	3.35	3.87	5.13	4.59	4.00
Kharavela	4.70	3.57	2.87	3.52	4.00	3.91	5.44	4.59	4.08
Gajapati	5.20	3.41	3.70	3.00	4.32	3.89	4.41	2.91	3.85
Surendra	4.30	3.32	3.22	2.78	5.00	4.37	4.50	3.13	38.3
Pratap	4.26	3.24	3.43	2.57	4.26	3.76	5.20	3.35	3.76
Tapaswini	4.59	3.69	2.87	1.56	4.04	3.72	5.41	5.33	3.91
Jaya	3.20	2.52	1.74	1.22	4.09	3.37	5.37	3.64	3.15
ORS 201-5	5.01	3.94	3.43	3.48	3.91	4.39	4.07	2.04	3.79
Vijetha	4.78	3.59	3.72	2.87	4.37	3.56	3.76	2.68	3.67
Env. Mean	4.25	3.50	3.10	2.81	3.92	3.44	3.95	2.94	3.49
	Genotype in Environment			Environment			Genotypes		
CD (P=0.05)	7.88			1.53			2.77		

from regression.

Based on regression co-efficient (b) and deviation from regression (S^2_d), the genotypes are classified into four adaptive groups (Table 4). The genotypes Daya, Lalat, Bhuban, Birupa, Samanta, Gajapati, Surendra and Vijetha with b values greater than 1.0 and S^2_d values not significantly different from zero are treated as varieties with “below average stability” which indicated that these genotypes are likely to be better adapted to favourable environments and there is yield reduction in the unfavourable environments. Similarly, Sebati, Konark, IR 64 and ORS 199-5 with b values less than 1.0 and S^2_d not significantly different from zero are regarded as genotypes with “above average stability”, where higher mean yield is sacrificed with changes in the environment or in other words where yield is not much affected by the change in the mean yields over the environments. Genotypes like Sarathi and IR 36 with b values equal to 1.0 and S^2_d estimate not significantly different from zero are considered as varieties with “average stability” because the yield response of these varieties are almost parallel to the change of the mean yield in environments. In other words these genotypes are grouped as stable

Table 3. Stability parameters for grain yield (t ha^{-1}) under linear regression model in relation to environments (sowing dates)

Genotypes	Mean	b	MS-Dev.	S^2_d	R^2 (%)
Daya	3.52	1.498±0.172*	5.558	0	92.7
Sarathi	2.92	1.027±0.128	3.130	0	91.4
Shrabani	2.67	0.942±0.453	38.911*	31.019*	41.9
Lalat	3.46	1.226±0.289	15.830	7.938	75.0
Ananga	2.88	0.706±0.455	39.284*	31.392*	28.6
Sebati	3.36	0.668±0.145	4.007	0	77.9
Bhoi	3.09	0.314±0.371	26.081*	18.189*	10.7
Konark	3.47	0.638±0.266	13.442	5.550	49.0
IR 36	3.16	0.978±0.190	6.818	0	81.5
IR 64	2.50	0.557±0.270	13.826	5.934	41.5
ORS 199-5	3.48	0.291±0.289*	16.003	8.111	14.5
CR 749-20-2	2.93	0.774±0.401	30.472*	22.580*	38.4
Bhuban	3.94	1.218±0.285	15.367	7.475	75.3
Gouri	3.78	1.075±0.544	56.203*	48.311*	39.4
Birupa	3.97	1.366±0.319	19.313*	11.421	75.3
Samanta	3.80	1.176±0.285	15.427	7.535	73.9
Bhanja	3.74	0.828±0.409	31.812*	23.920*	40.6
Meher	4.00	0.512±0.481	43.967*	36.075*	15.9
Kharavela	4.08	0.861±0.528	52.952*	45.060*	30.7
Gajapati	3.85	1.387±0.217	8.964	1.072	87.2
Surendra	3.83	1.304±0.342	22.166*	14.274	70.8
Pratap	3.76	1.273±0.358	24.334*	16.442*	67.8
Tapaswini	3.91	1.301±0.841	134.367*	126.475*	28.5
Jaya	3.15	1.604±0.802	122.131*	114.239*	40.0
ORS 201-5	3.79	1.282±0.445	37.667*	29.775*	58.0
Vijetha	3.67	1.193±0.244	11.282	3.390	80.0

b: *significant > 0<1, at 5% level of significance; MS-Dev.: *significant > $Se^2_,$ at 5% level of significance; S_d^2: *significant > 0, at 5% level of significance

Table 4. Classification of genotypes on the basis of 'b' and 'S^2_d'

Groups	Characteristics	Stability performance	Genotypes
Group I	b>1,S^2d_i H"0	Below average stability	Daya, Lalat, Bhuban, Birupa, Samanta, Gajapati, Surendra Vijetha
Group II	b<1, S^2d_i H"0	Above average stability	Sebati, Konark IR64, ORS 199-5
Group III	b=1, S^2d_i H"0	Average stability	Sarathi, IR 36
Group IV	b= any value S^2d_i =significant	Unstable	Shrabani, Ananga, Bhoi ,CR 749 20-2, Gouri, Bhanja Meher, Kharavela, Pratap, Tapaswini, Jaya, ORS 201-5

genotypes with general adaptability. The remaining genotypes Shrabani, Ananga, Bhoi, CR 749-20-2, Gouri, Bhanja, Meher, Kharavela, Pratap, Tapaswini , Jaya and ORS 201-5 with b any value and S^2_d significantly different from zero are considered to be varieties with unpredictability of stability in respect of grain yield.

It was observed from the present study that majority of the high yielding genotypes in both mid-early group (Daya, Lalat, Sebati, Konark and ORS 199-5) and medium maturity group (Bhuban, Birupa, Meher, Kharavela and Tapaswini) with high yield potential have either above average (b>1) or below average (b<1) responses. It has been reported earlier in wheat that cultivars bred in good environments and also possessing high yield potential have yielded the most in sub-optimal environments (Walton, 1968; Laing and Fischer, 1977) and the response of these varieties was higher (b>1) under favourable environments and lower (b<1) under sub-optimal conditions. Mishra and Mahapatra (1998) suggested to evaluate these genotypes in favourable as well as less favourable environment and to carry out the regression analysis separately to identify varieties combining high yield potential with wider array of adaptation to variable environments. It was also revealed during the present investigation that the genotypes like Sarathi and IR 36 with low yield potential exhibited average stability with unit regression and S^2_d values not significantly different from zero. The results thus conforms that the varieties with low productivity usually exhibit wide adaptability over a wider range of environments and high yielding genotypes which are brought about by genetic manipulation will necessarily lead to loss of yield stability. It is therefore necessary to design breeding programmes aiming at combining these two important genetic traits like high yield and greater stability in the development of superior varieties in rice.

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