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Stability Analysis for Grain Yield of Lowland Rice for the Largest Rice-Growing Region of Eastern india

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ABSTRACT: Twenty-one lowland rice genotypes were evaluated for their stability parameters with respect to grain yield in a multi locational trial at five different sites of Eastern India viz. CRRI, Cuttack (Orissa); OUAT, Bhubaneswar (Orissa); CRS, Masodha (UP); RAU, Pusa (Bihar) and RARS, North Lakhimpur (Assam). Pooled analysis of variance reflects existence of genotype x environment interactions and contribution of both linear and non-linear components to genotype (G) x environment (E) interactions. Through stability parameter analysis it was found that Rayda B_3, CR 778-95 and CR 661-236 were suitable for over all environments where as Sabita, OR 1334-16 and OR 1358-RGA-4 were suitable for rich environments. PSR 1209-2-3-2, CR 780-1937, Ambika, OR 877-ST-4-2 and CR 662-2211 were identified for poor environments.

***Keywords*: rice, grain yield, stability, G x E interaction**

Rice (*Oryza sativa* L.) is the most important cereal crop of India. As this crop is grown under a varied range of agroclimatic conditions ranging from upland to lowland and irrigated to rainfed situations, their phenotypic responses vary greatly in accordance with the environment. Rainfed lowland environments are mostly unfavourable and characterized by variable water regimes, occurrence of submergence and water logging. Nearly 38 million hectare in the world is rainfed lowland out of which 35 million ha is in South-east Asia. Water depth in rainfed fields is mostly variable depending on rainfall distribution, pattern and soil topography. OToole & Chang (1978) analyzed the rice growing environments and found physical environmental constraints the major factors which limit the rice productivity. The major efforts in crop technology under unfavourable environment should be yield stabilizing, cost reducing, risk minimizing and returns enhancing (Nanda & Tomar, 1981). The genotypes should therefore be high stability cultivars besides high yielding cultivars. Many methods are available for assessing the stability of performance of crop varieties. Finlay & Wilkinson (1963), Eberhart & Russell (1966), Perkins & Jinks (1968) and Freeman & Perkins (1971) have given some stability models. These models are helpful in identification of adaptable genotypes over a wide range of environments; achieving stabilization in crop production over locations; developing phenotypically stable high potential cultivars; effective selection for yield stability and prediction of varietal responses over changing environments. The present investigation was aimed at identifying high yielding and high stability cultivars for rainfed unfavourable lowlands of eastern India.

MATERIALS AND METHODS

Twenty-one lowland genotypes viz. NDR 40001-1-2, NDR 40055-2-1, Rayda B_3, Borjohingia, LPR 106, Panikekoa, PSR 1209-2-3-2, RAU 1306-2-2, CN 1035-61, Sabita, Purnendu, Hanseswari, Ambika, CR 778-95, CR 662-2211, CR 661-236, CR 780-1937, CR 682-162, OR 1334-16, OR 1358-RGA-4 and OR 877 ST-4-2 were evaluated for yield under multi- locational trials at five locations of Eastern India viz. CRRI (Cuttack, Orissa), OUAT (Bhubaneswar, Orissa), CRS (Masodha, U.P.), RARS (North Lakhimpur, Assam) and RAU (Pusa, Bihar) during the wet season of 2000 (Table 1). The materials were transplanted with 20×15cm spacing in Randomized Block Design (RBD) with three replications with plot size of 15 m^2. Recommended management practices were followed. The maximum water depth in the plots during the experimental period was 50 - 60 cm. The replication wise plot yield data of individual entries were recorded and computed in tons per hectare. Stability parameters were estimated following Eberhart & Russell (1966) model

$$Y_{ij} = \mu_i + \beta_i \cdot I_j + \sigma_{ij},$$

Where Y_{ij} is the performance of i-th variety at j-th environment, μ_i is the mean of i-th variety over all environments, β_i is the regression coefficient of the i-th variety on environmental means, I_j is the environmental idex obtained as the mean of all varieties at the j-th environment (minus grand mean), and σ_{ij}, is the deviation from regression of the i-th variety under j-th environment.

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RESULTS AND DISCUSSION

Analysis of variance (Table 2) for grain yield revealed significant differences among the genotypes and environments. Highly significant mean squares due to genotype×environment (G×E) interaction revealed that the genotypes interacted considerably with environmental conditions. Both linear and non-linear components of G×E interaction were found to be significant for grain yield as indicated by highly significant mean squares due to G×E (linear) interaction and polled deviation.

Environmental index (Ij) directly reflects the poor or rich environment in terms of negative or positive values of Ij respectively. Hence, CRRI (Cuttack), OUAT (Bhubaneswar) and CRS (Masodha) represent poor environment (when inputs are limited and conditions are unfavourable / stress conditions) whereas RARS (North Lakhimpur) and RAU (Pusa) represent rich environment (when inputs are unlimited and conditions are favourable) (Table 3).

Table 2. Analysis of Variance for stability of grain yield over environments.

Source of variation	df	Mean Square
Genotypes (G)	20	4.24*$
Env.+(G* Env.)	84	1.96$
Environments (Env.)	4	5.30*$
G* Env.	80	1.79$
Environments (Lin.)	1	21.20*$
G* Env. (Lin.)	20	1.48$
Pooled Deviation	63	1.81$
Pooled Error	200	0.01

*Significant against pooled deviation; $significant against pooled error at 5% probability leve

Table 1. Environmental conditions at multi-location site of Eastern India from June to November 2002.

Location/Site	Average Max. Temp (°C) (Mean)	Average Min. Temp (°C) (Mean)	Total rainfall (mm) (Mean)	Avg. Sunshine hours (Mean)
CRRI (Cuttack, Orissa)	31.9	24.3	166.7	6.1
OUAT (Bhubaneswar, Orissa)	32.2	22.3	250.8	5.9
CRS (Masodha, UP)	30.6	20.7	163.8	5.8
RAU (Pusa, Bihar)	30.8	24.7	167.8	5.4
RARS (N. Lakhimpur, Assam)	36.3	4.7	350.8	6.0

Table 3. Means table for grain yield (t/ ha) over five different locations of Eastern India.

S. No.	Designation	CRRI Orissa	OUAT Orissa	NDUAT UP	RARS Assam	RAU Bihar	Gen. mean
1	NDR 40001-1-2	0.39	1.05	3.30	3.15	1.50	1.88
2	NDR 40055-2-1	1.00	1.20	5.20	3.60	2.00	2.60
3	Rayda B_3	2.70	2.70	4.60	4.70	4.27	3.79
4	Borjohingia	1.20	3.20	2.60	5.60	1.35	2.79
5	LPR 106	1.75	1.00	1.00	3.80	2.00	1.91
6	Panikekoa	2.08	0.70	3.05	4.30	3.95	2.82
7	PSR 1209-2-3-2	4.30	3.00	3.10	3.00	3.30	3.34
8	RAU 1306-2-2	1.50	2.84	1.00	3.30	3.30	2.39
9	CN 1035-61	0.61	3.60	1.30	3.00	3.90	2.48
10	Sabita	5.75	2.30	1.00	5.90	3.70	3.73
11	Purnendu	6.30	2.05	2.50	3.00	4.00	3.57
12	Hanseswari	6.75	2.50	3.00	3.40	4.11	3.95
13	Ambika	4.54	2.31	3.50	3.20	3.90	3.49
14	CR 778-95	3.90	3.30	3.60	4.90	4.20	3.98
15	CR 662-2211	3.50	3.10	5.80	5.00	3.90	4.26
16	CR 661-236	4.40	5.95	4.90	5.90	5.30	5.29
17	CR 780-1937	5.90	5.50	4.00	4.52	5.50	5.08
18	CR 682-162	3.40	3.15	2.10	1.20	3.10	2.59
19	OR 1334-16	0.83	3.30	3.00	6.00	3.50	3.33
20	OR 1358-RGA-4	1.66	6.00	1.20	6.50	4.80	4.03
21	OR 877 ST-4-2	2.05	4.40	3.80	3.00	5.00	3.65
Environmental Index (Ij)		–0.306	–0.372	-0.353	0.763	0.268	
			Grand Mean = 3.38				

The yield of different genotypes under study (Table 3) varied from 0.39 t·ha^{-1} (NDR 40001-1-2) to 6.75 t·ha^{-1} (Hanseswari) at CRRI, Cuttack; from 0.70 t·ha^{-1} (Panikekoa) to 6.00 t·ha^{-1} (OR 1358-RGA-4) at OUAT, Bhubaneswar; from 1.00 t·ha^{-1} (LPR 106, RAU 1306-2-2 and Sabita) to 5.80 t·ha^{-1} (CR 662-2211) at CRS, Masodha; from 1.20 t·ha^{-1} (CR 682-162) to 6.50 t·ha^{-1} (OR 1358-RGA-4) at RARS, North Lakhimpur and from 1.35 t·ha^{-1} (Borjohingia) to 5.50 t·ha^{-1} (CR 780-1937) at Rau, Pusa. The population mean is 3.38 t·ha^{-1}. Eleven genotypes viz. Rayda B_3, Sabita, Purnendu, Hanseswari, Ambika, CR 778-95, CR 662-2211, CR 661-236, CR 780-1937, OR 1358-RGA-4 and OR 877 ST-4-2 recorded better yield than the average whereas two genotypes (PSR 1209-2-3-2 and OR 1334-16) were at par with the average yield (Table 3). The general mean over locations revealed that CR 661-236 was the best with highest value (5.29 t·ha^{-1}) followed by CR 780-1937 (5.08 t·ha^{-1}), CR 662-2211 (4.26 t·ha^{-1}), OR 1358-RGA-4 (4.03 t·ha^{-1}) and CR 778-95 (3.98 t·ha^{-1}).

The grain yield of rice fluctuates considerably with the change in environmental conditions. Hence, a variety possessing reasonable stability for yield is desirable for minimising the risk of yield loss in harsh environments of unfavourable low land situation. Finlay & Wilkinson (1963) suggested linear regression co-efficient as a measure of phenotypic stability. Eberhart & Russell (1966) emphasised that both linear (bi) and non-linear (S^2di) component of G x E interactions should be considered while judging the phenotypic stability of a genotype. They further suggested that an ideal variety should have high mean with linear regression co-efficient equal to unity and S^2di as small as possible. Later Breese (1969), Paroda & Hayes (1971) and Jatsara & Paroda (1980) have emphasized the use of deviation from regression as a measure of stability whereas the linear regression could be treated as a measure of varietal response to environments. Accordingly the mean and the deviation from regression of each genotype was considered for stability and linear regression was used for testing the varietal response.

In the present study, the genotypes Rayada B_3, CR 778-95 were found to be suitable for general adaptation, i.e. suitable for overall environmental condition as their bi (linear response) was around 1.0 with least deviation from linearity and above average mean (Table 4). Though the genotype NDR 40001-1-2 had bi value around 1.0, it was rejected because of its low mean performance.

The highest yielding genotype CR 661-236 was found to be slightly less responsive as its bi value (0.626) was less than 1.0 (Table 4). The second highest yielding genotype CR 780-1937 was found to be least responsive because of its negative bi value (-0.338) (Table 4). The other varieties with negative bi values are Purnendu and Hanseswari. All these genotypes are suitable for poor environments. The genotypes like Sabita and OR 1358-RGA-4 were found to be suitable for better environments as their bi values are significantly higher than 1.0. The analysis of variance (Table 2) revealed significant difference among genotypes and environments. Significant G × E interaction indicated considerable interaction of genotypes with environmental conditions that existed at different locations. These results were in conformity with the earlier reports of Maurya & Singh (1977), Ganesh & Sounarapandian (1988), Kulkarni & Eswari (1994), Roy & Panwar (1994) and Reddy & Chaudhary (1991) in rice. The linear contribution of environmental effects on the performance of genotypes was reflected by highly significant mean square due to environment (linear). The significant mean square due to genotype × environment (linear) interaction (Table 2) indicated that considerable proportion of genotype × environment interaction was contributed by the linear component. Therefore, prediction for most

Table 4. Mean performance and stability parameters for grain yield.

S. No.	Designation	Mean (t/ha)	bi	S^2di
1	NDR 40001-1-2	1.88	1.120	1.789
2	NDR 40055-2-1	2.60	0.689	4.038
3	Rayda B_3	3.79	1.263	0.810
4	Borjohingia	2.79	2.138	2.679
5	LPR 106	1.91	2.152	0.179
6	Panikekoa	2.82	2.341	0.992
7	PSR 1209-2-3-2	3.34	−0.349	0.347
8	RAU 1306-2-2	2.39	1.518	0.736
9	CN 1035-61	2.48	1.336	2.193
10	Sabita	3.73	2.497	3.981
11	Purnendu	3.57	−0.212	3.775
12	Hanseswari	3.95	-0.357	3.666
13	Ambika	3.49	0.001	0.900
14	CR 778-95	3.98	1.160	0.034
15	CR 662-2211	4.26	0.583	1.527
16	CR 661-236	5.29	0.626	0.436
17	CR 780-1937	5.08	−0.338	0.781
18	CR 682-162	2.59	−1.195	0.637
19	OR 1334-16	3.33	2.946	1.563
20	OR 1358-RGA-4	4.03	3.052	4.915
21	OR 877 ST-4-2	3.65	0.024	1.781
	Mean	3.38	1.000	
	SE (m)	±0.67		
	SE (b)		±1.340	

* bi and S^2di represent linear and non-linear component

Table 5. Genotypes recommended for various environments.

S. No.	Adaptive Specificity	Varieties Suitable
1	Rich Environment	Sabita, OR 1334-16, OR 1358-RGA-4
2	Poor Environment	PSR 1209-2-3-2, CR 780-1937, Ambika, OR 877 ST-4-2, CR 662-2211
3	Over all Environment	Rayda B_3 , CR 778-95 and CR 661-236

of the genotypes appeared to be feasible for yield. Highly significant mean squares due to pooled deviation for yield revealed the importance of non-linear component accounting for total genotype x environment interaction. Therefore, genotypes differed considerably with respect to their stability for yield. Similar results were obtained by Kulkarni *et al.* (1988) and De *et al.* (1990) in rice. Hence, it is obvious that both linear and non-linear components contribute to the G × E interaction for grain yield indicating the importance of both regression co-efficient (bi) and deviation from regression (S^2di) in determining the stability of grain yield. These results suggested that wide differences existed among the genotypes over the range of environments and it may be possible to classify these genotypes for their adaptation behaviour.

In the present study, only three genotypes Rayda B_3, CR 778-95 and CR 661-236 fulfilled the conditions for an ideal variety with high mean, linear response and least deviation from linear regression. Hence, these genotypes were identified as suitable for general adaptation i.e. suitable for growing over all the environments under study.

The entries, PSR 1209-2-3-2, CR 780-1937, Ambika, Purnendu and Hanseswari are identified for poor environment as they exhibited high mean and negative bi (Table 4). That means they reflect negligible response to the environmental changes i.e. remain steady under poor conditions but cannot exploit the positive improvement in the favourable environment. Among these PSR 1209-2-3-2 and CR 780-1937 are steady althrough with low S^2di value whereas Ambika deviates moderately with a moderate S^2di value. Purnendu and Hanseswari fluctuate considerably with high S^2di. Hence only PSR 1209-2-3-2, CR 780-1937 and to certain extent Ambika can be recommended for the poor environments studied. OR 877-ST4-2 and CR 662-2211also recorded high yield, low response to environment and moderate fluctuation from linearity (Table 4). Hence, these two varieties may also be recommended for poor environment.

Sabita, OR 1334-16 and OR 1358-RGA-4 exhibited high mean, high bi and high S^2di (Table 4). It suggests that these varieties are highly sensitive to environment under intensive agriculture responding 2-3 times for a unit change in the environmental milieu, when inputs are no limitations, such varieties can yield maximum, whereas in poor conditions they fail miserably. Hence, these varieties can be recommended for rich environments studied. Therefore following recommended varieties / entries are suitable under different or fragile environmental conditions (Table 5).

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