Doi: HTTPS://DOI.ORG/10.23910/IJBSM/2018.9.1.3C0293

Genotype×Environment Interactions and Stability for Grain Yield and its Components in WBPH Tolerant Rice (*Oryza sativa* L.) Genotypes

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Article History

Article ID: 3C0293
Received in 03rd October, 2017
Received in revised form 29th December, 2017
Accepted in final form 25th January, 2018

Abstract

The present study was conducted during *kharif*, 2013–2015 with three different seasons at Main Rice Research Station, Anand Agricultural University, Nawagam, Gujarat. The stability analysis was carried out to study genotype x environment interaction for grain yield per plant. Analysis of stability parameters revealed that the mean squares due to genotypes were significant for all the characters. However, variances for environments were significant for all the characters studied except plant height and hulling per cent revealed that environment differ from season to season. The mean sums of squares for genotype×environment interactions in pooled analysis were found significant only for grain yield per plant. This suggested that the genotypes under study had reacted differently to the environments for grain yield per plant and remaining characters showed non-significant mean squares indicated that environment had little effects on the expression of those characters. Based on stability parameter for grain yield per plant, genotypes *viz*., IR 71700-247-1-1-2, IR 13146-45-2-3, IR 04A 395, IR 09A 102, IR 09N 190, IR 10A 110, IR 78581-12-3-2-2, GAR 13 and Gurjari were identified as stable genotypes with average stability and wider general adaptability over the environments. While, IR 02A 585, IR 77334-99-2-3-2 and IR 09A 104 were identified stable for favorable environments.

Keywords: Genotype×environment interaction, stability analysis and rice

1. Introduction

Rice (*Oryza sativa* L.) is considered as one of the most important crop plants from *Poaceae*. Globally rice is planted in about 150 million ha and 497 million tonnes of produce is harvested annually (Anon., 2015). Out of this, Asia accounts for 90% of the production and consumption of rice. India has the world's largest area under rice with 36.84 mha and is the second largest producer (124.05 mt in 2015-16) next only to China. The world population will increase to over 4.6 billion by 2050, which demands more than 50% of rice needs to be produced what is produced at present to cope with the growing population (Sreedhar *et al.* 2011).

India is largest rice growing country in the world; however its productivity per unit area is low. Therefore, efforts to enhance rice productivity coupled with stability of performance under varying environments must receive top priority. As stability testing of promising early genotypes of prime importance for increasing and stabilizing yield in crop plants, present investigation was undertaken to isolate stable genotypes in rice. G×E interaction underlies the very success of a scientific crop improvement programme related to stability of genotype/varieties. Not only this, G×E also influences the post-breeding adaptive evaluation of improved strains before being released for commercial cultivation. In any crop, genotypes differ for their yielding ability when grown in different agro-ecological niches. An ideal genotype is one that yields high and stable in its performance across environments. Its stability can be judged on phenotypic basis, where phenotype may be defined as a linear function of genotype, environment and their interaction effects. Relative importance of main and interaction effects may vary from genotype to genotype and with environment. Thus, the study of G×E interaction serves as a guide and helps in identifying suitable genotype for various environmental niches and evaluation of high yield and desirable grain quality for different environments is one of the exciting research leads to successful evaluation of stable genotype against WBPB, which could be used for general cultivation. Therefore, the present investigation was carried out, identifying stable genotypes with high yield (Ajmera et al., 2017)

2. Materials and Methods

Fifty one WBPH resistance genotypes received from IRRI, Philippines along with checks (GAR 13, Gurjari and GR 11) were evaluated in Randomized Block Design with three replications in three different seasons *viz.,* E1: *Kharif* (2013), E2: *Kharif* (2014) and E3: *Kharif* (2015) at Main Rice Research Station, Anand Agricultural University, Nawagam (Gujarat). Each plot consisted of twenty plants in a row keeping 20 and 15 cm inter and intra row spacing, respectively. The recommended package of practices was adopted to raise a good crop. Five competitive plants were randomly selected and tagged excluding border plants to minimize border effect. The observations on tagged plants were recorded on twelve characters *i.e*., day to 50% flowering, plant height (cm), panicle length (cm), effective tillers plant^{-1}, test weight (g), grain yield per plant (g), grain length (mm), grain breadth (mm), grain length : breadth ratio, hulling (%), milling (%), head rice recovery (%). The character day to 50% flowering was recorded on per plot basis. The data obtained were analysed for stability parameters as per method proposed by Eberhart and Russell (1966).

3. Results and Discussion

The data obtained from three seasons were subjected to statistical analysis as per Eberhart and Russell model (1966). The analysis of variance for stability with regard to grain yield and other related traits in rice are presented in Table 1. The mean squares due to genotypes were significant for all the characters; while, the mean square for environments were found to be significant for all the traits except plant height and hulling per cent when tested against pooled error. The genotype x environment interaction was highly significant only for grain yield per plant. This indicated that the genotypes interacted significantly to different environments for grain yield per plant only. Further the environments+(genotypesxenvironments) mean squares revealed higher magnitude of environments (linear) and genotypes x environments (linear) components indicating that the predictable component accounted major part of total variation. The environments + (genotypesxenvironments) interaction was observed to be significant for the characters days to 50 per cent flowering, panicle length, test weight and grain yield per plant. The further partitioning of environments + (genotypesxenvironments) component of variation revealed that the environments (linear) component of variation were observed to be significant for all the characters except plant height and hulling percentage. Further, the higher magnitude of mean squares for environment (linear) compared to genotypes x environments (linear) indicated that linear response of environment account for the major part of total variation for all the characters studied. However mean square for pooled deviation was significant only for grain yield per plant. The results are akin with the findings of Bhelkar *et al.* (2004) and Bhakta and Das (2008).

Several workers also reported significant genotype x environment interaction for grain yield *viz*., Belhekar et al. (2004), Munisonnappa et al. (2004), Senapathi and Sarkar (2004), Babu et al. (2005); Bhakta and Das (2008); Das et al. (2010); Ahmad and Torabi (2011), Waghmode and Mehta (2011), Bose et al. (2012); Patel et al. (2015).

The relative magnitude of linear and non-linear components

Table 1: Analysis of variance for phenotypic stability for different characters in rice

Sr. No.	Characters	Mean sum of squares							
		Genotypes (G)	Environments (E)	Genotypes ×Environments (G x E)	E + (G ×E)	Environments (linear)	G×E (linear)	Pooled deviation	Pooled error
Degree of freedom		53	2	106	108	1	53	54	318
1.	Days to 50% flowering	172.00**	143.26**	6.18	8.67**	286.51**	10.51**	1.80	6.89
2.	Plant height (cm)	973.89**	5.01	5.17	5.16	10.02	7.36	2.92	18.43
3.	Panicle length (cm)	5.25**	53.51**	3.00	3.92**	107.02**	3.85**	2.12	2.72
4.	Effective tillers plant^{-1}	1.30**	3.88**	0.74	0.80	7.76**	0.72	0.74	1.59
5.	Test weight (g)	23.93**	182.96**	1.61	4.91**	365.92**	3.22*	0.02	5.33
6.	Grain yield plant^{-1} (g)	5.92**	39.65**	2.86**	3.53**	79.30**	3.46**	2.20**	1.28
7.	Grain length (mm)	2.14**	0.53**	0.01	0.01	1.06**	0.01	0.014	0.059
8.	Grain breadth (mm)	0.67**	0.36**	0.01	0.01	0.72**	0.01	0.01	0.038
9.	Grain L:B ratio	1.65**	1.00**	0.03	0.01	2.01**	0.06	0.01	0.14
10.	Hulling (%)	3.08**	0.18	0.24	0.24	0.36	0.24	0.23	1.58
11.	Milling (%)	3.21**	2.94**	0.16	0.21	5.88**	0.05	0.26	0.93
12.	Head rice recovery (%)	27.15**	12.61**	0.15	0.38	25.23**	0.02	0.27	5.96

*, and ** Significant at (p=0.05) and (p=0.01) levels of probability, respectively.

of G x E interaction would decide, whether the performance of a genotype for the character under consideration would be predictable or not? Since, when both linear and non-linear (pooled deviation) components of G x E interaction are significant, the magnitude of both the components need to be considered and greater magnitude of linear component [G x E (L)* > G x E (NL)*] suggests the linear response of genotypes thereby possibility for prediction of performance of genotypes over the environments. Accordingly, three kinds of linear responses (b_i) *viz.*, b_i<1, b_i=1 and b_i>1 have been considered and interpreted as b_i=1, average stability and widely adapted to different environments; b_i>1 and significant, above average stability, increasing sensitivity to environmental changes and well adapted to favorable environment and b_i<1 and significant, below average stability, greater tolerance to environmental changes; thereby genotype would have specific adaptability to poor environment.In consideration to all above requirements and limitations, the stability parameters were worked out and interpreted only for grain yield per plant.

3.1. Environmental index

The environmental index computed for the twelve characters studied are presented in Table 2 indicated both the favorable and unfavorable environments for all the component characters. The environmental index calculated as the deviation of the mean of all the genotypes at a particular environment from the grand mean of all the genotypes revealed that E2 (*Kharif* - 2014) recorded a substantial increase in the values of environmental index and proved to be the favorable environment to realize increased grain yield per plant accompanied by increased values in the environmental index for other characters grain length, gain breadth and grain length: breadth ratio.

Table 2: Estimated environmental index for various characters in rice

Characters / Environment	Environmental index			$\sum I^2_j$
	E_1	E_2	E_3	
Days to 50% flowering	-0.679	1.842	-1.164	5.209
Plant height (cm)	0.030	0.285	-0.316	0.182
Panicle length (cm)	-1.076	0.214	0.862	1.946
Effective tillers per plant	-0.170	-0.136	0.306	0.141
Test weight (g)	-2.010	1.003	1.103	6.653
Grain yield per plant (g)	-0.771	0.910	-0.138	1.442
Grain length (mm)	-0.105	0.090	0.015	0.019
Grain breadth (mm)	0.087	-0.073	0.014	0.013
Grain length : breadth ratio	-0.153	0.103	0.050	0.036
Hulling (%)	-0.010	-0.052	0.062	0.007
Milling (%)	0.210	-0.247	0.037	0.107
Head rice recovery (%)	0.494	-0.463	-0.031	0.459

E_1: *Kharif* 2013; E_2: *Kharif* 2014; E3: *Kharif* 2015

The environments E3 (*Kharif* - 2015) are found suitable for days to 50 per cent flowering, plant height, panicle length, effective tillers per plant, test weight and hulling %. The environment E1 was found to be the suitable for the characters *viz*., milling and head rice recovery percentage.

3.2. Phenotypic stability parameters

The estimates of stability parameters for only grain yield per plant were computed to evaluate relative stability of 54 different genotypes as per Eberhart and Russell (1966). The results are presented in Table 5. The genotypes with higher mean values, regression coefficient value near to unity (bi = 1) and non-significant deviations from linear regression (S^2di = 0) were considered as stable genotype for that trait and adaptable to varied environmental conditions studied in the present investigation. However, genotypes with a higher mean value and value of regression coefficient more than unity with non-significant deviation from linear regression were considered to be responsive and suitable for favourable environmental conditions. Further, the genotypes with higher mean values and regression coefficient less than unity or negative and non-significant deviations form linear regression were considered to be responsive and suitable for poor environmental conditions. Accordingly, the genotypes were classified as suitable for varied environmental conditions as per Table 3.

The stability parameters of grain yield per plant revealed that 24 genotypes exhibited high mean as compare to population mean. The genotype IR04N 106 (15.42 g) registered the highest grain yield per plant. Out of 54 genotypes studied the genotype TN 1 (6.23 g) exhibited lowest grain yield per plant. The average grain yield per plant over population and environments was 11.00 ± 0.65 g, hence genotypes with higher grain yield than 11.65 g were considered as better performing genotypes for grain yield per plant.

Among 54 genotypes, 22 genotypes showed significant deviation from regression showing that their performance could not be predictable over environments and remaining 32 genotypes had non-significant deviation from regression showing the predictability of performance across the environments.

Summarizing the stability parameters it was seen that among all the genotypes which showed unit regression coefficient and non-significant deviation from regression, nine cultivars were identified as most promising as it yielded higher grain yield per plant than population mean coupled with unit regression coefficient and non-significant deviation from regression. The genotypes IR 02A 485, IR 78545-49-2-2, IR 09A 104 showed higher mean value as compared to overall mean and had bi > 1 and non-significant deviation from regression, was considered as "variety with above average stability" which indicating that the genotypes were likely to be better adapted to favourable environments and yield reduction is likely in the unfavourable environments (Table 4).

Table 3: Criteria for classification of genotypes for various characters on the basis of mean performance and stability parameters

Group	Mean	bi	S^2di	Behavior
I	High	Around unity	Around zero	Average response, high stability
II	High	Significantly deviating from zero	Around zero	
		(i) bi > 1		Above average response and high stability/better in good environments
		(ii) bi < 1		Below average response and high stability/better in poor environments
III	High	Significantly deviating from zero	Significantly deviating from zero	Unpredictable behavior
IV	High	Around unity	Significantly deviating from zero	Unpredictable behavior

Shanmuganathan and Ibrahim (2005) reported that the high yielding varieties do not necessarily exhibit stability for grain yield over the environments. Bhatka and Das (2008) confirmed that the varieties with low productivity usually exhibit wide adaptability over a wide range of environments and high yielding genotypes which are brought about by genetic manipulation will necessarily lead to loss of yield stability. The study of Munisonnappa *et al*. (2004) indicated that high

Table 4: Classification of genotypes for grain yield per plant on the basis of mean performance and stability parameters

Characters	Average stability and wide/ general adaptability	Below average stability and adapted to poor environment	Above average stability and adapted to better environment
	Genotypes		
1	2	3	4
Grain yield plant^{-1}	IR 71700-247-1-1-2	-	IR 02A 485
	IR 71700-247-1-1-2		IR 77734-93-2-3-2
	IR 13146-45-2-3		IR 09A 104
	IR 04A 395		
	IR 09A 102		
	IR 09N 190		
	IR 10A 110		
	IR 78581-12-3-2-2		
	GAR 13		
	Gurjari		

Table 5: Stability parameter for grain yield per plant in fifty four genotypes in rice

Sr. No	Genotypes	Mean	bi	S^2_{di}
1.	ARC 10550 (ACC12507)	11.10	-1.21	1.65*
2.	ASD 7 (ACC6303)	7.36	1.17**++	-0.43
3.	Chinsaba (ACC 33016)	7.69	0.95**	-0.25
4.	Milyang 46 (cheong-cheongbyeo)	8.44	-0.01	0.36
5.	Milyang 54 (gayabyeo)	9.40	0.56*+	-0.36
6.	BG 367-2	14.81	-0.71	3.06**
7.	Milyang 55	12.35	-1.55	7.6**
8.	Milyang 63	8.65	1.05**	-0.3
9.	Mudgo (ACC6663)	12.51	3.06*	2.46**
10.	Pokkali	8.43	3.33	5.49**
11.	Rathu Heenati (ACC11730)	7.84	0.74	0.51
12.	TN 1	6.23	1.31	1.41*
13.	Swarnalata (ACC33964)	6.95	0.9	0.46
14.	T 12 (ACC 56989)	9.66	-1.61	2.57**
15.	IR 64	10.43	-0.62	2.56**
16.	IR 71700-247-1-1-2	11.90	0.99**	-0.34
17.	IR 02A483	13.93	1.03	1.2
18.	PT B33	8.31	2.94**++	-0.16
19.	IR 02A485	12.41	1.38**++	-0.41
20.	IR 77734-93-2-3-2	12.89	2.01**++	-0.4
21.	IR 77186-148-3-4-3	13.62	-0.21	4.81**
22.	IR 77542-90-1-1-1-1-5	10.17	-0.35	3.51**
23.	IR 78119-24-1-2-2-2	9.91	2.41	3.51**

Continue...

Sr. No	Genotypes	Mean	bi	S^2_{di}
24.	IR 13146-45-2-3	11.87	1.53*	0.17
25.	IR 78545 -49-2-2-2	11.61	1.31**++	-0.42
26.	IR 04A 395	12.93	1.39**	-0.29
27.	IR 04N 106	15.42	-2.15	8.08**
28.	IR 05N412	12.55	0.19	0.18
29.	IR 06M147	11.56	2.49*	1.39*
30	MUTNS 1	9.34	0.55	-0.07
31.	IR 06N 119	12.86	-0.08	0.57
32.	IR 07A 166	10.54	1.93	2.58**
33.	IR 08 N210	15.39	-1.91	12.45**
34.	IR 09A 102	11.75	1.19**	-0.33
35.	IR 09A 104	13.12	1.64**++	-0.41
36.	IR 13540-56-3-2-1	7.87	0.08++	-0.36
37.	IR 09 A105	12.80	0.11	0.39
38.	IR 09N 190	12.78	1.15*	-0.13
39.	IR 09 N379	10.37	0.96	3.18**
40.	IR 09N 496	12.22	3.3*	3.57**
41.	IR 09N 534	10.86	3.41	4.03**
42.	RP 1486-842-1	8.83	2.52**+	0.42
43.	IR 09N 538	10.62	6.38	16.72**
44.	IR 10A 108	10.99	2.9	3.05**
45.	IR 10A 110	12.11	1.25**	-0.31
46	IR 10A 114	12.25	-0.97	2.23*
47.	IR 10A 115	9.51	1.62	1.47*
48.	Sinna sivappu (ACC 15444)	8.54	-0.2+	0.1
49.	IR 10A 117	8.46	2.05*	0.79
50.	IRRI 123	7.51	0.16**++	-0.43
51.	IR 78581-12-3-2-2	13.77	1.64**	-0.03
52.	GAR 13	13.04	1.74**	0.13
53.	GURJARI	15.03	1.34*	-0.03
54.	GR 11	10.91	-0.98++	0.21
Population mean			11.00	
SEm±			0.65	

*, ** =significant at (*p*=0.05) and (*p*=0.01) level respectively, ** = significant at (*p*=0.05) level when Ho : bi =0; ++ = significant at (*p*=0.05) level when Ho : bi =1

productivity does not always have stability of production. Hence the findings of the present investigation are in close agreement with the above findings.

4. Conclusion

In the study of Borthakur *et al*. (2005) local cultivars were reported to be stable in four environments created by manipulation of agronomic practices. Differences in stability were found to be both due to differences in linear response of genotypes and deviation from linear response, which is also in conformity with the findings of present investigation.

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