Journal of Applied Science and Agriculture, 9(1) January 2014, Pages: 56-62

AENSI Journals

Journal of Applied Science and Agriculture

ISSN 1816-9112

Journal home page: www.aensiweb.com/jasa/index.html

Stability for BRRI developed Promising Hybrid Rice for Yield and it's Related traits

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ARTICLE INFO

Article history:
Received 19 November 2013
Received in revised form 17 December 2013
Accepted 21 December 2013
Available online 5 March 2014

Keywords:
PCA, AEZ, RCBD, Biplot analysis.

ABSTRACT

The study was performed to analyze the genotype-by-environment (G x E) interaction for thirteen (13) promising rice hybrids over 5 locations in Bangladesh. The purpose of this study was to evaluate the magnitude of stability and adaptability of the genotypes in different regions of the country in different environmental status. Multivariate analysis (MANOVA) technique was used for grain yield, days to 50% flowering and number of panicles per m^2 where two genotypes used as local check. The AMMI (Additive Main effects and Multiplicative Interaction) model was used to assess the interaction and to select better performing ones having higher yield and other potential attributes. Considering the mean, regression coefficient (bi) and deviation from regression (S^2di), it was evident that all the genotypes showed different responses of adaptability under different environmental conditions. Analysis of variance (ANOVA) showed high significant effects of environments, genotypes and G x E for grain yield, days to 50% flowering and number of panicle per m^2. Among the hybrids BRRI 10A/BRRI 12R, BRRI 9A/BRRI 15R, BRRI hybrid dhan2, BRRI dhan28 and BRRI dhan29 found highly stable across the environments. BRRI 10A/BRRI 12R, BRRI 9A/BRRI 15R, II32A/BRRI 15R, II32A/BRRI 10R and BRRI hybrid dhan3 are highly stable as well as high yielder. BRRI hybrid dhan2 also highest yielder and stable across environment. Comilla and Shatkhira showed high mean with high negative interaction. Gazipur had moderate yielder with high positive interaction and Barisal given negligible interaction and found highly suitable region in Bangladesh for hybrid rice cultivation.

To Cite This Article: M. Umma Kulsum, M.Jamil Hasan, Md. Ismail Hossain and Niaz Md. Farhat Rahman., Stability for BRRI developed Promising Hybrid Rice for Yield and it's Related traits. ***J. Appl. Sci. & Agric.,*** *9(1): 56-62, 2014*

INTRODUCTION

Hybrid rice varieties are expected to shift the yield potential of the rice plant by 15-20% or more with same amount of agricultural inputs. The technology has attracted the attention of researchers and policy makers in all over the world as a viable option to overcome the yield ceilings of presently available modern rice varieties. By the year of 2030, Bangladesh has to produce 40 million tons rice from around 8.5 million hectare of land for 190 million peoples. In that case, an average yield of rice needs to be increased from 2.80 t/ha to 4.0 t/ha. To meet this global challenge of food security effectively, it is imperative that all possible resources be used judiciously and efficiently. Rice breeder will be key person to mitigate this huge task.

The Genotype x Environment interaction structure is an important aspect of both plant breeding programmes and the introduction of new crop cultivars (Freeman, 1985). Evaluation of interaction of genotypes with locations and other agro-management conditions would help in getting information on adaptability and stability of performance of genotypes. The AMMI model suggested by Zobel *et al*. (1988), Gauch (1992) and Purchase (1997) is considered to be a better model for analysis of G x E interaction in yield data of multilocation varietals trials. It not only gives estimate of total G x E interaction effect of each genotype but further partitions it into interaction effects due to individual environments. AMMI model is recently widely used for interpretation of G x E interaction, biplot are commonly used to interpret the AMMI analysis which considered yield in one axis and Principal Component Analysis (PCA) scores on another axis or two PCA axes scores on two axes (Crossa *et al*., 2002). The present study in hybrid rice was undertaken to analyze G x E interaction using AMMI model and to evaluate stability and adaptability genotypes in different environments.

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MATERIALS AND METHODS

The experiment was conducted in five different agro ecological zones (AEZ) in Bangladesh. Genotypes were evaluated in a randomized complete block design (RCBD) with three replicates in a plot size of 30m^2 at spacing of 20x15 cm^2. Eleven promising rice hybrids developed from BRRI with two popular check variety BRRI dhan28 and BRRI dhan29 were used as experimental materials in the present investigation. For final setting the experiment, 30 days old seedlings were used and one seedlings were transplanted as per hill. Adequate soil fertility was ensured by applying additional quantities of Urea- TSP-MP- Gypsum- $ZnSO_4$ @ 270:130:120:70:10 kg/ha, respectively. All intercultural operations were collected from ten randomly selected competitive plant of each plot while yield data was recovered on whole plot basis.

AMMI model was used to quantify the effect of different factors (genotype, location) of the experiment. The AMMI statistical model is most appropriately termed as a hybrid model. It makes use of standard ANOVA procedures to separate the additive variance from multiplicative variance (genotype by environment interaction). Then it uses a multiplicative procedure- PCA- to extract the pattern from the G x E portion of the ANOVA (Zobel *et al*., 1988). Thy hybrid model is:

$$Y_{ge} = \mu + \alpha_g + \beta_e + \sum_{n=1}^{N} \lambda n \gamma_{gn} \delta_{en} + \rho_{ge}$$

Where:

Y_{ge} = yield of the genotype (g) in the environment (e)

μ = grand mean

α_g = genotype mean deviation

β_e = environment mean deviation

N= No. of IPCAs (Interaction Principal Component Axis) retained in he model.

λn = singular value for IPCA axis **n**

γ_{gn} = genotype eigenvector values for IPCA axis **n**

δ_{en} = environment eigenvector values for IPCA axis **n**

ρ_{ge} = the residuals

The model further provides graphical representation of the numerical results (Biplot analysis) with a straight-foreword interpretation of the underlying causes of G x E ((Gauch, 1988), (Kempton, 1984), (Bradu and Gabriel, 1978)).

Results:

The AMMI analysis of variance is presented in Table 1. It clearly indicated that highly significant (at 1% level) mean sum of squares due to genotype were lot of genetic diversity for productivity among the genotypes. Highly significant mean sum of squares due to environments in respect of days to 50% flowering, number of panicle per m^2 and yield indicate that the environments considered were highly diverse and suitable to test for the stability of a genotype.

Table 1: Analysis of variance of the G x E interaction of hybrid rice

Source of variation	df	Days to 50% flowering	Number of panicles per m^2	Yield (kg/plot)
Genotypes (G)	12	46.078***	1421.870***	29.797***
Environment (E)	4	412.848***	2191.790***	20.409***
Replication	2	11.836***	230.892ns	0.7414ns
Interaction G x E (GEI)	48	2.850***	427.342**	2.174**
AMMI Component 1	15	4.677ns	919.678***	3.965**
AMMI Component 2	13	3.805**	219.775ns	2.205ns
AMMI Component 3	11	1.365ns	218.428ns	1.268ns
AMMI Component 4	9	0.238ns	161.942ns	0.249ns
GxE (Linear)	12	5.523***	558.968**	3.601***
Pool deviation	36	1.959	383.467	1.698
Pooled error	128	1.622	378.006	1.65552

*** Significant at 1% level , ** Significant at 5% level

The genotype x environment interactions were found to be significant for days to 50% flowering, number of panicles per m^2 and grain yield, which indicated significant differences among the regression coefficient and that the data might be extended for stability analysis. The highly significant effects of environment indicate high differential genotypic response across the different environments. The variation in soil structure and moisture across the different environments were considered as a major underlying causal factor for the G x E interaction. The effect of genotype x environment interaction could be divided into four components for grain yield ie, IPCA1, IPCA2, IPCA3 and IPCA4 where IPCA1 is significantly different. The significant G x E (linear) interaction for days to maturity, number of panicles per m^2 and grain yield indicated the presence of the difference among the regression of the varieties on the environmental indices.

The hybrids BRRI1A/BRRI12R, BRRI10A/BRRI15R, BRRI9A/BRRI15R, BRRI hybrid dhan2, standard check variety BRRI dhan28 and BRRI hybrid dhan3 had negative phenotypic index (Pi), insignificant regression coefficient (bi) and deviation from regression (S^2di) indicated that they are exhibited comparatively less days to 50% flowering and stable across the environments. The hybrids II32A/BRRI16R and BRRI10A/BRRI13R had positive phenotypic index (Pi), regression coefficient (bi) value significantly different from the unity with non significant deviation from regression (S^2di) value indicating highly responsiveness of these two hybrids for Gazipur, Barisal, Shatkhira and Comilla (Table 2).

Table 2: Stability analysis for days to 50% flowering of thirteen promising hybrid rice in five environments (boro 2009-10).

En.No	Pedigree	Locations						Phenotypic Index (Pi)	bi	S^2di
		Gazipur	Barisal	Shatkhira	Comilla	Rangpur	Overall Mean			
1	BRRI 1A/ BRRI 12R	112.7	112.3	114.3	112.3	124.0	115.1	-3.60	0.873	1.37
2	BRRI 10A/ BRRI 12R	116.0	118.3	118.7	120.3	130.0	120.7	2.00	0.957	0.68
3	II32 A/ BRRI 15R	115.0	117.3	117.3	120.3	131.0	120.2	1.50	1.106	1.61
4	II32 A/ BRRI 16R	116.0	117.3	118.3	118.0	127.0	119.3	0.60	0.776 *	0.05
5	II32 A/ BRRI 10R	114.7	117.7	116.0	118.0	132.0	119.7	1.00	1.230	1.75
6	II32 A/ BRRI 12R	115.0	116.3	120.3	119.7	130.0	120.3	1.60	1.021	1.97
7	BRRI 10A/ BRRI 13R	114.3	116.7	120.0	120.3	135.0	121.3	2.60	1.421 *	1.26
8	BRRI 10A/ BRRI 15R	111.0	114.7	116.7	117.0	124.0	116.7	-2.00	0.795	3.26
9	BRRI 9A/ BRRI 15R	116.0	116.7	115.7	114.3	124.0	117.3	-1.40	0.631	2.61
10	BRRI Hybrid dhan 2	114.0	114.0	113.7	113.3	127.0	116.4	-2.30	1.024	2.52
11	BRRI dhan 28	108.0	109.7	113.3	113.3	122.0	113.3	-5.40	0.928	2.51
12	BRRI dhan 29	122.0	120.7	123.7	122.7	136.3	125.1	6.40	1.118	1.57
13	BRRI Hybrid dhan 3	115.7	115.7	115.7	115.3	130.0	118.5	-0.20	1.120	2.34
	Mean	114.6	115.9	117.2	117.3	128.6	118.7			
	E index (Ij)	-4.10	-2.80	-1.50	-1.40	9.90				
	CV (%)	0.44	0.37	1.29	0.79	0.38				
	LSD (0.05)	0.85	0.72	2.54	1.56	0.83				

Among the hybrids BRRI hybrid dhan2 have the highest phenotypic index (Pi), insignificant regression coefficient (bi) and deviation from regression (S^2di) value indicating this hybrid is stable over the five locations Gazipur, Barisal, Shatkhira, Comilla and Rangpur. The hybrids II32A/BRRI16R, BRRI10A/BRRI13R, BRRI hybrid dhan3 gave positive and considerable phenotypic index (Pi) values along with insignificant regression coefficient (bi) and deviation from regression (S^2di) values indicating these three hybrids are stable over the all environments. The hybrids BRRI1A/BRRI12R, BRRI10A/BRRI12R, II32A/BRRI15R, II32A/BRRI10R, II32A/BRRI12R BRRI10A/BRRI15R and BRRI9A/BRRI15R had negative phenotypic index (Pi), insignificant regression coefficient (bi) and deviation from regression (S^2di) indicating they are stable but these seven hybrids can not be considered over these environments due to their lower number of panicles per m^2 (Table 3).

The environmental mean and genotypic mean of grain yield ranged from 17.64 to 20.09 kg/plot and 13.87 to 23.53 kg/plot respectively. Nine genotypes showed positive phenotypic index while the other genotype had negative phenotypic index for yield. Thus, positive phenotypic index indicate the higher yield and negative indicated the lower yield among the genotypes. Again, positive and negative environmental index (Ij) reflects the rich or favorable and poor or unfavorable environments for this character respectively. The environmental index (Ij) directly reflects the poor or rich environments in terms of negative and positive Ij, respectively. Thus the environment Gazipur, Barisal and Rangpur were indentified as poor, Shatkhira and Comolla were rich environments for rice hybrid production (Table 4).

Among the promising hybrids BRRI hybrid dhan2, BRRI 10A/BRRI 12R, II32A/BRRI 10R, BRRI 9A/BRRI 15R and BRRI hybrid dhan3 were higher yielding as well as stable over the environments other 4 hybrids II32A/ BRRI 15R, II32A/BRRI16R, II32A/BRRI 12R and BRRI 10A/BRRI 13R also stable with moderate yielding.

Table 3: Stability analysis for number of panicles per m^2 of thirteen promising hybrid rice in five environments (boro 2009-10).

En. No	Pedigree	Locations						Pheno typic	bi	S^2di
		Gazipur	Barisal	Shatkhira	Comilla	Rangpur	Overall			

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							Mean	Index (Pi)		
1	BRRI 1A/ BRRI 12R	216.0	225.3	248.7	264.0	220.7	243.9	-0.90	0.806	388.44
2	BRRI 10A/ BRRI 12R	298.1	233.0	217.0	226.0	245.0	243.8	-1.00	1.740	686.94
3	II32 A/ BRRI 15R	248.6	233.7	200.7	236.0	239.0	231.6	-13.20	1.204	115.64
4	II32 A/ BRRI 16R	275.0	222.0	211.0	257.0	262.0	245.4	0.60	1.841	244.08
5	II32 A/ BRRI 10R	242.0	231.7	218.0	232.0	211.0	226.9	-17.90	0.682	98.40
6	II32 A/ BRRI 12R	270.6	220.3	212.7	220.7	250.0	234.9	-9.90	1.220	469.22
7	BRRI 10A/ BRRI 13R	264.0	228.0	209.7	285.3	250.0	247.4	2.60	2.053	226.24
8	BRRI 10A/ BRRI 15R	264.0	219.3	184.0	236.0	197.3	220.1	-24.70	2.272	173.45
9	BRRI 9A/ BRRI 15R	252.8	235.0	232.3	244.7	243.3	241.6	-3.20	0.582	12.83
10	BRRI Hybrid dhan 2	259.5	242.3	241.0	269.0	272.3	256.8	12.00	0.695	177.02
11	BRRI dhan 28	231.0	272.7	265.0	273.0	230.7	254.5	9.70	-0.566	562.37
12	BRRI dhan 29	245.4	322.0	290.0	319.3	268.0	288.9	44.10	-0.726	1332.21
13	BRRI Hybrid dhan 3	270.6	231.3	226.7	250.7	256.0	247.1	2.30	1.197	114.76
	Mean	260.2	239.7	227.4	254.9	241.9	244.8			
	E index (Ij)	15.40	-5.1	-17.4	10.10	-2.90				
	CV (%)	5.04	3.27	4.35	4.73	4.96				
	LSD (0.05)	22.08	13.22	16.67	20.33	20.24				

Table 4: Stability analysis for yield (kg/plot) of thirteen promising hybrid rice in five environments (boro 2009-10).

En.No	Pedigree	Locations						Phenotypic Index (Pi)	bi	S^2di
		Gazipur	Barisal	Shatkhira	Comilla	Rangpur	Overall Mean			
1	BRRI 1A/ BRRI 12R	15.14	16.65	21.87	21.03	12.82	17.50	-1.8	2.783	3.70
2	BRRI 10A/ BRRI 12R	20.61	19.15	20.62	22.68	19.14	20.44	1.14	1.057	0.47
3	II32 A/ BRRI 15R	20.35	18.02	20.47	23.08	18.46	20.08	0.78	1.435	1.05
4	II32 A/ BRRI 16R	20.65	17.56	20.67	20.03	20.72	19.93	0.63	0.138	2.40
5	II32 A/ BRRI 10R	20.86	21.22	20.73	22.73	18.11	20.73	1.43	1.147	0.95
6	II32 A/ BRRI 12R	20.88	19.05	19.18	19.49	18.92	19.50	0.20	0.143	0.81
7	BRRI 10A/ BRRI 13R	18.80	19.71	20.16	24.66	17.27	20.12	0.82	1.955	2.22
8	BRRI 10A/ BRRI 15R	14.84	15.36	20.13	15.59	12.73	15.73	-3.57	1.358	5.91
9	BRRI 9A/ BRRI 15R	20.36	19.41	20.79	22.11	19.61	20.46	1.16	0.787	0.26
10	BRRI Hybrid dhan 2	22.88	23.01	23.53	25.53	22.71	23.53	4.23	0.778	0.52
11	BRRI dhan 28	14.21	13.92	13.60	14.70	12.90	13.87	-5.43	0.424	0.23
12	BRRI dhan 29	19.42	19.43	17.93	19.26	17.20	18.65	-0.65	0.362	1.12
13	BRRI Hybrid dhan 3	21.14	20.29	21.49	20.55	18.69	20.43	1.13	0.632	0.73
	Mean	19.24	18.68	20.09	20.88	17.64	19.30			
	E index (Ij)	-0.06	-0.62	0.79	1.58	-1.66				
	CV (%)	3.02	2.40	1.11	3.07	3.29				
	LSD (0.05)	0.98	0.75	3.27	1.08	0.98				

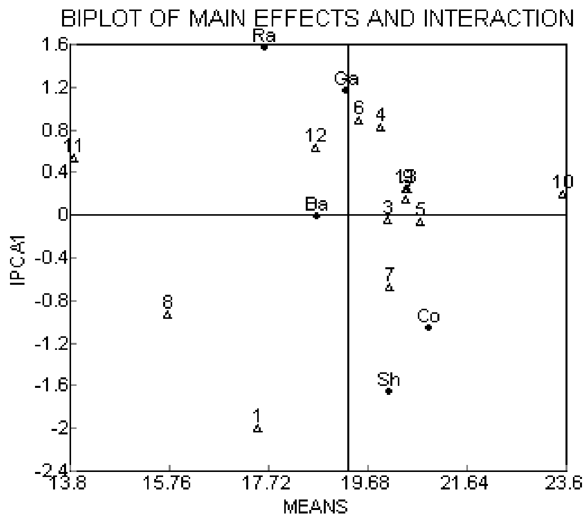

Fig. 1: Biplot of the first AMMI interaction (IPCA1) scores (Y-axis) plotted against mean grain yield (X-axis) for 13 rice hybrids in 5 environments in Bangladesh.

The G x E interaction was partitioned into IPCA1 and IPCA2. The most powerful interpretive tool in analysis of G x E interaction in AMMI model is the biplot analysis. The biplots permit easy visualization of differences in interaction effects. In AMMI biplot, the IPCA1 scores of genotypes and environments are plotted against their respective means and in AMMI 2 biplot the IPCA1 and IPCA2 scores of genotype and environments are plotted against each other. AMMI 1 biplot for grain yield of the 13 genotypes at 5 environmental conditions is presented in figure 1. The AMMI 1 biplot gave a model fit of 91.7%. The scatter of the genotype points in the AMMI biplot (Fig. 1) showed five adaptive groups of genotypes. The genotypes BRRI hybrid dhan2 formed an adaptive group with high mean accompanied with moderate positive interaction. The genotype II32A/BRRI15R and II32A/BRRI10R and BRRI 10A/BRRI 13R formed two adaptive groups having moderately high mean but the former group had negligible interaction, while the latter group had moderate negative interaction. Genotypes BRRI dhan28 and BRRI 10A/BRRI 15R and BRRI 1A/BRRI 12R formed two adaptive groups having similar low mean but the former group had moderate positive interaction, while the latter had high negative interaction. The remaining six genotypes, which scattered singly in the biplot, differed from each other both in mean and interaction effects. Among the environmental conditions, Comilla and Shatkhira had high mean with high negative interaction Gazipur had moderate yielder with high positive interaction, Rangpur and Barisal had low mean yield but Rangpur showed high positive interaction while Barisal showed negligible interaction.

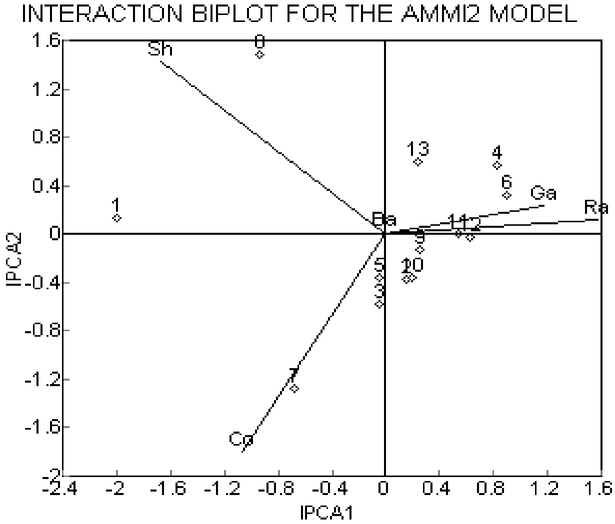

Fig. 2: Biplot of the first AMMI interaction (IPCA 2) score (Y-axis) plotted against AMMI interaction (IPCA 1) score (X-axis) for thirteen promising hybrid rice genotypes and five environment.

Figure 2 gives the AMMI 2 biplot for yield. Distribution of genotype points in the AMMI 2 biplot revealed that the genotypes BRRI 10A/BRRI 12R, BRRI9a/BRRI 15R, BRRI hybrid dhan2, BRRI dhan28 and BRRI dhan29 scattered close to the origin, indicating minimal interaction of these genotypes with environments. The remaining 8 genotypes scattered away from the origin in the biplot indicating that the genotypes were more sensitive to environmental interactive forces. Interaction of genotypes with specific environmental conditions was judged by projection of genotype points on to environment spokes.

On this basis the genotypes II32A/BRRI16R, II32 A/BRRI 12R, BRRI dhan28 and BRRI dhan29 had moderate positive interaction and BRRI 1A/BRRI 12R, BRRI 10A/BRRI 13R and BRRI 10A/BRRI 15R had moderate negative interaction under Gazipur and Rangpur region. Barisal present close to the origin indicating minimal interaction of this environments. BRRI 10A/BRRI 13R had moderate interaction under Comilla while BRRI 1A/BRRI 12R and BRRI 10A/BRRI 15R had moderate interaction under Shatkhira region.

Genotype with IPCA1 scores near zero had little interaction across environments while genotypes with very high IPCA1 values had considerable interactions across environments. Of the 13 genotypes seven had negligible interactions characterized by low IPCA scores. BRRI 10A/BRRI 12R, II32A/BRRI 15R, II32A/BRRI 10R, BRRI 9A/BRRI 15R, BRRI hybrid dhan2, BRRI dhan28 and BRRI hybrid dhan3 (Table 5) are relatively stable showing broad adaptation across environments. Six genotypes with higher IPCA scores were highly interactive and were unstable across environments, these were BRRI 1A/BRRI 12R, II32A/BRRI 16R, II32A/BRRI 12R, BRRI 10A/BRRI 13R, BRRI 10A/BRRI 15R and BRRI dhan29. Barisal was more stable environment than other locations for grain yield. Shatkhira and Comilla were highly productive but unstable environments. Rangpur were characterized with lower grain yield that was mainly due to edaphic and harsh climatic condition experienced here.

Table 5: AMMI mean yield and IPCA1 scores for 13 rice hybrids genotypes grown in 5 environments

Genotypes	ID	AMMI mean yield (kg/plot)	IPCA1 score
BRRI 1A/ BRRI 12R	1	17.502	-2.002
BRRI 10A/ BRRI 12R	2	20.441	0.15
II32 A/ BRRI 15R	3	20.076	-0.051

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II32 A/ BRRI 16R	4	19.927	0.833
II32 A/ BRRI 10R	5	20.73	-0.055
II32 A/ BRRI 12R	6	19.505	0.897
BRRI 10A/ BRRI 13R	7	20.12	-0.68
BRRI 10A/ BRRI 15R	8	15.73	-0.938
BRRI 9A/ BRRI 15R	9	20.457	0.249
BRRI Hybrid dhan 2	10	23.533	0.194
BRRI dhan 28	11	13.867	0.533
BRRI dhan 29	12	18.648	0.627
BRRI Hybrid dhan 3	13	20.431	0.243
Environments			
Gazipur	Ga	19.243	1.167
Barisal	Ba	18.675	-0.005
Shatkhira	Sh	20.09	-1.662
Comilla	Co	20.88	-1.065
Rangpur	Ra	17.637	1.566

Discussion:

The error from uncontrolled variation were calculated using the methods described by Gauch and Zobel (1997). The mean sum of squares due to genotype x environment interaction were also found highly significant which indicate that the yield performance of the genotypes was varied in different locations. Similar findings were also reported by Miah *et al*. (1994), Kumari *et al*. (1999) and Mahapatra *et al*. (1999) in rice. The significance exhibited by G x E interaction indicated that each of the genotype interacted differentially in various environment tested. Haque *et al*. (1991) reported significant mean squares due to genotypes and environments in rice. Sinha and Biswas (1986) also reported significant genotype x environment interaction for growth duration and grain yield. However, contrasting reports of significant G x E (linear) for grain yield have been reported indicating linear relationship in the expression of grain yield with different environments (Mahapatra and Das, 1999; Nanitadevi *et al*., 2006).

AMMI analysis (Zobel *et al*., 1988; Gauch, 1992; Purchase, 1997) gives estimate of total G x E interaction effect of each genotype and also further partitions it into interaction effects due to individual environments. Low G x E interaction of a genotype indicates stability of the genotype over the range of environments. A genotype showing high positive interaction in an environment obviously has the ability to exploit the agro-ecological or agro-management conditions of the specific environment and is there fore best suited to that environment. AMMI analysis permits estimation of interaction effect of a genotype in each environment and it helps to identify genotypes best suited for specific environmental conditions. Though analysis of G x E interaction of multilocation yield data in AMMI model have been reported by Mclaren and Chaudhury (1998); Ise *et al*. (2001); Vijayakumar *et al*. (2001); Asenjo *et al*. (2003); Mahalingam *et al*. (2006); Naveed *et al*. (2007) and Das *et al*. (2009) in rice, Tarakanovas and Ruzgas (2006) and Mohammadi *et al*. (2007) in wheat, Shinde *et al*. (2002) in pearl millet, Hariprasanna *et al*. (2008) in groundnut and few other crops but such reports in finger millet is lacking. All these workers found significant G x E interaction for grain yield and stressed the usefulness of AMMI analysis for selection of promising hybrid rice for specific locations or environmental conditions. Silveira and Vencovsky (1983) also reported stable rice cultivar with high yield. Genotypes with IPCA1 scores near zero had little interaction across environments. While the genotypes with large IPCA1 scores, either positive or negative direction were highly interactive. Similarly, locations with IPCA1 scores near zero had little interaction across genotypes and low discrimination among genotypes, genotypes and location combinations with IPCA1 scores of the same sign produced positive specific interaction effects, whereas combinations of opposite sign had negative specific interactions (Crossa, 1990; Crossa *et al*., 1991; Asenjo *et al*., 2003).

Biplots of IPCA1 and IPCA2 based on grain yield determined that the genotypes had wide or specific adaptation. Sutjihno (1996) reported that genotype located near the origin or point (0, 0) was classified as stable. The underlying causes of the interaction observed can therefore be based on both the genetic differences between these genotypes and the different environments by wallace *et al*. (1995).

Conclusion:

The AMMI statistical model has been used to diagnose the GxE interaction pattern of grain yield of hybrid rice. The hybrids BRRI 10A/BRRI 12R, II32A/BRRI 15R, II32A/BRRI 10R, BRRI 9A/BRRI 15R, BRRI hybrid dhan2 and BRRI hybrid dhan3 showed broad adaptation. They were hardly affected by the GxE interaction and thus will perform well across a wide range of environments. Barisal as good selection sites for identifying broad based and adaptable rice hybrid genotypes and for other improvement work on hybrid rice.

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