SHORT COMMUNICATION

Oryza Vol. 54 No. 2, 2017 (234-238)
DOI 10.5958/2249-5266.2017.00030.3

Stability analysis for grain yield in rice in demonstrations conducted during *rabi* season in India

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Received : 12 May 2016 Accepted : 18 February 2017 Published : 28 September 2017

ABSTRACT

Rice (Oryza sativa L.) is the staple food for more than 50 per cent world's population and 85 per cent Indian population. The rice production areas in the country are very diverse; hence, evaluation of genotype for its stable performance across the environment is very important. The study was undertaken to identify the stable rice variety in demonstration trials conducted on eleven varieties tested in five environments in rabi season. Among many available statistical techniques, the additive main effect and multiplicative interaction (AMMI) has been extensively used for GE interaction and stability analysis. First two PCA's are significant at 1 per cent and explained 89 per cent of the total variation with 24 degrees of freedom. The biplot obtained from AMMI analysis displayed PCA scores plotted against each other provides visual inspection. AMMI Stability Index (ASI) has been used to get quantitative value for stability analysis which helps in interpretation of the results. But, stable genotype may not always be high yielder which is the major requirement of farmers; therefore a new index namely 'Rank Based Stability Index (RBSI)' is proposed which identifies the stable genotype with high yield. The result showed that G1 and G2 were the most stable varieties with high grain yield, whereas G7 and G11 were found to be least stable. All eleven varieties were grouped into four clusters. First cluster consists of two varieties G1 and G2; second cluster contains four varieties G6, G10, G5 and G9; third cluster includes two varieties G4 and G11; and fourth cluster comprised of three varieties G8, G3 and G7.

Key words: *Rice, AMMI stability index, rank based selection index, rabi*

Rice (*Oryza sativa* L.) is the staple food for more than 50 per cent worlds population and 85 per cent Indian population. India is the second largest rice producing country in the world. In India, rice was cultivated on 42.75 million hectares with a production of 105.24 million tons and productivity of 2.46 tons ha^{-1}. Although more than 1000 rice varieties have been released in India, many of them are no longer cultivated within a few years due to inconsistent performance in diverse environments and only few varieties with stable performance continue under cultivation. The rice production areas in the country are very diverse in hydrology and combined to other soil and climatic factors make a difference in rice yield (Singh et al., 1997).

A genotype that shows consistent performance across different environments over years for a given trait is considered stable. Interpretation of performance of a number of genotypes in a broad range of environments is always affected by genotype × environment (GE) interactions (Gauch and Zobel, 1996). A genotype that has stable trait expression across environments contributes little to GE interaction and its performance should be more predictable from the main effects of genotypes and environments than the performance of an unstable cultivar (Sneller et al., 1997). The statistical methods to study stability analysis can be divided into two broad groups: univariate and multivariate stability statistics (Lin et al., 1986). Various statistical methods have been proposed by several authors to study GE interactions and stability analysis (Lin et al., 1986; Becker and Léon, 1988; Crossa, 1990; Lin and Binns, 1994; Hussein et al., 2000; Mohammadi and Amri, 2008; Mohammadi et al., 2010; Paul et al., 2016; Singh et al., 2016). Among multivariate methods, the additive main effect and multiplicative interaction analysis (AMMI) has been extensively applied in the statistical analysis of multi-environment cultivar trials (Kempton, 1984; Crossa, 1990; Gauch and Zobel, 1997).

The AMMI model combines ANOVA for the genotype and environment main effects with principal components analysis of GE interaction into the unified approach (Gauch, 1988; Gauch and Zobel, 1996 and Zobel et al., 1988). The biplot display of PCA scores plotted against each other provides visual inspection and interpretation of GE interaction components (Thillainathan and Fernandez, 2001). The AMMI model does not make provision for a quantitative stability measure, such a measure is essential in order to quantify and rank genotypes according to their yield stability. Gauch and Zobel (1996) recommended that the most accurate model for AMMI can be predicted using the first two IPCAs. Jambhulkar et al., (2015) proposed AMMI Stability Index (ASI) to quantify the result based on first two IPCAs.

But, it may happen that the stable genotype always may not be high yielding genotype. Hence, a new index *i.e.,* Rank Based Stability Index (RBSI) is proposed based on AMMI stability index (ASI) and yield of the genotype. With this background the present study was undertaken to identify the high yielding stable rice genotypes based on proposed index, rank them and to classify the genotypes based on different studied parameters.

The data on grain yield of rice used in this study was taken from the demonstration plot of National Rice Research Institute, Cuttack, India during five consecutive years from 2009-10 to 2013-14 in rabi season. Seeds of eleven rice varieties including two hybrids (Table 1) were sown in the nursery bed and subsequently twenty five days old seedlings were transplanted in the demonstration plot. Fertilizer was applied @ 100:50:50 kg ha^{-1} of N:P:K for hybrid varieties (Ajay and Rajalaxmmi) and 80:40:40 kg ha^{-1} of N:P:K for other high yielding varieties. The entire dose of P and K along with one third dose of N was applied as the basal dose, while remaining two third dose of N was applied in two equal split. First dose applied at tillering and the other dose was applied at panicle initiation stage. Appropriate cultural practices such as weeding, intermittent irrigation and need-based plant protection measures were undertaken to raise a healthy crop. Grain yield (t ha^{-1}) was recorded by bringing down the moisture level to 12 per cent. Data analysis was done by using SAS 9.2 software.

The AMMI analysis first fits additive effects for genotypes and environments by the usual additive analysis of variance procedure and then fits multiplicative effects for genotype × environment by principal component analysis. The AMMI model was

$$Y_{ij} = \mu + g_i + e_j + \sum_{k=1}^{n} \lambda_k \alpha_{ik} \gamma_{jk} + \varepsilon_{ij}$$

where Y_{ij} is the yield of the ith genotype in the jth environment, g_i is the ith genotype mean deviation, e_j is the jth environment mean deviation, λ_k is the square root of the eigen value of the PCA axis k, α_{ik} and γ_{jk} are the principal component scores for PCA axis k of the ith genotype and the jth environment, respectively and ε_{ij} is the residual.

The environment and genotypic PCA scores are expressed as unit vector times the square root of λ_k *i.e.,* environment PCA score = $\lambda_k^{0.5}\gamma_{ik}$; genotype PCA score = $\lambda_k^{0.5}\alpha_{ik}$5.

Jambhulkar et al., (2015) proposed AMMI Stability Index (ASI) to quantify the result based on first two PCAs has been calculated as follows:

$$ASI=\sqrt{\frac{\left[\left(IPCA1_{score}\right)^2 X \left(IPCA1_{\%explainedsumofsquare}\right)^2\right] +}{\left[\left(IPCA2_{score}\right)^2 X \left(IPCA2_{explainedsumofsquare}\right)\right]}}$$

where, $IPCA1_{score}$ - First principal component score of interaction effect

$IPCA2_{score}$- Second principal component score of interaction effect

$IPCA1_{\%\exp lainedsumofsquares}$ - Percentage sum of squares explained by first principal component interaction effect

$IPCA2_{\%\exp lainedsumofsquares}$ - Percentage sum of squares explained by second principal component interaction effect. The genotype with lowest ASI value is most stable genotype.

It may not always be necessary that the stable genotype will be the high yielding genotype. Therefore one new genotype selection index *i.e.*, Rank based stability index (RBSI) is proposed. The rank based stability index is calculated as follows:

RBSI = R (ASI) + R (GY)

where R(ASI) is the rank of AMMI Stability Index and R(GY) is the rank of grain yeld.

The genotype with smallest value of RBSI is considered as most stable genotype with high yield.

The GE interaction was studied by additive main effect and multiplicative interaction (AMMI) analysis. In AMMI, the additive portion is separated from interaction by analysis of variance. Then the principal component analysis, which provides a multiplicative model, is applied to analyze the interaction effect from the additive model. First principal component explained 65 per cent of the variation with 13 degrees of freedom and second principal component explained 24 per cent of the variation with 11 degrees of freedom. So, the first two principal components cumulatively explained 89 per cent of the total GE interaction variation with 24 degrees of freedom. Both first two principal components were significant at 1 per cent level of significance. Third and fourth principal components were explained 7 per cent and 4 per cent variation respectively, but both were non significant at 5 per cent.

A biplot was generated using first two principal components. A biplot generated using genotypic and environmental scores of the first two AMMI components (Vargas and Crossa, 2000) have four sections, depending upon signs of the genotypic and environmental scores. In biplot, the genotypes which are close to intersection lines of zero are considered as stable. It can be seen from Fig. 1 that G1, G2, G6 and G10 were close to the intersection line of zero. Genotypes G4 and G5 were best for environment E4 and E5; genotypes G3, G7 and G8 were suitable for environment E1 and E2; and the best genotype with respect to environment E3 is genotype G11 (Fig. 1).

Table 1. Variety name along with its grain yield, ASI, RBSI value and its rank

SR	Name	Grain Yield (t/ha)	Rank (GY)	ASI	Rank (ASI)	RBSI	Rank (RBSI)
G1	Rajalaxmi	7.08	2	1.800	3	5	1
G2	Ajay	7.12	1	1.923	4	5	1
G3	Geetanjali	4.04	9	3.944	7	16	6
G4	Naveen	4.86	5	6.385	10	15	5
G5	Chandan	5.26	4	3.818	6	10	3
G6	Hazaridhan	4.28	7	1.011	1	8	2
G7	Kamesh	3.96	10	5.385	9	19	8
G8	Sadabahar	3.66	11	2.275	5	16	6
G9	Satyakrishna	6.12	3	4.307	8	11	4
G10	IR 64 Sub 1	4.14	8	1.138	2	10	3
G11	Improved Lalat	4.7	6	7.262	11	17	7

Considering all the environments, no single environment had both IPCA1 and IPCA2 nearer to the zero line which indicated the presence of GE interaction over the grain yield performance of the eleven rice varieties. In general, factors like type of crop, diversity of the germplasm, and range of environmental conditions will affect the degree of complexity of the best predictive model (Crossa et al., 1990).

Gauch and Zobel (1996) recommended that the most accurate model for AMMI model can be predicted using the first two interaction principal component axis. This can also be verified using our results that, the first two principal components explained 89 per cent of the total variation and also significant at 1 per cent. AMMI stability index (ASI) has been computed for all the eleven varieties. The result shows that G6 ranks first followed by G10, but G6 ranks 7th and G10 ranks 8th position in grain yield. G9 and G11 ranks 3rd and 6th in grain yield, but ranked 8th and 11th respectively position

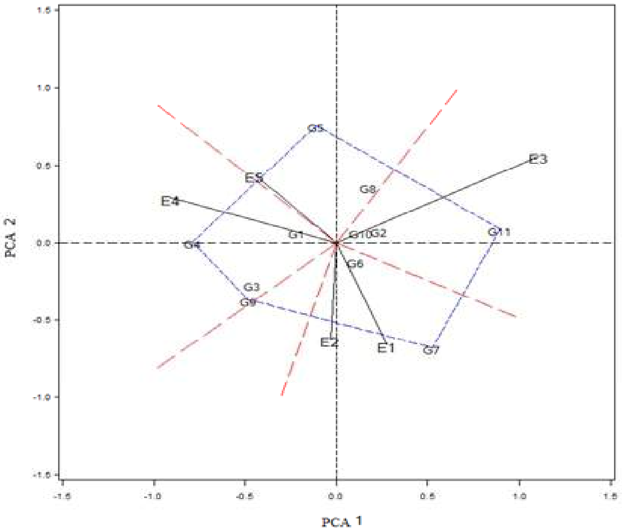

Fig. 1. Biplot of PCA score from AMMI analysis of eleven rice varieties grown in five environments

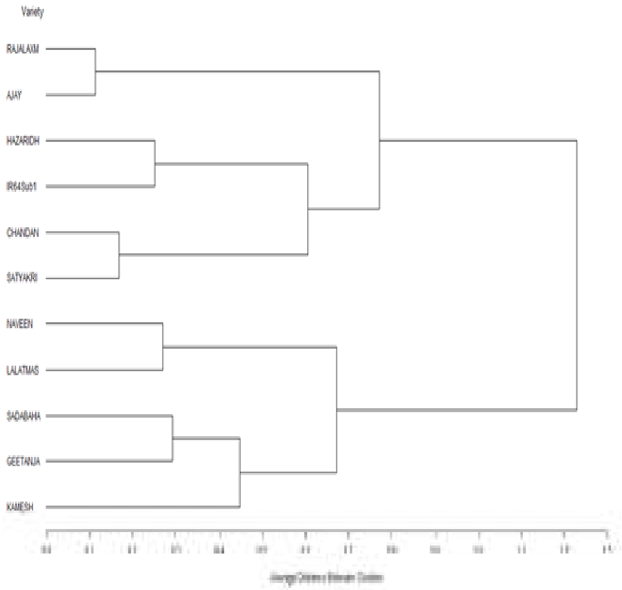

Fig. 2. Hierarchical cluster analysis of the eleven rice varieties

in ASI (Table 1). However, G8 ranks 5th in ASI, but it ranks 11th in grain yield. This showed that high yielding variety need not necessarily to be stable always. Hence RBSI is calculated to identify the stable variety with high grain yield. According to RBSI, G1 and G2 were the most stable varieties with high grain yield (Table 1). G7 and G11 were found to be the least stable varieties.

Further, each variety was grouped according to their grain yield ranking, ASI and RBSI (Fig. 2). All the eleven varieties were grouped into four clusters. Cluster 1 comprises two varieties G1 (Ajay) and G2 (Rajlaxmi) which are stable with high grain yield; cluster 2 consists of four varieties G6 (Hazaridhan), G10 (IR 64 Sub 1), G5 (Chandan) and G9 (Satyakrishna); cluster 3 includes two varieties G4 (Naveen) and G11 (Lalat Mas); and cluster 4 involves three varieties G8 (Sadabahar), G3 (Geetanjali) and G7 (Kamesh) which are least stable and low grain yielding varieties (Fig. 2).

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