

## AMMI ANALYSIS FOR YIELD AND STABILITY IN DIRECT SEEDED RAINFED RICE

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### Abstract

The genotype × environment interaction and stability performance of 15 rice landraces was studied using the additive mean effects and multiplicative interaction (AMMI) analysis. The overall, results indicated that significant genotype × environmental interaction (GEI) influenced the relative ranking of the rice landraces across the years/seasons. It was evident from AMMI analysis that first two principal components accounted for 91.90%, which is enough to explain the variability among the landraces. The landraces, G8 (Kallurundaikar), G4 (Sivapuchithiraikar) and G5 (Kuruvaikalanjiyam) exhibited high grain yield. The AMMI 2biplot revealed that the rice landraces, G12 (Poongar), G14(Kala namak) and G15 (Kichali samba) are close to the origin indicating non sensitive nature of these genotypes with the years/seasons and highly stable genotypes across the environments with low yield potential when compared to others. According to the polygon view of GGE biplot, the genotype G8 (Kallurundaikar) was the winner in the environments E2 and E5 whereas the genotypes G5 (Kuruvaikalanjiyam) and G7 (Mattaikar) were the winners in the environment E1, E3 and E4. The landrace, G8 (Kallurundaikar), has high mean yield with stable performance over five environments being the overall best and it may be considered for the direct seeded rice cultivation in the rainfed ecosystem.

### Introduction

Rice (*Oryza sativa* L.) feed the world by standing as topper on table of the stable food crops. Indian farmers are witnessing severe problems associated with the scarcity of water, labour, and resources with changing climatic conditions. Direct-seeded rice (DSR) can effectively address the problem of water-labour shortage in both rainfed and irrigated areas through reduced use of water for land preparation. In India 12 mha area is occupied by direct seeded rice and 28% to the total rice area. Although many more rice varieties have been released, many of them were no longer cultivated within a few years due to inconsistent performance in diverse environments and only a few varieties with stable performance continue under cultivation after many years (Bose *et al.* 2014).

The performance of any character is a combined result of the genotype (G) of the variety, the environment (E) and the interaction between genotype and environment (GE). To evaluate the consistency of rice grain yield and develop genotypes that respond optimally and consistently across years and geographic regions, it is necessary to research on yield stability and GE interactions (Blanche *et al.* 2009). Better understanding of GE interactions and stability in crops was used as a decision tool, particularly at the final stage of variety introduction process, to generate essential information on pattern of adaptation in breeding lines, screen new varieties for release, and determine the recommendation domains for released varieties (Yan and Kang, 2003).

A genotype may be considered to be stable if its environmental variance is small. The level of performance of a character is a result of the genotype of cultivar, the environment in which it is

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grown and interaction of G and E. Interaction between these two explanatory variables gives insight for identifying genotypes suitable for specific environments. The environmental effect is typically a large contribution to total variation (Blanche *et al.* 2009). Moreover GE interaction greatly affects the phenotype of a variety and informs us to perform stability analysis to know the performance of varieties in different environments to help the plant breeders in selecting desirable genotypes.

Various statistical procedures have been proposed to find out the stability of new cultivars, many of them are based on a regression model (Yates and Cochran 1938). Additive main effect and multiplicative interaction (AMMI) is especially effective tool where the assumption of linearity of the response of genotype to a change in the environment is not fulfilled (Zobel *et al.* 1988, Yan and Hunt 1998) and which usually separates the interaction part of the multiplicative components into the additive main effects by principal component analysis. Thus, the present study was aimed to identify more high yielding stable promising varieties and to determine the environment where rice varieties would be adapted by AMMI model. Therefore, using the AMMI analysis with biplot facility, yield data were analyzed to determine the nature and magnitude of G x E interaction effects on grain yield in consecutive five years.

### Materials and Methods

The experimental material comprised with 15 rice landraces which were evaluated in a randomized block design with three replications at Agricultural Research Station, Tamil Nadu Agricultural University, Paramakudi during Rabi 2015-16, Rabi 2016-17, Rabi 2017-18, Rabi 2018-19 and Rabi 2019-20. The experimental site is located at 9° 21' N latitude, 78° 22' E longitudes and an altitude of 42 m above mean sea level with average annual rainfall of 840 mm. This site has clay loam soil texture with pH of 8.0. Each genotype was raised in 5 x 2 m plot keeping 15 x 10 cm spacing. The recommended agronomic practices followed to raise good crop stand. The grain yield per plot (kg) was recorded on ten randomly selected plants from each replication and converted into kg per hectare.

The data were subjected to analysis of variance and then taken for AMMI analysis for identification of stable genotypes. The pooled analysis of variance was proceeded to look at G x E and stability of the genotypes across all environments. Analysis of variance was significant for genotypes, environments and (G x E) components indicating the usefulness of AMMI analysis in identifying the stable genotypes. The AMMI model, which combines standard analysis of variance with PC analysis, was used to investigate of G x E interaction. In AMMI model the contribution of each genotype and each environment to the GEI was assessed by use of the biplot graph display in which yield means are plotted against the scores of the IPCA1 (Zobel *et al.* 1988). ANOVA and Stability analysis for yield trait was carried out by using the AMMI model R-packages 1.5, PB Tools 1.4 version IRRI. The G x E interaction was analyzed following AMMI biplot (Gauch and Zobel 1989).

### Results and Discussion

The details of the rice landraces and testing years/seasons presented in Table 1 showed that combined analysis of variance for genotype, environments and genotype x environment interactions of 15 landraces in five production years/seasons were highly significant for grain yield indicating the use of AMMI analysis. Further, it indicated that 67.92% of the total sum of squares was attributed to genotypic effects, 2.43% to genotypic effects and 29.65% to genotype x environment interaction effects (Table 2). The presence of genotype x environment interaction (GEI) was clearly demonstrated by the AMMI model and variance of G x E was partitioned into

two significant principal components. This implied that the first two principal components are enough to explain the interaction effects of 15 rice landraces in five production years/seasons. These findings are in agreement with the findings of Devi *et al.* (2020).

**Table 1. The details on rice landraces and environment.**

Sl. No.	Genotype code	Genotype name	Environment code	Environment name
1.	G1	Norungan	E1	Rabi 2015-16
2.	G2	Nootripathu	E2	Rabi 2016-17
3.	G3	Vellaichithiraikar	E3	Rabi 2017-18
4.	G4	Sivapuchithiraikar	E4	Rabi 2018-19
5.	G5	Kuruvaikalanjiyam	E5	Rabi 2019-20
6.	G6	Kuliyadichan	-	-
7.	G7	Mattaikar	-	-
8.	G8	Kallurundaikar	-	-
9.	G9	Arubadhanguvuvai	-	-
10.	G10	Chandikar	-	-
11.	G11	Kattanur	-	-
12.	G12	Poongar	-	-
13.	G13	Mysore malli	-	-
14.	G14	Kala namak	-	-
15.	G15	Kichali samba	-	-

**Table 2. AMMI analysis of variance for grain yield over five years/seasons.**

Source of variation	D.F.	S.S.	M.S.	% S.S. explained
Genotypes (G)	14	9315.22	665.37**	67.92
Environments (E)	4	333.84	83.46**	2.43
G x E	56	4066.12	72.61**	29.65
PCA 1	17	3270.74	192.40**	-
PCA 2	15	466.96	31.13**	-
Total	74	13715.18	-	-

D.F. = Degrees of freedom S.S. = Sum of squares M.S.- Mean Sum of squares.

Biplots are graphs where both genotypes and environments are plotted on the same axes that interrelationships can be visualized (Anowara *et al.* 2014). The mean grain yield value of genotypes averaged over environments indicated that the genotypes, G8 and G12, had the highest (3475 kg/ha) and the lowest (2399 kg/ha) yield, respectively. Different genotypes showed inconsistent performance across all the environments. The environmental mean grain yield range was found to 2776 Kg/ha for E1 to 2960 kg/ha for E3 and mean grain yield over environment and genotype was 2888 kg/ha.

In the AMMI 1 biplot, the usual interpretation of biplot is that the displacements along the axis indicate difference in mean (additive) effects, whereas displacements along the ordinate indicate differences in interaction effects. Genotypes and that group together have similar adaptation while environments which group together influence the genotype in the same way (Kempton 1984). If a genotype has an IPCA score of nearly zero it has small interaction effect with environment and considered as stable. Mean grain yields of rice landraces and IPCA1, IPCA2 values are presented in Table 3. Genotypes and environments on the same parallel line relate or ordinate have similar yields and a genotype or an environment on the right side of the midpoint of this axis has higher yield than those of left hand side. In the present study, the landraces, G8 (Kallurundaikar), G4 (Sivapuchithiraikar) and G5 (Kuruvaikalanjiyam), exhibited high mean grain yield with high additive effects showing positive IPCA1 score and the genotype, G8, recorded the overall best in terms of yield (Fig. 1). The rice landrace G8 (Kallurundaikar) can perform better in the environments E2, E3 and E5. The genotypes, G4 (Sivapuchithiraikar) and G5 (Kuruvaikalanjiyam) and G7 (Mattaikar) can perform well in the environments E2 and E3. A similar outcome was reported by (Das *et al.* 2009). The rice landraces, G12 (Poongar), G13 (Mysore malli), G14 (Kala namak) and G15 (Kichali samba) performed better in environment E1 and E4. These findings are more or less similar with the findings of Lingaiah *et al.* (2020).

**Table 3. Mean yield and IPCA1, IPCA2 values for 15 rice landraces over five years.**

Sl. No.	Genotype	E1	E2	E3	E4	E5	Mean	PCAI	PCA2
1.	Norungan	2443	2808	2857	2748	3118	2795	-0.22	-0.25
2.	Nootripathu	2412	2610	2613	2570	3528	2747	-0.61	-0.08
3.	Vellaichithiraikar	2562	2484	2507	2442	2755	2550	-0.13	0.22
4.	Sivapuchithiraikar	3337	3465	3532	3403	3201	3387	0.20	0.01
5.	Kuruvaikalanjiyam	3548	3461	3551	3394	2536	3298	0.67	0.25
6.	Kuliyadichan	2901	2802	2820	2762	3132	2883	-0.17	0.24
7.	Mattaikar	3279	3424	3537	3344	2376	3192	0.72	0.00
8.	Kallurundaikar	3247	3531	3592	3468	3535	3475	0.00	-0.16
9.	Arubadhanguvuvai	2651	2860	2900	2806	3153	2874	-0.19	-0.08
10.	Chandikar	2780	2480	2454	2461	3355	2706	-0.51	0.45
11.	Kattanur	2939	3474	3549	3400	3519	3376	-0.07	-0.43
12.	Poongar	2308	2454	2513	2393	2329	2399	0.10	-0.01
13.	Mysore malli	2318	2599	2673	2531	2375	2499	0.15	-0.15
14.	Kala namak	2435	2565	2617	2508	2548	2535	0.03	0.01
15.	Kichali samba	2475	2639	2693	2581	2639	2605	0.02	-0.03
	Mean	2776	2910	2960	2854	2940	2888	-	-

In AMMI II biplot, the environmental scores are joined to the origin by sidelines (Fig. 2). Sites with short spokes do not exert strong interactive forces; those with long spokes exert strong interaction. The IPCA 1 versus IPCA 2 biplot explains the magnitude of interaction of each genotype with the environment. The points representing E1, E2, E3, E4 and E5 are connected to the origin. The genotypes falling in the circle or near to origin will tend to have similar yields in all the environments. Hence, the genotypes which are near to the origin, G12 (Poongar), G14

(Kala namak) and G15 (Kichali samba) are not sensitive or had little interaction with environment and considered as more stable genotypes over all environments. Genotypes distant from the origin are sensitive and have large interaction with the environments. In the present study, the rice landraces, G10 (Chandikar) and G5 (Kuruvaikalanjiium) were found to be more sensitive to environments. Similar results were previously reported by Devi *et al.* (2020).

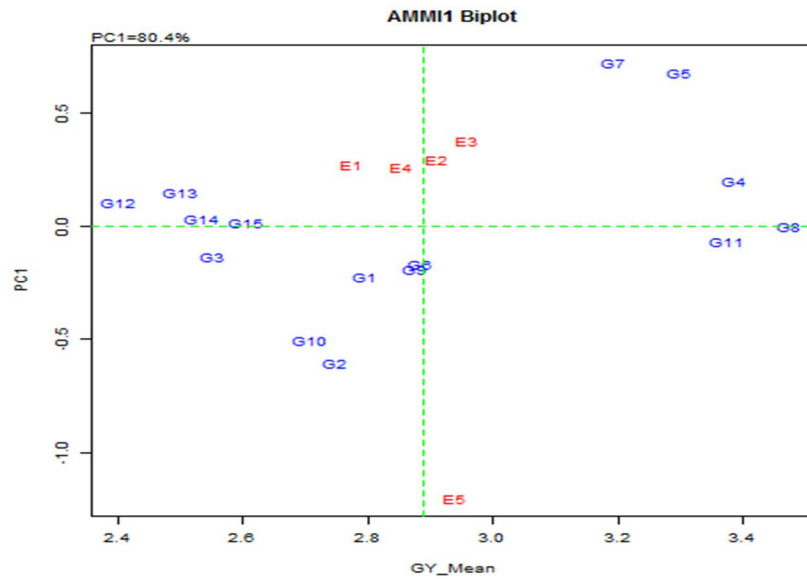


Fig.1. Biplot of the first interaction principal component axis (IPCA1) versus mean yields.

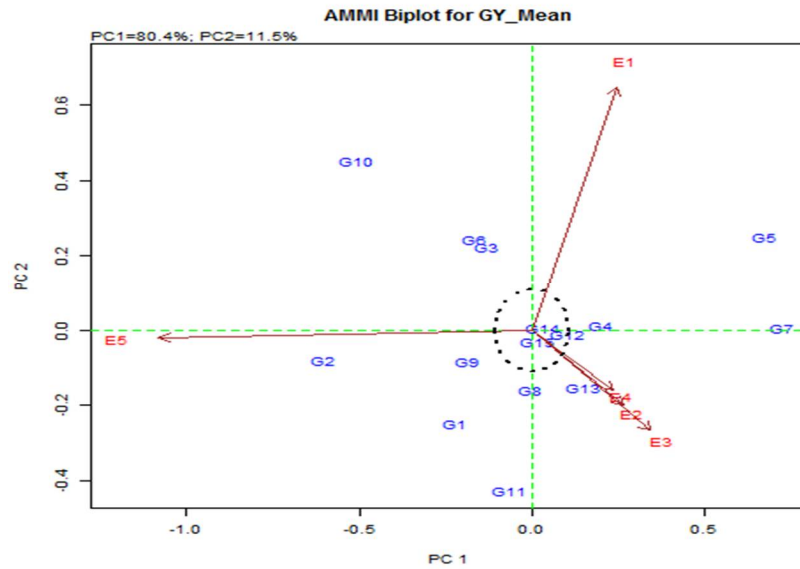


Fig. 2. Biplot of the first interaction principal component axis (IPCA1) versus the second interaction principal component axis (IPCA2).

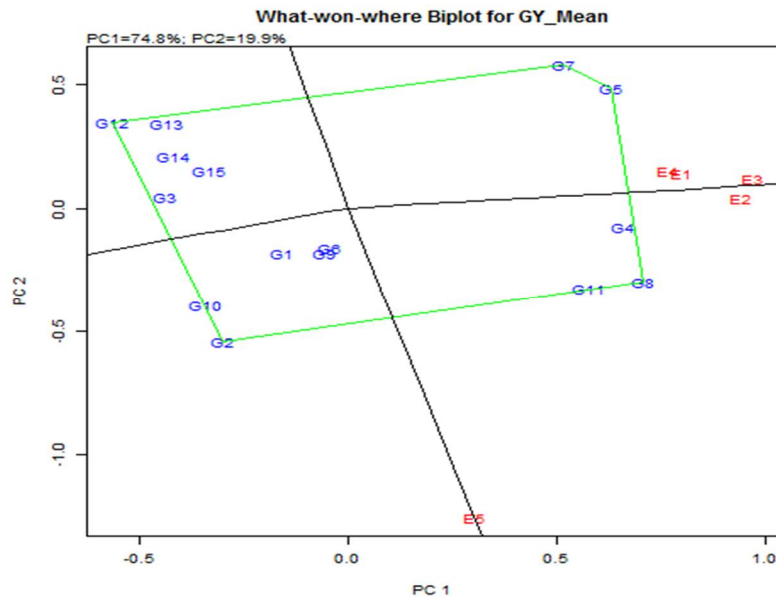


Fig. 3. The what-won-where view of the GGE biplot to show which genotype performed best in which environment.

The striking feature of what-won-where GGE biplot is its ability to show the what-won-where pattern of a genotype by environment. A polygon is first drawn on genotypes that are furthest from the biplot origin so that all other genotypes are contained within the polygon. Then perpendicular lines to each side of the polygon are drawn, starting from the biplot origin (Yan and Tinker 2006). These perpendiculars divide the biplot into several sectors. There are four sectors and the environments fall into the two of them. The environment group within each sector and the genotypes at the polygon's extremity characterized the mega environment (Yan and Rajkan 2002). The polygon view of GGE biplot (Fig. 3) is the best way for the identification of winning genotypes with visualizing the interaction patterns between genotypes and environments. There are two mega environments one with E2 and E5 and second consisting of E1, E3 and E4.

Hence the genotype G8 (Kallurundaikar) was the winner in the environments E2 and E5 whereas the genotypes G5 (Kuruvaikalanjium) and G7 (Mattaikar) were the winners in the environments E1, E3 and E4. This pattern suggests that the target environment may consist of two mega environments and that different genotypes should be selected for each environment.

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