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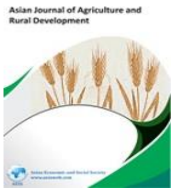

STABILITY OF MAIZE HYBRIDS ACROSS ENVIRONMENTS USING GGE BIPLOT AND AMMI ANALYSIS

Saleem Abid [a] ⧫ ,

Saleem Zahid [b]

[a] ⧫ Statistics and Computing Program, Social Sciences Research Institute, PARC National Agricultural Research Centre, Islamabad, Pakistan.
[b] Institute of Business and Management Sciences, The University of Agriculture, Peshawar, Pakistan.

⧫ ✉ saleemabidpk@gmail.com *(Corresponding author)*

⧫ **Corresponding Author**

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ABSTRACT

Twenty six yellow maize hybrids on the basis of stability analysis were evaluated in National Uniform Maize Hybrid Yield Trials conducted across eight diversified environments of Pakistan. Combined analysis of variance based AMMI analysis shown highly significant differences for environments, genotypes and their interactions. The environments explained about 78 percent of the total yield variation followed by genotype by environment interaction. Environment was the main aspect that influences the performance of maize yield in study area. The first two interaction principal component axes (IPCA1 and IPCA2) explained about 63 percent of the grain yield variation due to genotype and genotype by environment interaction (GGE). The GGE biplot analysis shown that entry-2 (Mex-YLHY2) was the most stable hybrid and can be considered as adaptable to all the environments.

Contribution/ Originality

The main objective of this study was to identify the promising maize hybrid for their adaptability and stability using GGE biplot and AMMI Analysis under different agro-climatic conditions in Pakistan.

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1. INTRODUCTION

In Pakistan, maize is cultivated in an area of 1334 thousand hectares resulting with total production of 6130 thousand tonnes with an increase of 16.3% over previous year production of 5271 thousand tonnes (Government of Pakistan, 2017). Moreover, there is a big gap between actual and potential yield of maize within Pakistan. The demand for maize has significantly increased due to the extension in the poultry and livestock industries (Kabir, 2009). Maize has a diverse genetic crop and can be planted in different agro-ecological zones. Improved maize varieties give high and stable yields in the environment where adopted. The improved hybrids should have the charcteristics of adoptibility across a wide range of different environments (CIMMYT, 1991). Stability of a hybrid over different locations is needed feature and depends upon the size of hybrid and enviroment interactions (Ahmad *et al.*, 1996). The genotypes are considered stable if their variations among environments are small, which is called statistical stability. A stable genotype does not change or at least change the performance, regardless of changes in the environmental conditions (Baker and Leon, 1988). There are two types of stability measures: non-parametric and parametric (multivariate and univariate) stability measures. The main problem in nonparametric and univariate stability statistics is that it cannot provide a real picture of the complete response pattern, as the genotype‘s response is of multivariate nature in different environments (Lin *et al.*, 1986; Akpan and Udoh, 2017). Hence, using multivariate analysis i.e. additive main effects and multiplicative interactions (AMMI) model is more useful for description of genotype by environment interaction (GEI) than univariate stability methods (Crossa *et al.*, 1990). AMMI model improve the accuracy of yield estimates when the main effects and interaction effects are important. The AMMI method pools principal component analysis (PCA) and Analysis of Variance (ANOVA) into an integrated approach. In this approach, the adjustment is done by using the information from other environments to refine the estimates within a given environment (Sadeghi *et al.*, 2011). A number of researchers have accomplished substantial work on stability analysis using AMMI analysis and GGE biplot analysis for different crops such as Munawar *et al.* (2013); Banik *et al.* (2010); and Francis and Kannenberg (1978) for maize crop, Wieslaw *et al.* (2011); Crossa *et al.* (1990); Kaya *et al.* (2002) for wheat crop, Kilic (2014) for barley crop, Mahalingam *et al.* (2006) for rice crop; and Sadeghi *et al.* (2011) for tobacco crop. The main objective of this study was to identify the promising maize hybrid for their adaptability and stability using GGE biplot and AMMI Analysis under different agro-climatic conditions in Pakistan.

2. MATERIALS AND METHODS

This study was conducted with a view to identify the most stable hybrid of maize crop across different environments. For this purpose twenty six maize hybrids were tested in eight diversified environments of Pakistan; Islamabad, Yousaf Wala, Vehari, Sahiwal, Lahore, Dadu, Faisalabad and Nowshera. These maize hybrids were FB-1142, Mex-YLHY2, 6619, 6655, ST-6253, ST-6293, Kolosseus, BP-3, KXB-2572, HSM-34, Tara-G-866, Tara-LP-1243, 20-R-52, Mex-YLHY1, Mex-YLHY3, Mex-YLHY4, Mex-YLHY5, MSM-1, Y.W- Hybrid, Y.W- 1898, 1515, 1516, 1616, FH-1046, FH-1036, and Monsanto. The experiment was designed in a randomized complete block design with three replications, in all locations. The combined analysis of variance was performed for the eight environments and then genotype by environment interaction was divided according to additive main effects and multiplicative interactions (AMMI) model Gauch and Zobel (1997). Additive main effects and multiplicative interactions analysis pools principal component analysis (PCA) of the G x E interaction with the analysis of variance for the genotype and environment main effects (Kilic, 2014). The model equation is:

$$Y_{ij} = \mu + G_i + E_j + \sum_{k=1}^{n} \lambda_k \alpha_{ik} \gamma_{jk} + e_{ij}$$

where Y_{ij} is the maize yield of *ith* genotype in *jth* environment; *Gi* and *Ej* are the genotype and environment deviations from the grand mean, respectively; μ is the grand mean; λ_k is the eigenvalue of the principal component analysis axis k; α_{ik} and γ_{jk} are the genotype and environment principal component scores for axis k; n is the number of principal components retained in the model and e_{ij} is the error term. The GGE biplot and AMMI analysis were carried out using GEA-R software (CIMMYT, 2015).

3. RESULTS AND DISCUSSION

The performance of hybrid can change when grown in diversified environments, demonstrated by fluctuations in the relative ranking of hybrid over environments. The hybrids commonly retained in a breeding program are those having a high mean performance, as hybrids are seldom selected on the basis of their performance in specific environments. The mean performance of grain yields for twenty six maize hybrids and their combined means across eight environments were presented at Table-1. The mean of grain yield of maize hybrids across the environments showed significant variations in ranks among the hybrids, which demonstrate high hybrid and location interactions (Baker, 1988). Statistically significant differences were observed for mean grain yield among the hybrids in all the eight environments of the study. The mean grain yield over environments ranged from 6.905 tons ha^{-1} (Y.W- Hybrid) to 11.026 tons ha^{-1} (ST-6293) with a grand mean of 9.086 tons ha^{-1}. Out of twenty six 13 of the hybrids (50%) had above the mean average yields (Table 1). The ST-6293 was found to be the highest yielding maize hybrid giving the mean yield of 11.026 tons ha^{-1} followed by FH-1036 (10.507 tons ha^{-1}), ST-6253 (10.062 tons ha^{-1}) and so on, whereas Y.W-Hybrid (6.905 tons ha^{-1}) produces the lowest yield combined over the environments.

Table 1: Mean performance of grain yields for twenty six maize hybrid (tons ha^{-1}) and their combined means across eight Environments of Pakistan

S#	Maize Hybrid	Environments								Hybrid Means
		1	2	3	4	5	6	7	8	
		Islamabad	Yousaf Wala	Vehari	Sahiwal	Lahore	Dadu	Faisalabad	Nowshera	
1.	FB-1142	11.03	11.48	12.21	11.26	9.85	3.50	4.17	5.07	8.571
2.	Mex-YLHY2	10.85	10.95	11.03	11.65	10.68	4.80	9.08	5.16	9.275
3.	6619	12.67	10.79	12.77	14.58	11.08	4.20	9.51	4.41	9.999
4.	6655	11.69	11.56	10.56	12.08	11.76	3.72	6.62	3.29	8.909
5.	ST-6253	11.67	12.27	11.76	13.67	10.31	3.17	11.37	6.28	10.062
6.	ST-6293	13.37	13.69	11.21	17.17	11.53	4.73	8.69	7.82	11.026
7.	Kolosseus	10.34	11.31	12.32	12.08	9.14	5.15	7.48	6.48	9.286
8.	BP-3	10.06	14.65	11.38	12.35	6.60	4.34	7.76	4.54	8.959
9.	KXB-2572	13.42	10.81	9.06	12.80	7.54	4.68	7.85	4.13	8.786
10.	HSM-34	12.70	12.01	12.41	10.74	7.89	4.68	8.63	4.23	9.162
11.	Tara-G-866	11.23	11.11	12.29	11.28	7.06	4.77	10.77	5.69	9.273
12.	Tara-LP-1243	12.83	10.71	8.08	10.82	6.89	5.36	8.00	3.13	8.226
13.	20-R-52	11.68	10.17	10.70	11.22	10.09	3.73	6.00	4.20	8.473
14.	Mex-YLHY1	9.82	11.71	10.68	11.58	8.46	4.48	5.47	3.67	8.233
15.	Mex-YLHY3	12.81	11.31	10.49	12.02	9.58	5.45	7.17	3.21	9.005
16.	Mex-YLHY4	11.00	11.17	11.33	11.18	11.22	4.33	8.85	3.37	9.055

17. Mex-YLHY5	11.04	12.72	12.27	11.31	10.05	4.26	7.71	3.23	9.073
18. MSM-1	11.73	11.42	11.12	14.82	7.83	3.62	8.11	4.61	9.156
19. Y.W- Hybrid	4.72	10.78	10.07	8.77	5.10	4.03	7.49	4.29	6.905
20. Y.W- 1898	8.17	11.33	11.82	6.79	5.09	4.87	8.66	5.35	7.761
21. 1515	12.65	10.97	12.24	12.67	11.41	4.96	8.40	4.17	9.682
22. 1516	10.28	10.87	10.89	13.92	10.31	4.58	9.35	4.74	9.369
23. 1616	12.49	11.44	12.30	11.92	7.85	5.41	10.11	4.97	9.561
24. FH-1046	11.12	8.84	10.41	9.05	6.32	5.04	11.75	4.41	8.366
25. FH-1036	15.62	11.09	11.95	15.54	10.24	3.47	12.11	4.05	10.507
26. Monsanto	12.18	12.40	11.50	14.94	8.80	4.03	8.37	4.19	9.552
Locations Means	11.43	11.44	11.26	12.16	8.95	4.44	8.44	4.57	9.086

Underlined values are highest yields at each test environments. LSD$_{0.01}$ (Locations) = 0.2796; LSD$_{0.01}$ (Hybrids) =0.5041

Combined analysis of variance for grain yield based on AMMI model is presented in Table 2. The results of analysis of variance showed statistically highly significant differences (P<0.01) for genotypes, environments and their interaction. The interaction principal component axis (IPCA) are ordered according to decreasing contribution to variation. The F-test was statistically highly significant (P<0.01) for all the IPCA axes. The environments explained 77.7% of the total yield variation followed by the G × E interaction (16%). Genotypes contributed only 6.3% which indicates that in the multi environment trials (METs) genotypes contribute the least to the total variation. The environment is a major factor that affecting maize productivity in most parts of the study area. The first seven IPCA axes are highly significant and explained 100% of the G x E interaction. The first two interaction principal component axes (IPCA1 and IPCA2) explained 62.6 percent of the grain yield variation due to genotype and genotype by environment interaction (GGE).

Table 2: AMMI analysis of variance of grain yield of maize trails over eight environments

Sources	DF	Sum of Square	Mean Square	Total variation explained (%)	G x E explained (%)	Cumulative (%)
Environments (E)	7	5283.33	754.7**	77.7		
Genotypes (G)	25	428.48	17.14**	6.3		
G × E	175	1088.87	6.22**	16		
IPC1	31	423.71	13.67**		38.9	38.9
IPC2	29	258.36	8.91**		23.7	62.6
IPC3	27	149.92	5.55**		13.8	76.4
IPC4	25	123.7	4.95**		11.4	87.8
IPC5	23	58.86	2.56**		5.4	93.2
IPC6	21	48.67	2.32**		4.5	97.7
IPC7	19	25.65	1.35**		2.4	100
Error	416	194.95	0.47			
Total	623	6995.63				

**P < 0.01; Grand Mean = 9.09; CV = 7.43%; IPC = Interaction principal component axis

The AMMI model biplot based on IPCA1 and the genotype means for twenty six maize hybrids across the eight environments was constructed to show the performance and association of the genotypes. The Figure displays that entry 6 (ST-6293) was the highest yielding followed by entry 25 (FH-1036) and entry 5 (ST-6253). The lowest yielding among the 26 maize hybrids was entry 19 (Y.W- Hybrid) located at the top left corner of the biplot. Entry 2 (Mex-YLHY2) was the most stable as it is the closest to the IPCA1 axis and can be considered as adaptable to all the environments.

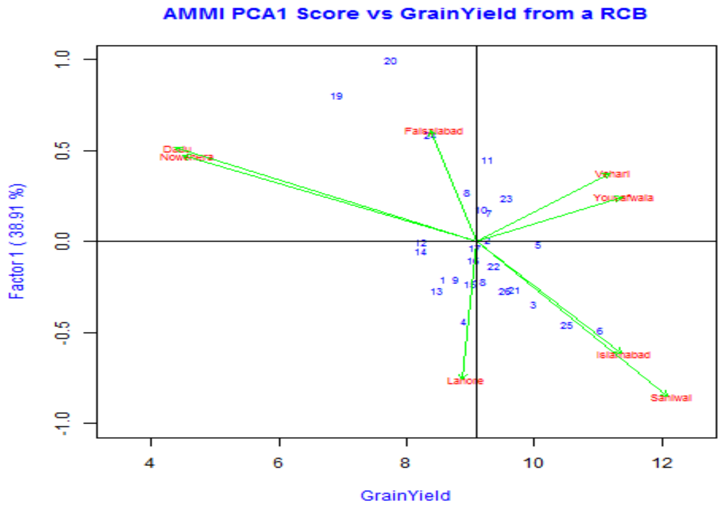

Figure 1: Biplot analysis of GEI for the PCA1 scores and grain yield of 26 maize hybrids across eight environments

The GGE biplot analysis based on AMMI model for the first two IPC scores (PC1 vs PC2) was presented in Figure-2. The GGE biplots based on the performance of 26 maize hybrids evaluated under 8 environments were constructed based on the values of the first two interactions principal component scores (PC1 and PC2) which explained 62.6% of the grain yield variation due to genotype and G x E interaction (Figure 2). Figure-2 shows the association or relationship between the different environments. Faisalabad was the most discriminating environment due to its longest distance from the origin of the biplot. Environments with small vector angles tend to have closer similarity and those with wide vector angles show minimum association. Similarly the rug plot also displays the proximity among the different environments based on the angle variation of the vectors. All the managed drought environments were displayed close to each other as their deviation from each other was small.

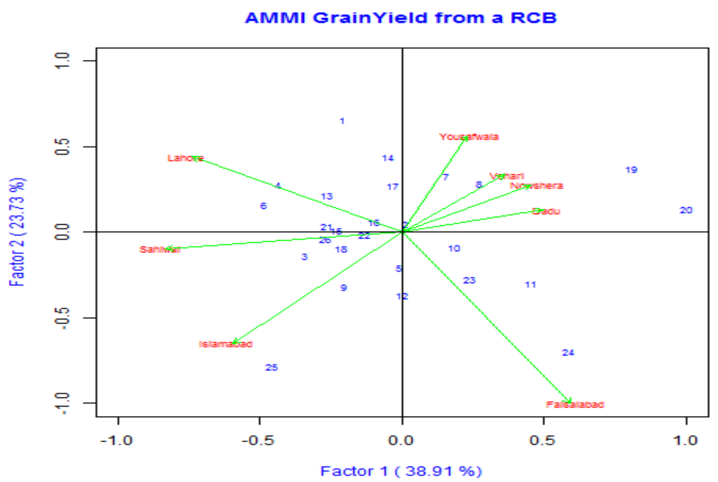

Figure 2: Biplot analysis of GEI for first two IPC scores (PC1 vs PC2)

The dendrogram (Figure 3) displays the information in the form of tree diagram in our experiment, locations Islamabad, Sahiwal, Lahore make-up the first cluster; locations Yousaf wala, Vehari, Nowshera make-up the second cluster and Dadu and Faisalabad make-up the third cluster on the basis of similarity levels of environment.

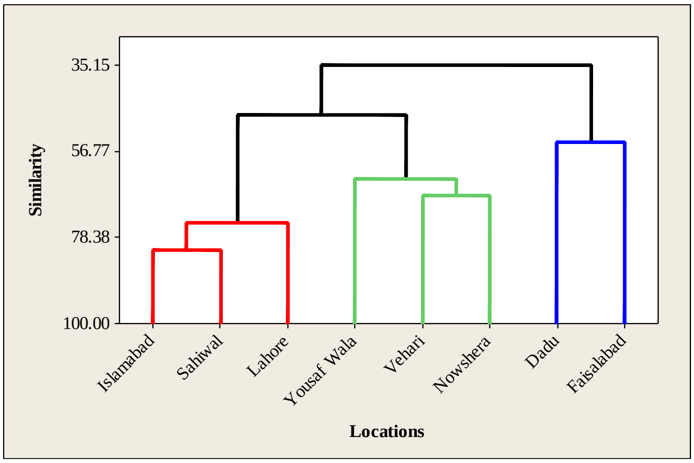

Figure 3: Dendrogram showing clustering of eight locations of experiment

4. CONCLUSION

The combined analysis of variance based on AMMI analysis shown highly significant differences for environments, genotypes and their interactions. The environments explained about 78 percent of the total yield variation followed by genotype by environment interaction. Environment was the main aspect that influences the performance of maize yield in study area. The first two interaction principal component axes explained about 63 percent of the grain yield variation due to genotype and genotype by environment interaction (GGE). It was concluded from the study that GGE biplot analysis shown that entry-2 (Mex-YLHY2) was the most stable hybrid and can be considered as adaptable to all the environments.

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