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Evaluation of Maize (*Zea mays* L.) Hybrids under Different Environments by GGE Biplot Analysis

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Abstract: Multi-environment yield trials in maize are important for evaluation of genotype by environment (GE) interaction and identification of superior genotypes in the final selection cycles. The objective of this study was to evaluate stability and adaptability of grain yield of exotic maize hybrids by GGE (Genotype and Genotype by Environment Interaction) biplot analysis. Experiments were carried out in randomized complete block designs (RCBD) with six exotic hybrids grown in three replication for the year 2012 at four different locations viz., Qasoor, Lahore, Sahiwal and Chechawatni of the Punjab Province of Pakistan. Analysis of variance (ANOVA) indicated significant effects of genotypes (G), environments (E) and their interaction (GE). On the same time, the highest percentage of variation was explained by E (79.22%) while G and GE effects together explained the rest of variation (<25%). Hybrid NK-8441 was the most desirable across the location followed by hybrid PL-091107. Qasoor and Lahore were the most representative locations for most of the hybrids while Sahiwal location was the least representative. GGE biplot analysis also indicated that NK-8441 and PL-091107 hybrids could be used in Qasoor and Lahore environments while PL-090149 (most representative) and PL-090433 (high grain yielding) in Sahiwal location. Thus GGE biplot methodology with graphical demonstration provided an effective overview of average performance and environmental stability useful for identifying locations that optimized cultivar performance and for making better use of limited resources available for the testing program.

Key words: Biplot analysis · Maize · Multilocational trial · Multienvironment stability · Adaptability · Yield trial

INTRODUCTION

Maize *(Zea mays* L.*)* is an important food and feed crop of the world and is often referred as "the king of grain crops". It ranks third in world production after wheat and rice and is important cereal crop of Pakistan. Besides being an important food grain for human consumption, maize has also become a major component of livestock and poultry feed [1-3]. In Pakistan, area under maize occupies third position after wheat and rice, 98% of maize is grown in Punjab. During the year 2011-12 Economic Survey of Pakistan reveals that the maize production increased to 4,271 thousand tons from 3,707 thousand tons in 2010-11, showing an increase of 15.2%. Grain yield is the combined outcome of genetic potential and environment interaction. Variability in genetic potential among varieties is a major component of variable yield.

Multi-location trials play an important role in plant breeding to estimates and predict yield based on limited experimental data, yield stability and the pattern of response of genotypes across environments. These provide reliable guidance for selecting the best genotypes for planting in future years at new sites [4]. Average grain yield of maize varieties in Pakistan is low on account of suboptimal plant density, inadequate inputs availability, biotic and abiotic stresses and the selection of unsuitable cultivars under a given set of environments [5]. Introduction, evaluation and adaptation of exotic germplasm or hybrids are essential to meet the increasing demand of maize. The GGE biplot in this regard provides a good tool for estimation of better performance and grain yield stability across the innovative environments. Maize varieties produce significantly different yields at different locations [6]. It is necessary to evaluate maize varieties in

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various agro-ecological zones for their adaptation and yield potential [7]. It is, therefore, imperative to understand the relationship among yield testing locations for better adaptation of germplasm to different production environments [8].

Keeping this in view, the present study was therefore, conducted to compare the performance of six exotic hybrids at four distinct locations for their adaptability and stability and to recommend a suitable one for the maize growing areas of Pakistan.

MATERIALS AND METHODS

Multi-environment trials (MET) were conducted during summer crop season (July-October, 2012) at four different locations viz; Sahiwal, Qasoor, Lahore and Chechawatni of Punjab Province of Pakistan. Six hybrids viz; PL-090140, PL-090081, PL-090150, NK-8441, PL-090433 and PL-091107 from different companies were used in this evaluation. The experiments were laid out in the randomized complete block designs (RCBD) with three replications at each location. Each plot comprised four rows of 5 m length with plant spacing between rows and within row 0.75 m and 0.20 m respectively. Two seeds per hill were planted and later thinned to single plant per hill, when plants were at 2nd leaf stage (V-2 stage). Nitrogen, Phosphorus and Potassium fertilizers were applied at rate of 280, 125 and 100 kg ha^{-1} respectively. Entire phosphates and potassium fertilizers were applied at the time of sowing while 1/4th of urea was applied during land preparation, 1/4th was applied when crop was at knee height stage, 1/4th at pollination stage and remaining 1/4th was applied at grain filling stage. At maturity (when black layer appeared at grain base) central two rows from each plot were separately harvested and the fresh weight was measured in each plot. Grains were shelled from ten randomly selected cobs to observe the percent grain moisture and shelling % at harvest for each plot. The Shelling % was calculated using following formulae.

$$Shelling\ percentage\left(SP\right)=\frac{GrainWeight}{CobWeight}\times 100$$

Grain yield kg ha^{-1} was calculated for every entry from the data of fresh ear weight per plot using the following formula.

$$Grain\ yield=\frac{y\times\left(100-MC\right)\times SP\times 10}{\left(100-15\right)\times 7.5}$$

Table 1: Analysis of variance of grain yield data (kg ha^{-1}) obtained from multi-location trials conducted during summer-2012.

Source	Df	Means squares
Location (L)	3	9,924,678** (79.22)
Reps with in L	8	596,796 (1.27)
Genotypes (G)	5	7,152,707** (9.52)
G × L	15	1,720,521** (6.87)
Error	40	293,415 (3.12)

** = Significant at 1% level of probability Values in parenthesis are percent of total sum of squares.

Where:

MC	=	Moisture content in grains at harvest (%)
SP	=	Shelling percentage
Area harvested plot^{-1}	=	7.5 m^2
1 hectare	=	10,000 m^2
15 %	=	Moisture content required in maize grain at storage

Statistical Analysis: The grain yield data were subjected to combined analysis of variance (ANOVA) across locations. Since, genotype × location interaction was significant (Table 1), then data was subjected to biplot analysis. The GGE biplot software [9] was used to generate groups showing (i) "which-won-where" pattern. (ii) Ranking of cultivars on the basis of yield and stability, (iii) Location vectors and (iv) comparison of locations to ideal location [10]. This GGE biplot is constructed by the first two principal components (PC1 and PC2, also referred to as primary and secondary effects, respectively.) derived from subjecting environment-centered yield data, i.e., the yield variation due to GGE, to singular value decomposition [11,12].

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) for yield at four environments indicated that the effects of genotype, environment and their interaction on yield were significant, with the proportion of the total treatment variation of 9.52% for genotype, 79.22% for the environment and 6.87% for interaction (Table 1). Fan *et al* [13], in their research, reported that the effects of environment and genotype explained 69% and 8.5% of total treatment variance respectively, whereas the interaction explained 16% of the total treatment variance. In standard multi-location trails, 80% of the total sum of treatments is environment effect and 10% effect of genotype and interaction [14]. The proportion of the total

treatment variation of 9.17% for genotype, 77.83% for the environment and 13% for interaction has also been reported in maize [15]. On the basis of average grain yield, maize hybrids were divided in two main sectors as shown in Fig. 1. The first sector (in the upper right section) exhibited hybrids with above average seed yield in kg ha^{-1}, while the rest (in sector 2, in upper left section) were inferior in performance with below average seed yield. Thus hybrid PL-091107, PL-090140 showed highest average grain yield and fell in first sector, while NK-8441 was found at the edge of the origin line. Similarly, PL-090150 also attained position in between the first and second sector.

PL-090433 and PL-090081 fell in second sector. This distribution showed a diversified genetic makeup of the studied maize hybrids. In 2010, similar results were also obtained from twenty genotypes of Chickpea dispersed in different sectors [16].

Genotype + Genotype × Location Interaction Biplot Analysis

Best Hybrid in each Location: The biplot represents a polygon view (Fig. 2) having some vertex hybrids while the rest are inside the polygon. The vertex hybrids are supposed to be the most responsive since they have longest distance from the biplot origin. Responsive hybrids are either best or poorest at one or all locations [17]. Thus hybrid NK-8441 was most responsive in Qasoor, Lahore and Chechawatni locations. Although it was high yielding only in Lahore and Chechawatni locations while in Qasoor location PL-091107 hybrid attained high yielding position. Similar behavior was executed by hybrids at Sahiwal location where hybrid PL-090140 showed most responsiveness because of high distance from biplot origin while PL-090433 hybrid was high yielding at Sahiwal location. None of the locations fell in the sector with PL-090081 and PL-090150 as the vertices genotypes, indicating that these hybrids were not best in any of the location. The hybrid PL-091107 seemed to be widely adapted across one of the three locations while NK-8441 showed wide adaptability across other two locations. GGE biplot also depicted the ideal genotype. An "ideal" genotype is defined as one that is the highest yielding across test environments and is absolutely stabile in performance (that ranks the highest in all test environments) [10]. Although such an "ideal" genotype may not exist in reality, it can be used as a reference for genotype evaluation. A genotype is more desirable if it is located closer to the "ideal" genotype [18]. When the ideal view was drawn Fig. 3, the hybrid PL-09107 was the closet to the ideal genotype, followed by NK-8441.

Average Yield and Stability of Hybrids: The average tester coordinate (ATC-X axis) or the performance line passes though the biplot origin with an arrow indicating the positive end of the axis presented in Fig. 3. The ATC Y-axis or the stability axis passes the plot origin with the double arrow head and is perpendicular to the ATC-X axis. The average yield of the hybrids is estimated by the projections of their markers to the ATC- X axis.

Thus the hybrid NK-8441 has highest average grain yield (10,009 kg ha^{-1}) as having the highest projection on the performance line, followed by PL-091107 (9616 kg ha^{-1}), which is located almost at the same site as occupied by NK-8441. On the other hand the lowest grain yield (7884 kg ha^{-1}) was produced by PL-090081 (Table 2).

The centre of the concentric circle in Fig. 4 represented the position of the ideal hybrid. Its projection on the ATC- X axis was designed to equal to the longest vector of all the hybrids and its projection on ATC- Y axis was obviously zero, indicating the stability of the hybrid. Therefore, the smaller the distance from a hybrid to such a virtual hybrid, the most ideal the hybrid is. So the hybrid

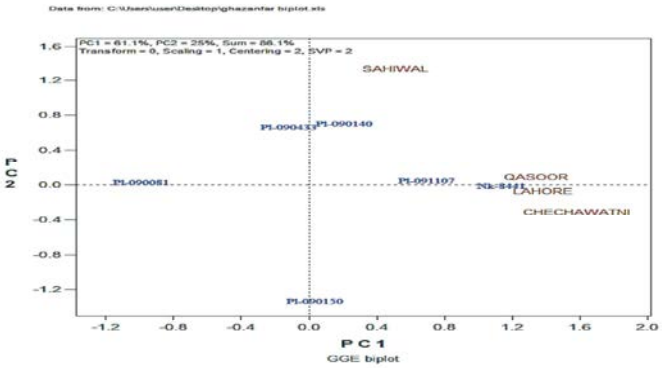

Fig. 1: genotype + genotype × environmental biplot showing hybrids and environments.

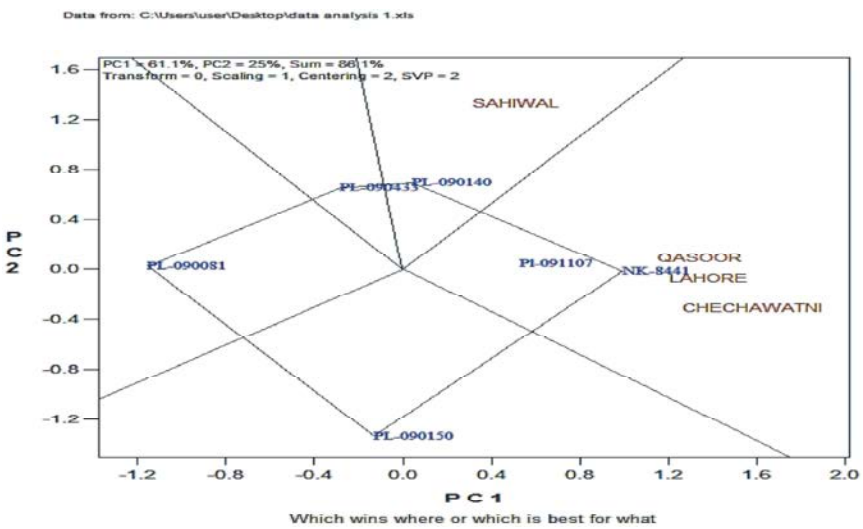

Fig. 2: Genotype + genotype × environmental interaction biplot showing hybrids in each environment.

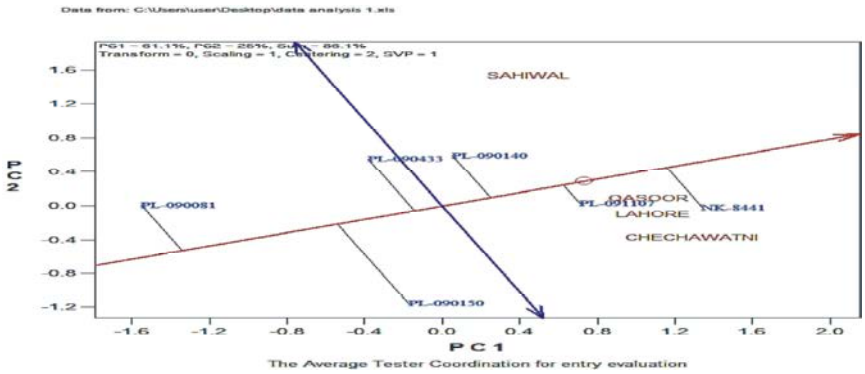

Fig. 3: Average tester coordination (ATC) view of the GGE biplot, hybrids in lower case and locations in upper case. PC1 and Pc2 are first and second principal components, respectively.

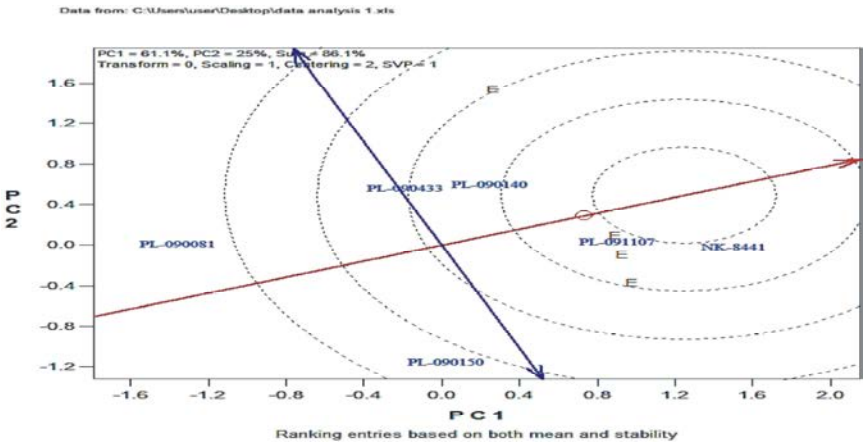

Fig. 4: Comparison of hybrids with the ideal hybrid. Locations are denoted by 'E' while hybrids are with original names.

PL-091107 was closest to the concentric centre and having the shortest GGE distance (0.5) followed by NK-8441. (GGE distance: 0.7) did not seem to be meaningfully different, while the hybrid PL-090081 was the least stable across all locations as the longest GGE distance (2.8) was observed (Table 2).

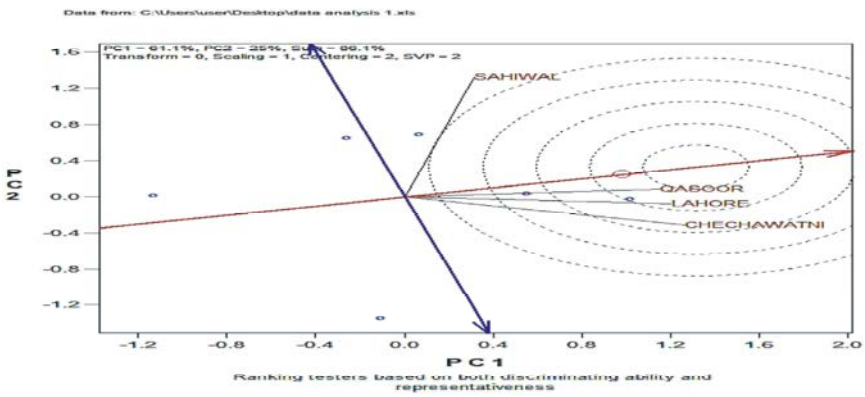

Fig. 5: Comparison of locations with the ideal location. The hybrids are indicated by scattered small circles and locations are in upper case.

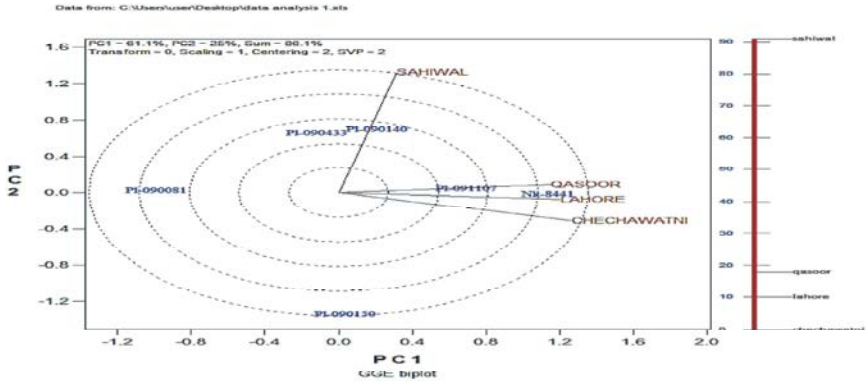

Fig. 6: A genotype + genotype × environmental interaction biplot showing relationships among four locations.

Table 2: Mean Grain yield (kg ha^{-1}), GGE distance and ranking of six maize hybrids across four locations of Punjab.

	Locations						
Maize Hybrids	GGE rank	GGE distance	Sahiwal	Chechawatni	Qasoor	Lahore	Hybrids Mean
PL-090140	3	1.2	8460	6275	9864	12459	9265bc
PL-090081	6	2.8	7548	5460	7934	10593	7884e
PL-090150	5	2.1	6420	7032	9055	12274	8695d
NK-8441	2	0.7	8106	8009	10116	14163	10099a
PL-090433	4	1.6	8517	6672	8528	11781	8875cd
PL-091107	1	0.5	7923	7481	11114	11946	9616b
Locations Mean			7829c	6822d	9435b	12203a	

Location Ranking Based on Both Discriminating Ability and Representativeness: Fig. 5 represents the discriminating ability and representativeness of locations. An ideal location is one that is most discriminating (longest distance between the marker of the location to the biplot origin, is a measure of its discriminating ability) for genotypes and is representative (shortest projection from the marker of the location onto the ATC Y axis is the measurement of its representativeness) of another environments [9,10]

Thus the location Chechawatni was discriminating because of longest distance from biplot origin while was not representative due to large projection on the ATC Y axis as compare to Qasoor that seemed to be most representative location followed by Lahore that was statistically similar with Qasoor (Table 2). Owing to small projection on ATC X axis the location Sahiwal had less discriminating ability but is not representative of the average location because of its very large projection onto the ATC-Y axis.

Relationship Among Locations: The relationship among the tested locations as in Fig. 6. showed that the vectors of all the four locations and the linear map at the right of the graph (in degrees) helps to indicate the relationship between the locations. The vector length also represents

the discriminating ability of the respective location and the cosine of angle between two locations exhibits the relationship among them [9]. Three of the locations viz; Qasoor, Lahore and Chechawatni possessed longest vector, thus they were the best for genetic differentiation of the hybrids. Sahiwal was the least representative for all of the cultivars. The smallest angle between Qasoor and Lahore indicated the highly strong relationship among them. While the large angle between Sahiwal to any other of three locations represented that there was no relationship among them and highly variability was found among all these locations.

CONCLUSIONS

The GGE biplot analysis identified that PL-090150 is the least desirable hybrid and PL-090081 is undesirable. It also revealed that hybrids NK-8441 was the most desirable hybrids across the locations followed by hybrid PL-091107. Qasoor and Lahore were not significantly different while there was distinct differentiation when comparing them with Chechawatni for genetic differentiation of genotypes. Qasoor and Lahore were the most representative locations for most of the hybrids while Sahiwal location was the least representative. Thus GGE biplot methodology was useful for identifying locations that optimizing cultivar performance and for making better use of limited resources available for the testing program.

REFERENCES

1. Achakzai, A.K.K., 2009. Effect of water stress on imbibition, germination and seedling growth of maize cultivars. Sarhad J. Agric., 25(2): 165-172.
2. Bukhsh, M.A.A.H.A., R. Ahmad, J. Iqbal, A. Rehman, S. Hussain and M. Ishaque, 2011. Potassium application reduces bareness in different maize hybrids under crowding stress conditions. Pakistan J. Agri. Sci., 48: 31-37.
3. Achakzai, A.K.K., M.O. Liasu and O.J. Popoola, 2012. Effect of mycorrhizal inoculation on the growth and phytoextraction of heavy metals by maize grown in oil contaminated soil. Pak. J. Bot., 44(1): 221-230.
4. Crossa, J., 1990. Statistical analysis of multilocation trials. Adv. in Argon., 44: 55-85.
5. Tahir, M., A. Tanveer, A. Ali, M. Abbas and A. Wasaya, 2008. Comparative yield performance of different maize (*Zea mays* L.) hybrids under local conditions of Faisalabad-Pakistan. Pak. J. Life Soc. Sci., 6(2): 118-120.
6. Olakojo, S.A. and J.E. Iken, 2001. Yield performance and stability of some improved maize varieties. Moor J. Agric. Res., 2: 21-24.
7. Olaoye, G., 2009. Evaluation of new generations of maize streak virus (msv) resistant varieties for grain yield, agronomic potential and adaptation to a southern guinea savanna ecology of Nigeria. J. Trop. Agric. Food, Environ. and Ext., 8(2): 104-109.
8. Trethowan, R.M., J. Crossa, M. Ginkel and S. Rajaram. 2001. Relationships among bread wheat international yield testing locations in dry areas. Crop Sci., 41: 1461-1469.
9. Yan, W., 2001. GGE Biplot- A windows application for graphical analysis of multi-environment trial data and other types of two-way data. Agron. J., 93: 1111-1118.
10. Yan, W. and M.S. Kang, 2003. GGE biplot analysis: A graphical tool for breeders, geneticists and agronomists. CRC Press, Boca Raton, FL, pp: 63-88.
11. Yan, W., 1999. Methodology of cultivar evaluation based on yield trial data-with special reference to winter wheat in Ontario. Ph. D Dissert. Univ. of Guelph, Ontario, Canada.
12. Yan, W., L.A. Hunt, W.Q. Sheng and Z. Szlavnics, 2000. Cultivar evaluation and mega-environment investigation based on the GGE biplot. Crop Sci., 40: 597-605.
13. Fan, X., M. Kang, H. Chen, Y. Zhang, J. Tan and C. Xu, 2007. Yield stability of maize hybrids evaluated in multi-environment trials in Yunnan, China. Agron. J., 99: 220-228.
14. Gauch, H.G. and R.W. Zobel, 1996. AMMI analysis of yield trials. In: Genotype by Environment Interaction, Kang, M.S. and H.G. Gauch (Eds.). Boca Raton CRC New York, USA., pp: 85-122.
15. Bojan, M., S. Dušan, T. Sanja, S. Milisav, I. Mile, B. Goran and R Miloš. 2012. Evaluation of experimental maize hybrids tested in multi-location trials using ammi and GGE biplot analyses. Turkish J. field Crops, 17(1): 35-40.
16. Hamayoon, R., H. Khan, L. Shenshah I. Naz1, M. Munir, I. Arif, A. Khalil and A.Z. Khan. 2011. Performance of chickpea genotypes under two different environmental conditions. African Journal of Biotechnology, 10(9): 1534-1544.
17. Yan, W. and I. Rajcan, 2002. Biplot analysis of test sites and trait relations of soybean in Ontario. Crop Sci., 42: 11-20.
18. Kaya, Y., M. Akcura and S. Taner, 2006. GGE biplot analysis of multi-environment yield trials in bread wheat. Turk. J. Agric. For., 30: 325-337.