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Performance assessment of wheat cultivars under three locations using GGE-biplot

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Abstract

A three field location experiments had carried out to select stable genotype of wheat in Iraq environmental conditions using methodology. Seed yield of 7 genotypes of wheat was investigated under three different environmental conditions of Iraq during 2006, 2007 and 2008 seasons that were combined in GGE-biplot analysis. The environmental locations were Latifiya, Twaitha and Tikrit. The experiments were arranged in the randomized complete block design (RCBD) with three replicates in each experiment. Within the environment, the main effect of a genotype was significant. Genotypes by environmental interaction was also significant. Genotypes at Latifiya and Twaitha significantly produced seed yield greater than at Tikrit. Cluster analysis showed that there is diversity in seed yield among wheat genotypes moreover the GGE biplot analysis showed that KH-57 was the most desirable genotype across all environments and the KH-49 and KH-69. While Jerardo and Horani were identified as bottom genotype in seed yield and undesirable for all environments. The stability analysis showed that the high performing genotype was stable for seed yield.

Key words: Wheat, Genotypes, Environment, Interaction, GGE biplot, Seed yield

Introduction

The improvement of cultivar performance, especially of wheat, requires a thorough understanding of the interaction between a cultivar and certain location or site (Mujahid *et al*., 2011). Therefore, in plant breeding adaptation of crops cultivars represents in terms of a trait of interest with respect to a given environment (Annicchiarico, 2002; van Eeuwijk *et al*., 2005), which Multi-environment trials (MET) are carried out for most crops throughout the agriculture world. In a MET, numerous cultivars are evaluated in various environments, represented by genotype X environment interaction (GEI) that is represented as an important aspect in plant breeding programs which are adapted as a major objective of plant breeders, geneticists and physiologists in selecting superior genotypes in crop performance trials (Mohammadi *et al*., 2010; Yan, 2001; Yan *et al*., 2007) to develop those cultivars. In nature, most important agronomical and economical traits such as grain yield are quantitative that affected by GEI (Xing-Ming *et al*., 2007). Grain yield used as a function to the differential response of cultivars to environmental inversions (Akçura *et al*., 2011). Furthermore, the sorting of crop evaluation in environment and perfect understanding at these conditions could increase heritability of measured traits, raise the selection, strengthen the potential competitiveness for seed production and maximize grain yields for farmers (Badu-Apraku *et al*., 2011; Gauch and W, 1997). At above point there had been many attempts to analyze GEI for recording cultivars of crops under different environment interaction using many methods that had proposed and developed for statistical analysis of GEI, to predict the phenotypic response to shifting in the environment, and to evaluate the performance of genotypes in those environments (Akçura *et al.*, 2011; Shojaei *et al.*, 2011). They differed in the parameters used in the assessment, the biometric procedures applied, and the analysis (Fritsche-Neto *et al.*, 2010), and to reveal patterns of GEI, such as joint regression (Eberhart and Russell, 1966; Finlay and Wilkinson, 1963; Perkins and

Jinks, 1968) additive main effects and multiplicative interaction (AMMI)(Gauch, 1992), type B genetic correlation (Burdon, 1977; Yamada, 1962), and sites regression (SREG) that is a graphical display known as GGE (G+GE interaction) biplot that evaluated cultivars by graph proposed by Yan *et al.* (2000). The biplot graphing technique was used to display the GGE of METs data (Yan, 2001; Yan *et al.*, 2007). This technique is originated from multivariate analysis by separation of GEI data to principal component analysis (Gabriel, 1971) which Yan *et al.* (2000) suggested that GGE-biplot based on singular value decomposition of environmental-centered or within-environment standardized GE data. This technique is increasingly used in GEI data analysis in agriculture (Akçura *et al.*, 2011; Badu-Apraku *et al.*, 2011; Francisco *et al.*, 2011; Fritsche-Neto *et al.*, 2010; Hamayoon *et al.*, 2011; Jandong *et al.*, 2011; Mohammadi *et al.*, 2010; Mujahid *et al.*, 2011; Shojaei *et al.*, 2011; Tonk *et al.,* 2011). The GGE-biplot had efficiently found very effectiv been by agronomists in Iraq (Eisahooki and Almehemdi, 2008; Abbas *et al.*, 2012) as on wheat. Dehghani *et al.* (2006) found that the application of GGE-biplot techniques was effective to make decision of selection under various locations conditions in Iran. In Algeria, used AMMI biplot to analyze genotypes of wheat in diverse locations which identified two genotypes as superior to response to locations. The objective was to analyze the GEI data by GGE-biplot technique to evaluate the efficacy of the test sites and to determine the performance of different wheat cultivars at three environments in Iraq.

Materials and Methods

Seven genotype of durum wheat (Jerardo, Kastal, Horani, JK-18, KH-49, KH-57, KH-69) have been grown in three locations (Latifiya, Twaitha and Tikrit) of Iraq. The experiments were a randomized complete block design (RCBD) with four replicates, and each experiment was repeated over three seasons (2005/2006, 2006/2007 and 2007/2008). The experimental unites were drilled in 3X3 m^2plots consisting of 18 rows with 15 cm left between rows. Seeding rate was 120 $kg.ha^{-1}$ for all locations and seasons. Phosphorus and nitrogen fertilizers were applied to each experiment as 100 $kg.ha^{-1}$ P_2O_5 and 100 $kg.ha^{-1}$ N respectively, at planting and 100 $kg.ha^{-1}$ N at tillering stage and at the stem elongation stage. As an indicator to the stability of the genotype through the locations the final grain yield was obtained in $ton.ha^{-1}$.

Statistical analysis: Grain yield data were analyzed in combined analysis of variance across locations using Mintab V. 16 (Table 1). Cluster analysis of wheat genotypes based on PRIMER6 v. 6.1.10 (Figure 1). Thereafter, data of grain yield were subjected to GGE biplot analysis to disintegrate the G x E interactions. The first two principal components (PC1 and PC2) as constructed in GGE biplot that were derived from subjecting environment-centered grain yield means for each location (averaged over the three seasons) to singular value disintegration. The data were not transformed ('Transform=0'), but standardized ('Scale=1), and were environment-cantered (Centering=2'). The graphs of GGE built showed yield analysis (Figure 2), "which-won-where" pattern (Figure 3), ranking of genotypes on the basis of both yield mean and stability (Figure 4), the average tester coordination of entry evaluation (Figure 5) and the relationship between entries (Figure 5; Yan, 2001).

Results and Discussion

Analysis of variance of the seed yield (ton.ha-1) showed highly significant differences among genotypes, environments and the interaction of genotype with the certain environment. The genotypes KH-57 and KH-49 were significantly higher than the overall rate of the rest genotypes at each location. However, they produced 4.10 and 4.09 $ton.ha^{-1}$ respectively. Minimum seed yield was 2.47 and 2.70 $ton.ha^{-1}$ obtained from Jerardo and Kastal respectively. Regard the environments, all genotypes in overall produced a significant yield in Twaitha (3.52 $ton.ha^{-1}$) and Latifiya (3.44 $ton.ha^{-1}$), comparing with Tikrit (3.27 $ton.ha^{-1}$). Similarly, the interaction of genotypes and environments showed superior of KH-57 and KH-49 where gave higher seed yield comparing with Jerardo and Kastal in each environment. It seems that KH-57 and KH-49 have high ability to adapt to a wide range of environments. However, they were superior in number of $spikes.m^{-2}$, kernels. $spike^{-1}$ and weight of 1000-kernels (g) (data not shown), therefore they produced significant yield comparing to the rest of genotypes.

Table (1): Mean presented are the yield average of the three seasons in (ton.ha^{-1}).

Genotypes	Latifiya LSD$_{(0.05)}$=0.167	Twaitha LSD$_{(0.05)}$=0.179	Tikrit LSD$_{(0.05)}$=0.14	Mean LSD$_{(0.05)}$=0.101
Jerardo	2.51^{e}	2.59^{d}	2.3^{e}	2.47^{e}
Kastal	2.77^{d}	2.74^{d}	2.6^{d}	2.70^{d}
Horani	2.92^{d}	2.98^{c}	2.76^{c}	2.89^{c}
JK-18	3.81^{c}	3.84^{b}	3.7^{b}	2.78^{b}
KH-49	4.09^{a}	4.23^{a}	3.94^{a}	4.09^{a}
KH-57	4.17^{a}	4.24^{a}	3.88^{a}	4.10^{a}
KH-69	3.84^{bc}	3.99^{b}	3.7^{b}	3.84^{b}
Mean LSD$_{(0.05)}$=0.067	3.44^{a}	3.52^{a}	3.27^{b}	

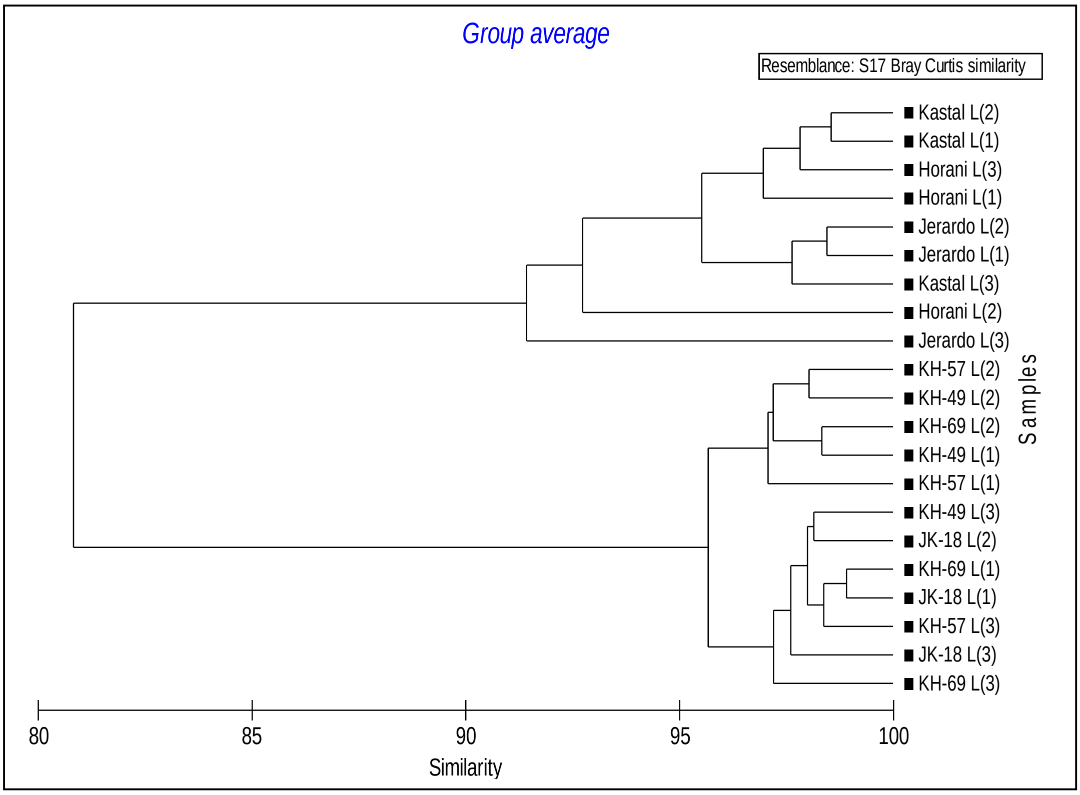


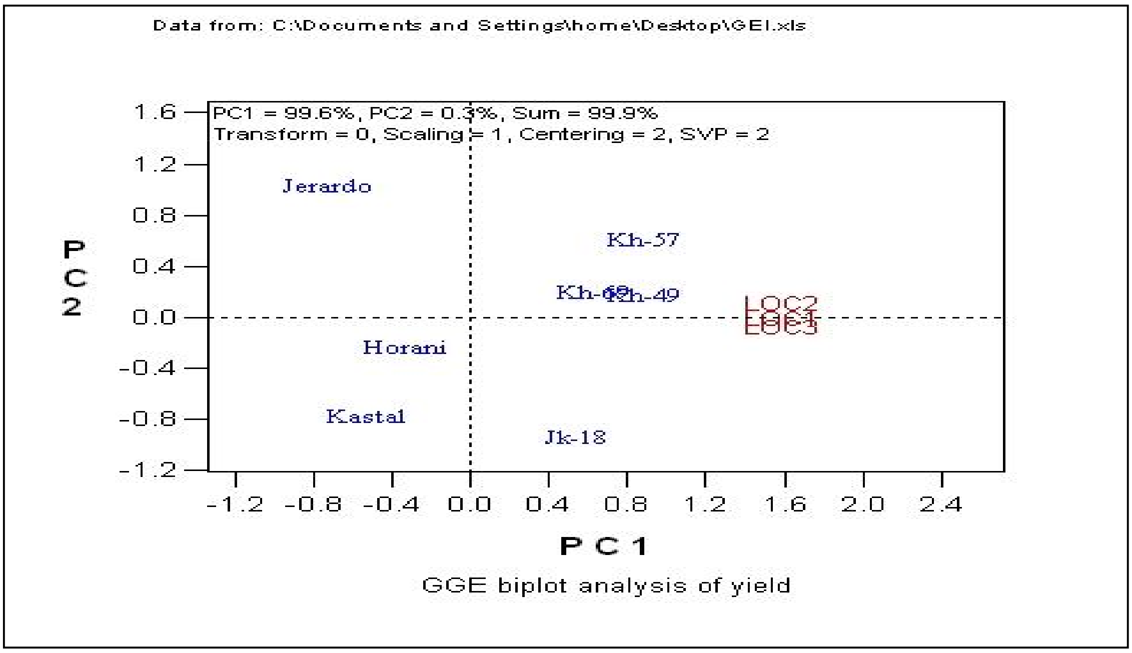
Figure (1): Diagram of cluster analysis of 7 wheat genotypes (Jerardo, Kastal, Horani, JK-18, KH-49, and KH-57and KH-69) within three locations each L1, 2 and 3 respectively based on the similarity for grain yield (ton.ha-1).

Cluster analysis: Combined cluster analysis of 7 divers wheat genotypes based on productivity (ton.ha-1) in each environment showed that genotypes were separated into two main clusters (Figure 1). The first cluster included genotypes (KH-57, KH-49, KH-69 and JK-18) in all environments under study while genotypes (Jerardo, Horani and Kastal) were fallen in the second cluster. But however, genotypes in each cluster were sub-divided into two and three sub-clusters respectively. The first sub-cluster includes genotypes: KH-69 (1, 3), JK-18 (2, 3), KH-57 (3) and KH-49 (3). While the second sub-cluster consisted of KH-57 and KH-49 in locations (1 and 2) and KH-69 (2). The second main cluster was again subdivided into three sub-clusters. First sub-cluster included Horani (2) and Jerardo (3), the second sub-cluster included Jerardo (1 and 2) and Kastal (3), while the third sub-cluster contained Horani in locations (1,3) and Kastal in locations (1,2). It is well known that the performance of genotypes can be different in according to the changes in environments, therefore a higher seed yield genotype in one environment may produce less yield elsewhere (Burdon, 1977). Many researchers have found that there is highly differentiation the yield among genotypes in different environmental conditions (Akçura *et al.*, 2011; Badu-Apraku *et al.*, 2011; Hamayoon *et al.*, 2011; Jandong *et al.*, 2011).

Cultivars performance in locations: A GGE-biplot analysis of yield showed that the PC1 interpreted 99.6% and PC2 of 0.3% of 99.9% total variance. GGE-biplot was divided into two sub-biplot, first was upper of horizontal zero line and second one which located under zero line. Figure (2) showed the possible relationship between the three locations those were so close to each other. This relationship was explained by the acute angle existing between each two axis of two locations. The cultivars located on the positive side of the axis (on the right side of the midpoint of the axis) had higher yield. But those located on negative side gave lower yield and cultivars or locations on the same parallel line, relative to the ordinate, had similar yield. Consequently, KH-57, KH-49 and KH-69 had higher yield. In contrast, Horani and Kastal gave lowest yield. Jerardo had high positive PC2, however it was unstable. The biplot sorts cultivars in relative of their yield as KH-57> KH-49> KH-69>JK-18>Horani>Kastal>Jerardo. For stability, the cultivars KH-69 were derivated as more stable than other cultivars. Generally, if any cultivar located near to the origin (midpoint), it would be considered as more stable that little interaction across environments. Cultivar KH-69 represented as ideal cultivar that should reveal a high yield and stability. The cultivar that would be optimal should be stood near to the positive end of the mean axis of the locations and vertical distance of that axis would be low. On this particular, the cultivar KH-57 was shown as the best cultivated.

Winning cultivars and multi-environment: Biplot visualization of the which-won-where pattern of multi-environment yield trials data (MEYT) is important for evaluating the existence of the diverse mega-environment in a certain region. From figure 3 the polygon view was constructed to determine the best cultivar for each location, because it is the best technique to visualize the interaction patterns between genotype and its environments and effective way to explain the biplot. The polygon is graphed by connecting the vertex cultivars that are further away from the biplot origin. The vertex cultivars in each sector had the highest yield in the location that falls within that particular sector. In figure3, the rays were formed from the origin of each side as stood in perpendicular to the sides of the polygon or their extensions to divide the figure into several sectors for identifying the special cultivar with broader adaptability. Thus, the cultivars KH-57, KH-49 and KH-69 offered better yield in their locations. The cultivar Horani located inside the polygon and near to the origin of the biplot that means had less reaction on the changing environment.

Ranking of Cultivars based on Mean and Stability: Figure (4) presents the ranking of the cultivars based on the best one. The cultivar KH-57 was closet t the most ideal cultivar that had inclined to the positive end of the axis with least vertical interval from the line which followed by KH-49, KH-69 and JK-18. An ideal cultivar can be defined as one that has the highest yield (longest projection on ATC x-axis) across tested environments and is stable which represented by the shortest projection on ATC y-axis performance (Hamayoon *et al.*, 2011; Xing-Ming *et al.*, 2007; Yan and Kang, 2003).



Figure(2): GGE-biplot based on seed yield data of 7 wheat cultivars.

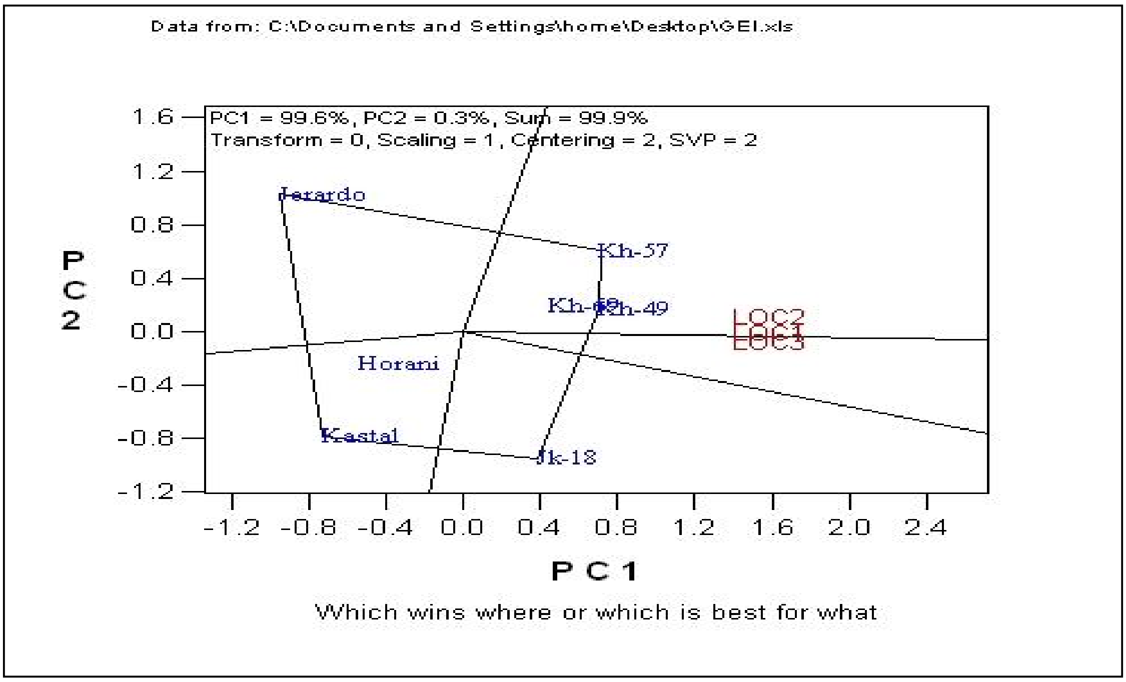
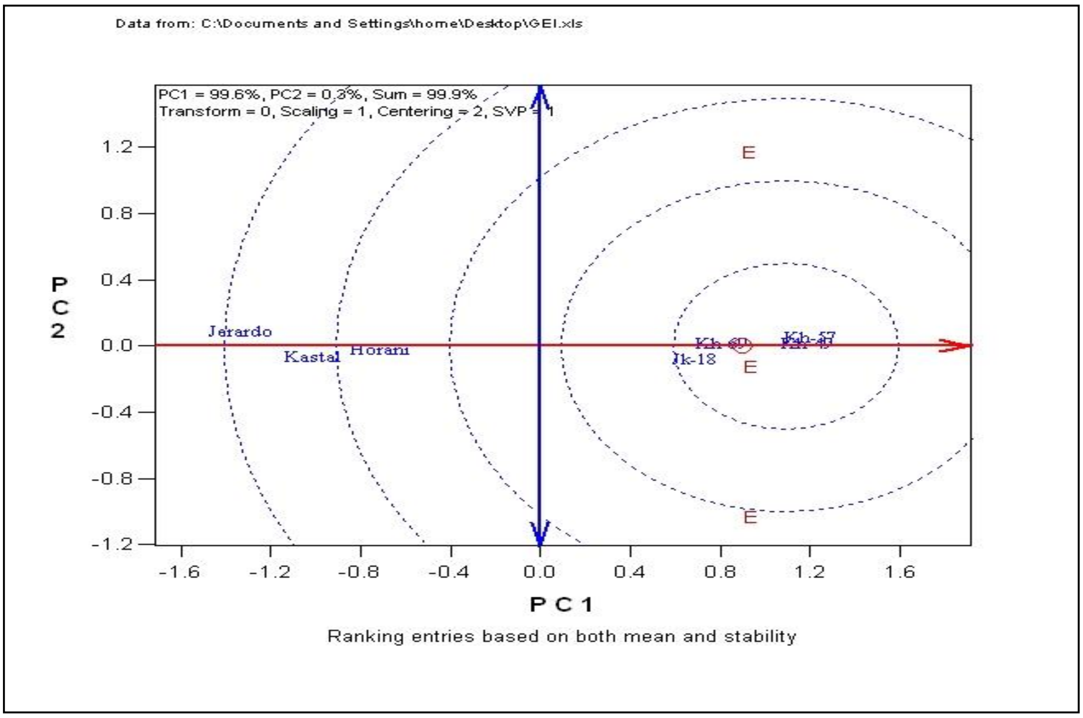


Figure (3): GGE-biplot of seed yield of 7 wheat cultivars in three locations.



Figure(4): Comparison of cultivars with the ideal cultivar. Locations are known as E.

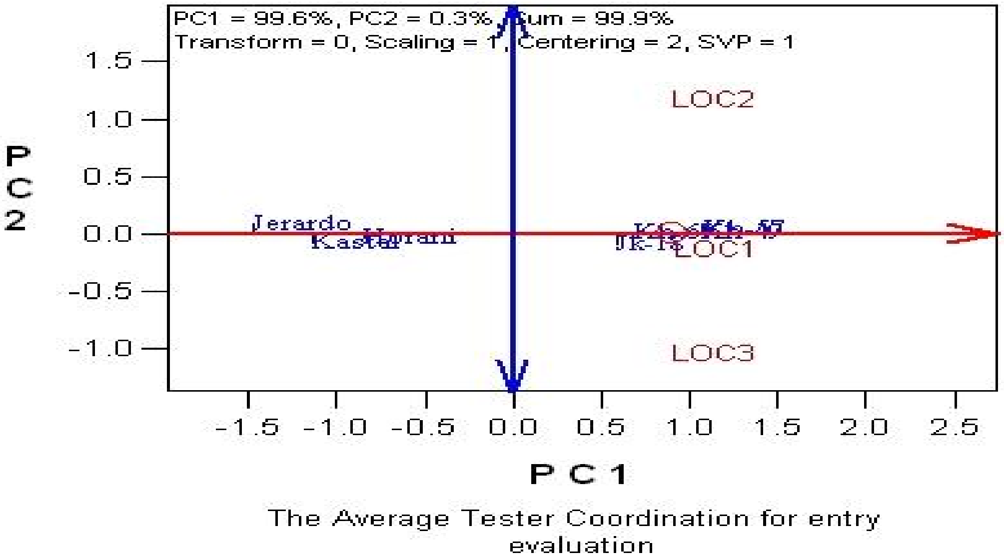
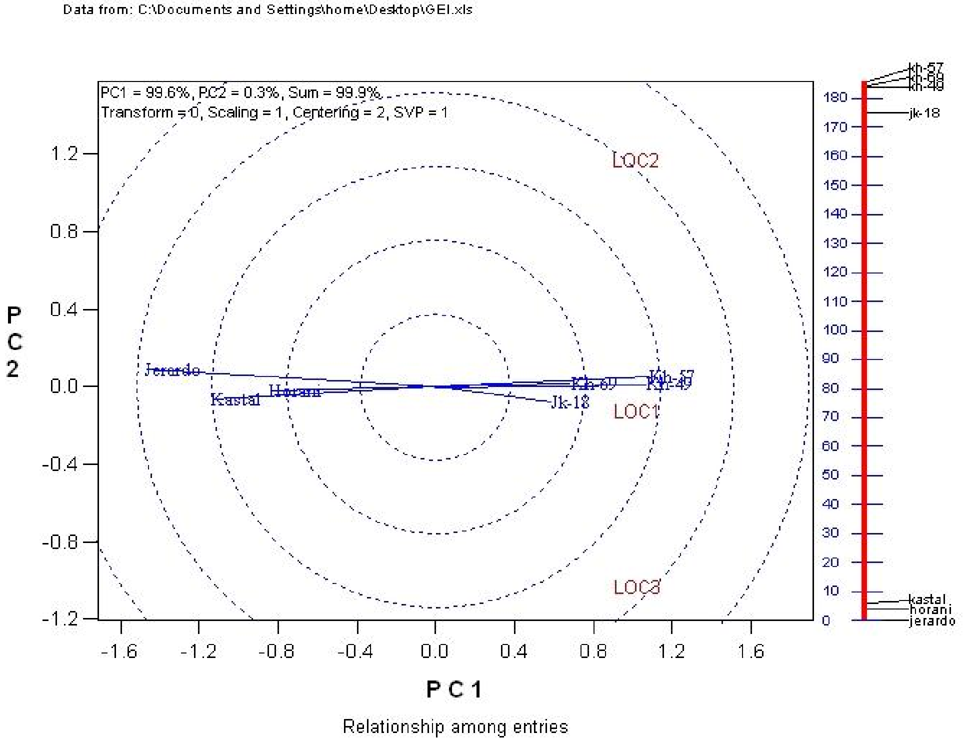


Figure (5): Average tester coordination (ATC) view of GGE-biplot. Cultivars on the parallel line with PC1 scores line and locations along with parallel with PC2 scores line.

Average yield and stability of cultivars: A GGE-biplot had specific option that allows integrating yield with stability performance among individuals of cultivars that tested in MET. Figure (5) revealed that the average testers coordinate (ATC x-axis) passes through the biplot origin and arrow indicates the positive end of axis. An axis ATC represents the mean yield and stability performance of cultivars which is approximated by the projection of their markers to the ATC axis. Thus, the biplot grouped the tested cultivars on the basis of their yield performance as KH-57> KH-49> KH-69> JK-18>Horani>Kastal>Jerardo. The cultivars KH-57, KH-49 and KH-69 were identified as top three cultivars and Horani,Kastal and Jerardo as the bottom three one.

Relationship among cultivars: Figure (6) indicates that the vectors of 7 wheat cultivars show their interrelationship and their linear map that locates on the right of the biplot indicates the relationship among cultivars too. The correlation between two vectors of cultivars is represented by the cosine of the angle between both (Hamayoon *et al.*, 2011; Yan and Kang, 2003). The graphed biplot of the relationship among cultivars revealed two different groups of cultivars. The first group located on the right side of the biplot midpoint included KH-57, KH49, KH-69 and JK-18. The second group located on the left side of the biplot midpoint that is included Kastal, Horani and Jerardo. This sorting is emphasized with linear map. It observed from linear map that showed KH-57, KH-49, KH-69 and JK-18 cultivars on top of the map and put Kastal, Horani and Jerardo in the bottom. Depending on this particular fact, the top individuals are so correlated. Similarly, the bottom ones are also being because the acute angles.



Figure(6): Biplot visualization of relationship among 7 wheat cultivars with linear map.

The GGE-biplot was identified KH-57 as the most desirable cultivar across environments followed by KH-49, KH-69 and JK-18. The cultivars like Horani, Kastal and Jerardo were undesirable in these environments. Even though the locations data were rather similar, the GGE-biplot methodology was a useful tool for identifying locations that were being best for genetic characterization of cultivars with limited resources (Hamayoon *et al.*, 2011; Shojaei *et al.*, 2011; Ullah *et al.*, 2011).Thus, the GGE-biplot technique may be represented as a toolbox for agronomists, plant breeders, geneticists and biometricians to interpret and understand the GEI data in MET.

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