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ANALYSIS OF GENETIC STABILITY USING GGE-BIPLOT TECHNIC TO WHEAT CULTIVARS (*TRITICUM AESTIVUM* L.) UNDER BASRAH DIFFERENT ENVIRONMENTAL CONDITIONS

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Abstract

A field experiment was carried out during the winter seasons (2016-2017& 2017-2018) in three locations in Basrah Governorate, AL-Daire, Qurna and AL-Madina to identify the cultivars with high stability for high grain yield study of genetic stability analysis of wheat cultivars (*Triticum aestivum* L.). The experiment included twelve cultivars of wheat (Abu Graib-3, Fatih, Rasheed, Furat, Latifih, Tammoz-2, Baraka, IPA -95 and IPA -99, Bhooth-10, Bhooth-22 and Bhooth-158). The studied the genetic stability of the cereal yield was studied using the analysis of stability GGE-Biplot, the result showed that PC1 values amounted to 84.1 and 84.0 for the first and second seasons in successively, and that PC2 values gave a ratio of 15.8 % and 15.9 % for the first and second season in successively and that AL-Rasheed Cultivar is the Ideal with a higher yield and genetically stable product. The Cultivar AL-Baraka is the type near the Ideal. Therefore, recommend that these two cultivars be cultivated under the conditions of this province.

Key words: Genetic stability using, field experiment, different Environmental Conditions

Introduction

Wheat *Triticum aestivum* L. is one of the most important small grain crops in the world and plays an important role in achieving food security. Because of its importance in producing bread loaf that is indispensable to most of the world's (Salim and Mahdi, 2012), which take the first place in the list of consumer food commodities. The wheat crop is considered an important nutritional value. It has a good balance between protein and carbohydrate, as well as containing fat, vitamins (B1 and B2) and some mineral salts (Yunis, 1992). Although Iraq has one of the original habitats for the emergence of wheat, and although it is one of the countries with the success factors of crop cultivation, its productivity is still low, with a global cultivated area of 736.5 thousand hectares and is expected to be productive according to FAO about 739.9 million ton.(FAO, 2017). The identification of stable varieties with a high yield is important for all plant breeders as the sedentary species is defined as the class that has the potential to avoid fluctuations in production if planted in several environments with a good yield. The status of the product is quantitative and usually shows a significant genetic-environmental (G.E.) interference and therefore the difference in the yield of the tested compositions is significant between the studied environments (Abbas, 2013). One of the most important matters for plant breeders to introduce new genotypes into a good performance assessment program under different environmental conditions. The grain producer traits are in the foreground treats. The grain producing is complex quantitative traits are controlled by multigene, and the response of the genotypes to environmental changes and instability of genotypes characteristics when they are grown in different environmental conditions is an obstacle in determining the superiority of them. Therefore, estimating the interference between the genetic and environmental conditions and determining the stability are important criteria to be considered. Estimating the interference between genetic and environmental of genotypes and determining stability is an important criterion to consider. Therefore, the performance of genotypes is tested in different locations. The cultivar gives a fixed product in the area unit for several locations for many years that one of the important criteria that help to identify the stability and performance of genotype in a wide range of different environments. Therefore, researchers were interested in studying the interaction between genetic × environments (GEI) and analyzing the experiments of cultivars in multiple environments using GGE -Biplot analysis to recommend the appropriate genotype of these environments (Yan and Kang, 2003). Thus, the adoption and registration of these genotypes depends on the stability of the product in multiple environments, and the optimum type of performance and stability can be determined across heterogeneous environments (Mohammadi *et al.,* 2010, Ullah *et al*., 2011) and Yan and Rajcan (2002) As noted EL-Sahookie and AL-Mehemdi (2008). To the efficiency of this technology in extracting the variations resulting from environmental interference with heredity and the ease of testing the varieties to a large extent in multiple environmental zones. Technology GGE-Biplot May represent a toolbox for crop researchers, plant breeders, genetics and statisticians to interpret data GEI in MEYTs (Multi Environment Yield trails) To estimate the genetic act and the locations of quantitative qualities, researchers who have used the technique GGE-Biplot Also Yan *et al*., (2001), Mohammadi *et al*., 2010), Mohammadi and Amri (2012), AL- Jumaily (2013), Farshadfar and Sadeghi (2014) and Mohammadi *et al.* (2015). and stated Dehghani *et al*., (2006) The application of this technique was instrumental in making the election decision in different locations. Through our observation of research results conducted on wheat yield in Basra Governorate (Habib, 2004, AL-Refai, 2006, AL.Shabeeb, 2013 and Al-Abdullah, 2015) show that there is a clear discrepancy in the results of these research, A particular cultivar is superior in one region while another cultivar is superior in another region in the same province, which indicates that there are no suitable cultivars for all the conditions of Basrah governorate (different soil and water conditions). which requires an evaluation of the cultivars currently available by planting them in different areas in Basrah governorate in order to studying the genetic stability of these cultivars in order to identify one or more cultivars It is suitable for the conditions of the province for its circulation on the farmers, and in the absence of studies related to analysis of the genetic stability of different varieties of wheat under the conditions of the province of Basrah carried out this study with the aim of: To evaluate the genetic formulas of the fine wheat under different environmental conditions and determine their responsiveness and stability to different environments by adopting stability parameters to determine the fixed item under these environments.

Materials and Methods

A field experiment was carried out during the winter seasons (2016-2017 & 2017-2018) in three locations in Basrah Governorate, AL-Daire (rivers banks locations), situated 50 km north of Basrah Governorate irrigated from Shatt AL-Arab water, and the Qurna site (rivers banks locations), situated 75 km north of the governorate center, and irrigated from The Ghmig River, and the location of the AL-Madina (Marsh areas), situated 105 km northwest of the Governorate and irrigated from the Euphrates River water. The aim of identifying the cultivars with a high stability high grain yield study of genetic stability analysis of wheat cultivars (*Triticum aestivum* L.). The experiment included twelve cultivars of wheat (Abu Graib-3, Fatih, Rasheed, Furat, Latifih, Tammoz-2, Baraka, IPA -95 and IPA -99, Bhooth-10, Bhooth-22 and Bhooth-158). The experiment was applied according to the design of the Randomized Complete Block Design (R.C.B.D) with three replicates. The studied the genetic stability of the cereal quotient was studied using the analysis of stability GGE-Biplot. Stability was analyzed using the parameters of the stability proposed by GGE-Biplot (Gabriel, 1971). The analysis of the characteristics of the studied genotypes was carried out by statistical analysis according to the design of (R.C.B.D) and the studied characteristics of each location. The least significant difference (L.S.D.) was determined by Al-Rawi and Khalaf Allah, (1980). The area culture was divided into 36 experimental units of 12 m^2 with dimensions of 3 m × 4 m, including 20 lines with a length of 3 m for the cultivated line, 15 cm between one line and another, and a distance of 1 m between The experimental units and 2 m between replicates, seed varieties were planted on 15/11/2016 for both seasons and at a rate of 120 kg h^{-1} (Abu El-Iss, 2004). The urea fertilizer was added by 100 kg ha^{-1} (Al-Abdullah, 2015) in two batches after the emergence of the seedling and the second in the elongation phase (Davis *et al.,* 2002). The irrigation and Hoeing and weeding operations were carried out during the two seasons and according to the need of the crop, and the plants were harvested on 15/4/2017 and 5/4/2018 for the first and second seasons successively at maturity stage. One square meter was taken from each plot to calculate the grain yield on a 14% moisture basis and then converted to 1 ton per hectare. GGE-Biplot was used to determine the genetically stable cultivars with high yield.

Genetic analysis: Use the GGE-Biplot method

GGE-Biplot technic is based on two concepts: the first is that only G and G.E. are used in the evaluation of genetic compositions (hence the label GGE) and the second is that Biplot Technic employs GGE in MEYT experiments (experiments in multiple environments, multi environment Yield Trails). GGE-Biplot builds on the primary and secondary effects of the PC1 and PC2 core components (components analysis Principle) resulting from the exposure of the environment centered yield) data, which are used to analyze the interference effect of the aggregate model and thus Collection of genetic compositions in aggregates based on similarity in performance during contrasting environments. The GGE-Biplot analysis model by (Yan, 2002), which builds on the single value analysis (SVD) of the first two main components, is:

$$Y_{ij} - \mu - \beta_j = \lambda_1 \Sigma_{i1} \eta_{j1} + \lambda_2 \Sigma_{i2} \eta_{j2} + E_{ij} \qquad (1)$$

Whereas: Measurement of installation Performance (i) in Environment j: Overall rate: the main effect of Environment j, and: Single values (SV) for the first and second core components (PC1 and PC2) in succession and are eigenvectors values for the first two basic components, and: eigenvectors for Environment j For the first two primary components, Eij is the error for installation i in Environment j. Eigenvectors for PC1 and PC2 values cannot form biplot immediately before individual values are fragmented into eigenvectors values of genetic composition and environment by:

$$g_{i1} = \lambda_1{}_1^{fi} \Sigma i1 \text{ and } e_{ij} = \lambda_1{}_1^{1-f} \eta_{ij} \qquad (2)$$

Whereas: *fi* the hash coefficient for PC1 values whose values are between 1 and 0 in order to generate GGE-Biplot, equation (1) will be written as follows:

$$\lambda_{ij} - \mu - \beta_j = g_{i1}e_{ij} + g_{i2}e_{2i} + E_{ij} \qquad (3)$$

When modifying data, the last equation becomes:

$$(Y_{ij} - \mu - \beta_j)/S_j = \Sigma_i^k g_{i1}e_{1j} + E_{ij} \qquad (4)$$

where *Sj* : Standard deviation in Environment j, i = 1, 2,........, K, gi 1 and e1j are PC1 values for installation cultivar i and j environment in succession. Equation (4) was used to form (2) and equation (3) to assess the relationship between composition and environment, analyzed and graph using the GGE-Biplot program (Yan and Tanker, 2005).

Results and Discussion

The results of table 3 show that the total values of the SST in PC1 and PC2 are 99.9% for the first and second seasons, which affect the size of the total variance that can be explained to determine the genetic and environmental variation between the planted genotypes in the environments under the test. That the differences between the two types PC1 and PC2 in both seasons were significant at 1%, that the stability of these genotypes was high and the effect of the environment on the genotypes was significant.

Table 2: Symbolizing of genotypes and environments in study.

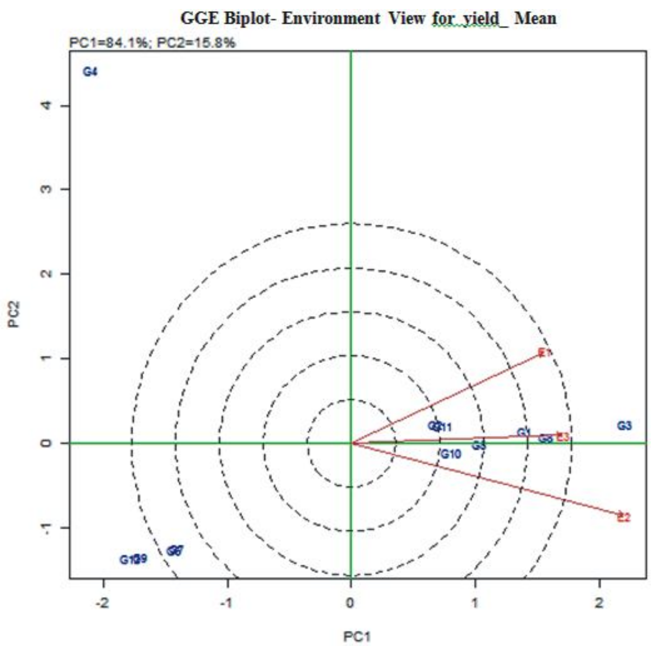
Cultivar	Symbol	Environments	Symbol
Abu Graib-3	G1	AL- Daire	E1
Fatih	G2	AL-Qurna	E2
Rasheed	G3	AL-Madina	E3
Furat	G4		
IPA-99	G5		
Latifih	G6		
Tammoz-2	G7		
Baraka	G8		
Bhooth-10	G9		
Bhooth-22	G10		
IPA-95	G11		
Bhooth-158	G12		

Table 1: Some chemical and physical characteristics of field soil before culture for two growth seasons.

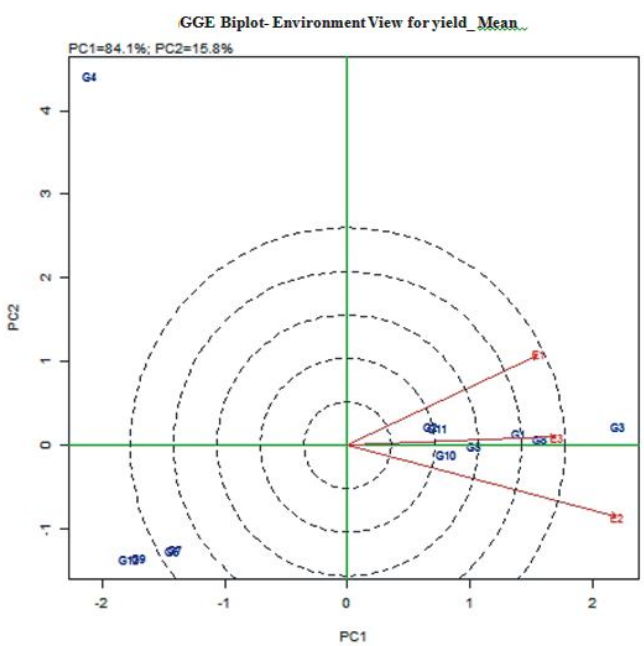
Nutrients Mg kg-1			Organic matter	EC m-1		pH		Soil	Location	
K	P	N	(g kg-1)	Soil	Water	Soil	Water	stricture		
180.17	9.91	40.0	1.02	2.60	6.90	7.7	7.9	silt clay	Daire	Season 12016-2017
190.50	11.30	56.0	3.24	1.90	5.80	7.4	7.6	silt clay	Qurna	
200.10	14.12	66.1	4.06	3.10	5.50	7.3	7.6	silt clay	Madina	
Nutrients Mg kg-1			**Organic matter**	**EC m-1**		**pH**		**Soil**	**Location**	
K	**P**	**N**	**(g kg-1)**	**Soil**	**Water**	**Soil**	**Water**	**stricture**		
169.50	8.50	38.4	1.11	2.90	7.20	7.3	7.6	silt clay	Daire	Season 12017-2018
187.30	9.20	44.3	3.20	2.10	6.40	7.3	7.8	silt clay	Qurna	
196.71	10.02	60.0	3.90	2.90	5.30	7.6	7.7	silt clay	Madina	

Table 3: GGE-Biplot analysis of grain yield for twelve genotypes in three environments for two season.

	Percent	Acum	d.f.	Sum. Sq.	Mean Sq.	F. Value	Pr.F	
PC1	84.1	84.1	12	30.687860	2.557322	39.75	0.0000**	The
PC2	15.8	99.9	10	5.762299	0.576230	8.96	0.0000**	first
PC3	0.1	100.0	8	0.037483	0.004685	0.07	0.9998	season
PC1	84.0	84.0	12	30.359219	2.529935	51.80	0.0000**	The
PC2	15.9	99.9	10	5.759641	0.575964	11.79	0.0000**	second
PC3	0.1	100.0	8	0.035102	0.004388	0.09	0.9994	season



First Season



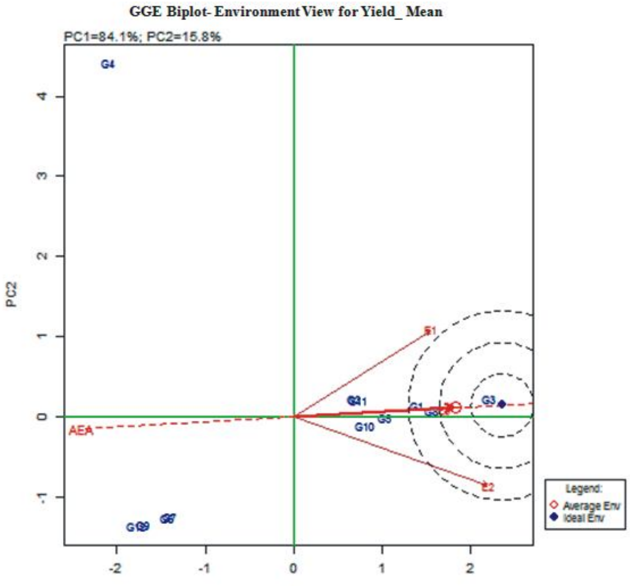
Second Season

Fig. 1: The relationship between environments for the first and second season.

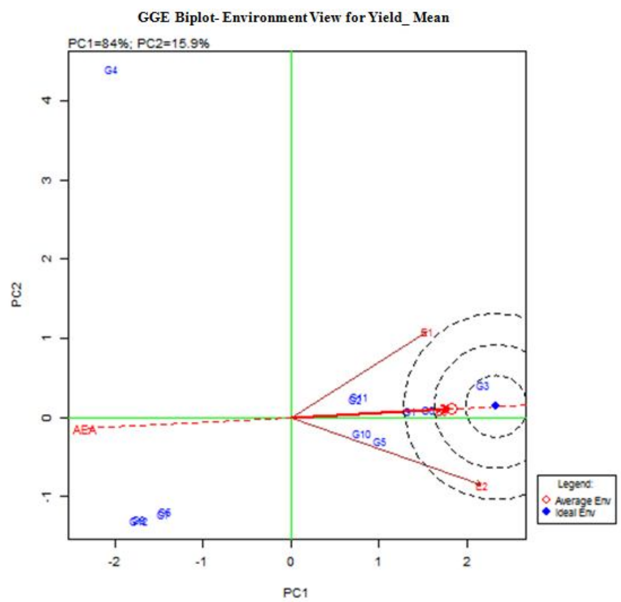
Fig. 1 and 2 shows the relationship between the environments. The relationship between PC1 and PC2, which summarizes the effect of environments on genotypes, shows that the third environment E3 had the least impact on the genotypes, whereas the first environment E1 had an effect an increase in grain product reversing the second environment E2.

PC1 represent 84.1% of total variance, which could show variation in genotypes, whereas PC2 15.8% of total environmental variations. It can be shown that genotypes that are higher than zero on the PC1 axis are oriented towards Increase the grain yield, while the genotypes located near zero on the axis of PC2 as a low productivity of a grain, which shows that the genotype G3 is a high productivity of the grain in the first group, the second group were represented in the genotypes G8, G1 then G5, the less genotypes is G12, which can be noted in Fig. 1 as concentric circles.

That the relationship between the environment is a direct relationship and this is evident from the values of the angles between the vectors of environments that were less than 90 degrees, and also show that the environment E3 is an ideal environment, since the ideal environment has the highest value PC1 and the lowest value of PC2, GGE-Biplot using the AEA coordinate. Based on Figs. 2, it was found that the stability of the environment is determined by the values of PC1 and PC2 where it is observed that the higher the positive values of PC1, the genotypes are stability while the length of the vector of the PC2 as stability of genotypes in the environment under study which shows that a better environment is E3. G3 is the most stable genotype in all environments and is applicable to the AEA axis, while other genotypes are proportional to the length of the vector on the AEA axis and the PC2 dimension values varied. The ideal genotype was G3 then G8 was close to Ideal because it was close to the center of the circuit and thus combined high yield and high stability, while the G12 and G4 structures were far from ideal. The G4 is suitable for environment E1 and the G3, G8, G1, G5, G10, G11, and G2 are suitable for environment E3, The rest genotypes is suitable for environment E2.

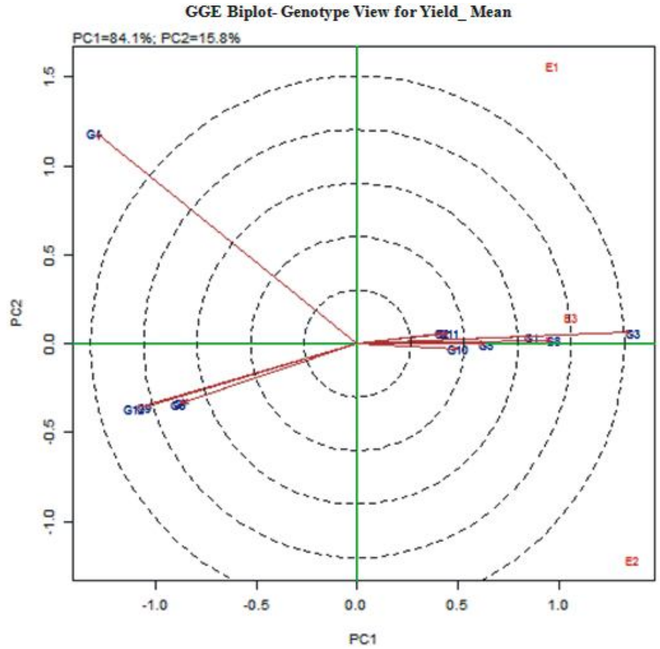


First Season

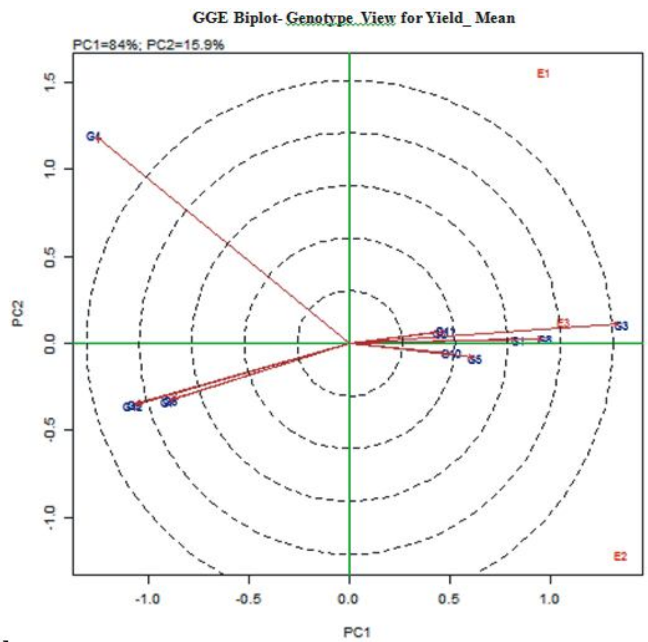


Second Season

Fig. 2: The Ideal environment for the first and second season.



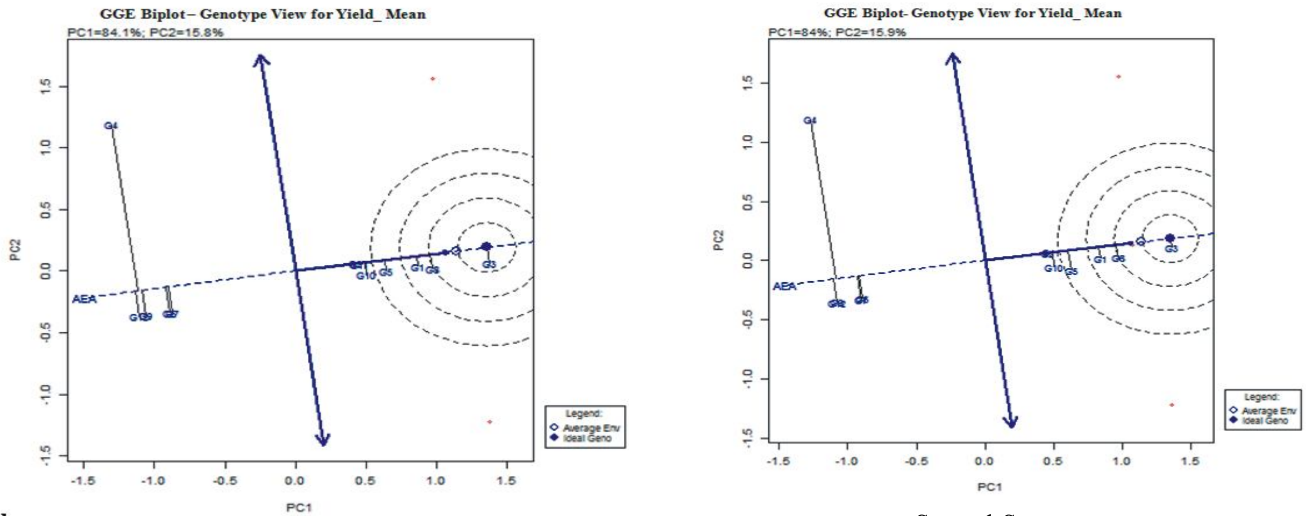
First Season



Second Season

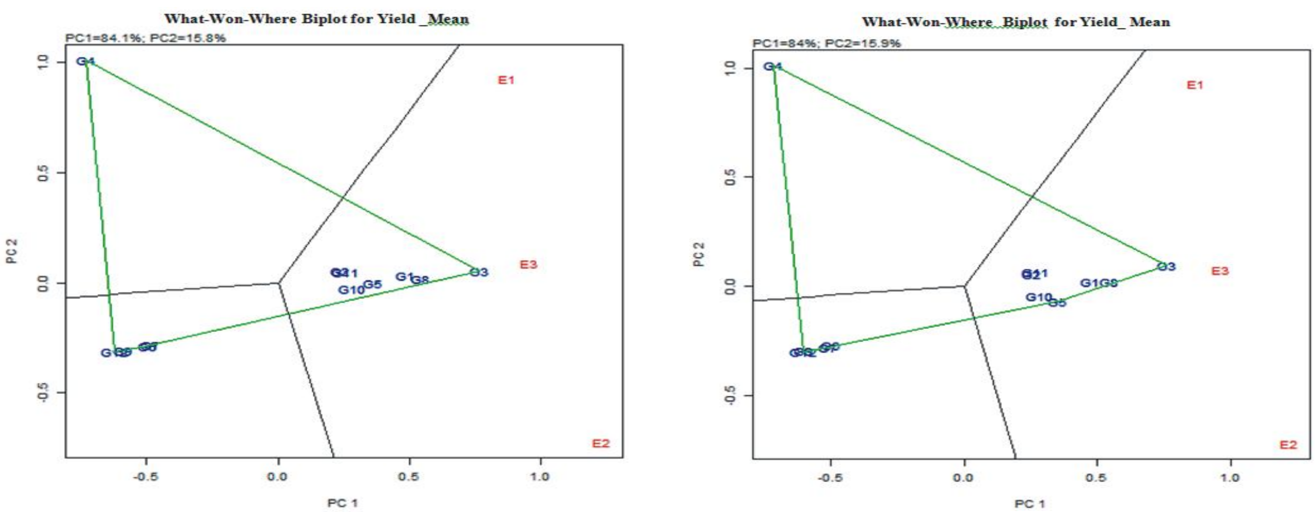
Fig. 3: The relationship between the genotypes for the first and second season.

Fig. 3 show the relationship between the genotypes. In these figures, the relationship between the environment and the genotypes can be clarified. It is consistent with Fig. 1 and 2 in the distribution of the stability of the genotypes under different environments. G3 genotype is a high yield in environment E3 and in other environments was one of the higher varieties. The stability was divided into five groups (circles) because each circle represented a group. The first group gave the highest yield, which was G3, followed by the G8, G1, and G5 and the third group has included the G10, G11, and G12, which was stability clear in the E3 has been observed that the genotypes showed different ratios stabilizing in environments E1 and E2 while the low stability in G2, G4, G6, G7, and G9. The vector emanating from origin and environment vector is called the Environment Factor. This can explain the correlation between different environments. The exact angle between any vectors of any environment corresponds to the values of relation value between them. Factor Length is the standard deviation of this environment and represents the susceptibility of this environment to the classification of genotypes with high genetic stability. The increase in the



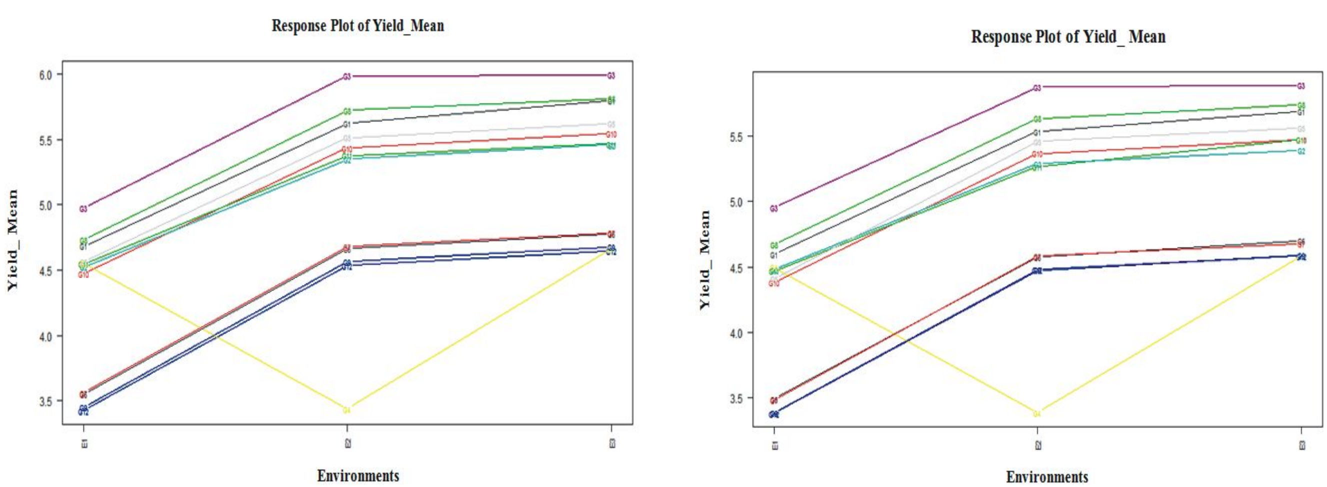
First Season Second Season

Fig. 4: The Ideal genotypes for the first and second season.



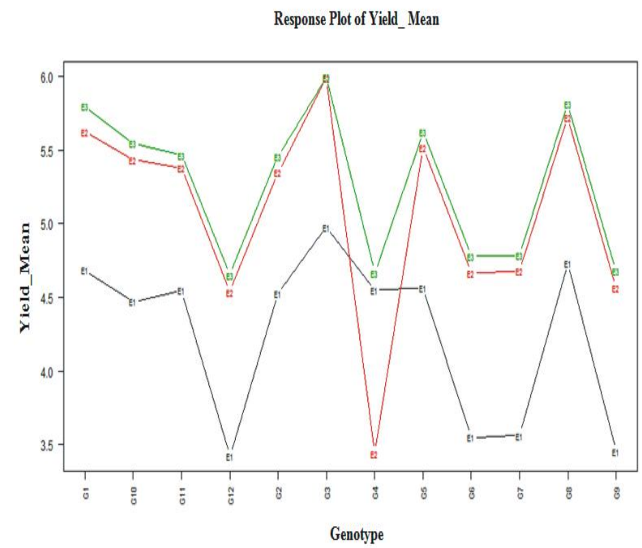
First Season Second Season

Fig. 5: High performance genotypes for each environment for the first and second season.

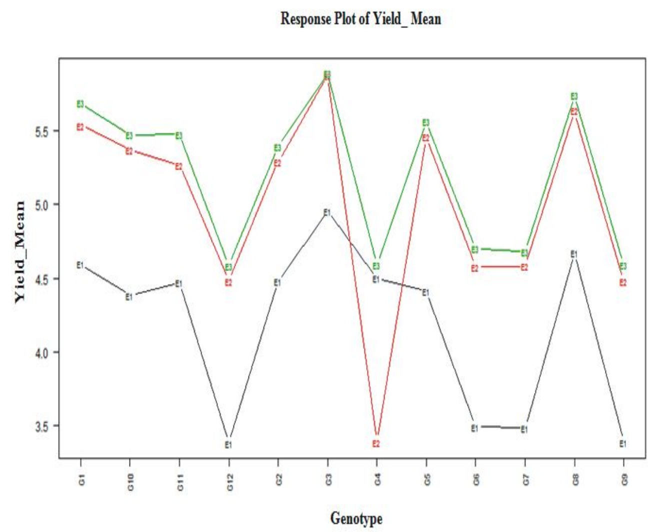


First Season Second Season

Fig. 6: The response between the environments and Yield of the first and second season.



First Season



Second Season

Fig. 7: The response between the genotypes and Yield of the first and second season.

length of the vector indicates an increase in the ability of this environment to classify the genotypes of genetic stability.

The positive relationship between genotypes depends on the sharp angle between their vectors. The G2, G6, and G12 are similar in their response to genetic-environmental interference. G3, G8, G1, G5, G10, G11 and G2 are also similar in response to genetic-environmental interference.

Fig. 4 show the ideal genotype in different environments. The first group has a high-grain yield containing the G3. The ideal genotype was a concentric circle, while the second group included G8 and G1 (Close to Ideal), the other genotypes were included in the third group. The genotype that has PC2 values close to one is adaptive and the genotype has values far from one are inadequate. It is clear that the G3, G8, G1, G5, G10, G11 and G2 are graduated stability they have shortest arrows from the point of origin. And that the ideal genotype was G3, and G8, which is close to the ideal because it was close to the center of the circle and thus combined the high yield and high stability, while the structures G12 and G4 the least and far from Ideal.

Fig. 5 show the relationship between the preferred genotypes of each environment. G3 is best in environment E3 and G3, G8, G1, G5, G10, G11, and G2 are suitable for E3 and other genotypes are E2, The E1 and E2 environments share the stability of each of the polygon-bound genotypes, while the G4 gene is less stable among the genotypes under study. This is consistent with Fig. 6 and Fig. 7. The best genotypes is G3 and that the best environments were E3 and Fig. 6 and Fig. 7 summarize the average effect Genotypes and environments under study.

The method of stability analysis using GGE-Biplot technic, which is one of the most effective methods in the analysis of the stability by showing the interrelationship between the genotypes and the environments under test and facilitating comparison by drawing the relationship between genotypes and environments, then facilitating the selection of high-stability genotypes. Mohammadi and Amri (2012), Farshadfar and Sadeghi (2014), Mohamed (2013), Temesgen *et al.,* (2015), Mehari *et al.,* (2015), Schafascheck *et al.,* (2017), Bacha *et al.* (2017), Jeberson *et al.,* (2017) and Bilgin *et al.,* (2018), they referred to the efficiency of this technology in the identification of genotypes stability and Ideal environment.

Conclusion

Al Rasheed genotype is the Ideal cultivar and the Baraka genotype is the near to the Ideal, so we recommend the cultivation of the to Al Rasheed and Baraka genotypes which high genetic stability at all studied environments.

References

Abu El-Iss, R.M. (2004). Wheat farming technology, general authority for agricultural extension and cooperation. Guidance leaflet.

Al-jumaily, J.M. (2013). Yield Stability of Soybean Genotypes in Two Locations. *The Iraqi Journal of Agricultural Sciences*, **44(2):** 200-205.

Habib, D., Abdul-Nabi Abdul Karim (2004). Response Cultivars from the (*Triticum aestivum* L.) for quantities of seeds.

Master thesis. college of Agriculture- University of Basrah.

Al-Rawi, M. and A.K. Allah (1980). Design and analysis of agricultural experiments. Dar al-Books for printing and publishing. University of Mosul. Ministry of Higher Education and scientific research. Iraq.

AL-Refai, S.I.M. (2006). Response of Wheat *Triticum aestivum* L. Cultivars to foliar feeding of Iron and Manganese. PhD Thesis- The college of Agriculture-Uni. Of asrah

Al-Shabeeb, E.A.B. (2013). Evaluation of Wheat Cultivars (*Triticum aestivum* L.) Cultured Under Different Nitrogen Fertilizers Levels and Determine Selection Index By Path Coefficient. Master Thesis-The college of Agriculture- Uni. of Basrah.

Abbas, S.H. (2013). Study in parameters stability of genotypes in bread wheat (*Triticum aestivum* L.) under different seeding rates.*Kufa Jou. for Agr. Sci*.,**5(2):**188-210.

AL- Abdullah, S.A.M. (2015). Effect of Nitrogen Application on N, P, K Uptake and Distribution Whihin Plant Parts, Growth and Yield of Three Wheat Cultivars *Triticum aestivum* L. PhD Thesis-The college of Agriculture-Uni. of Basrah.

AL-yunis, A.H.A. (1992). Production and improvement of field assets. Ministry of ducation and Scientific research, University of Baghdad.

Bacha,T., Z. Taddesse and M. Mehari (2017). GGE- Biplot Analysis of Genotype× Environment Interaction and Grain Yield Stability of Bread Wheat (*Triticum aestivum* L.) Genotypes in Ethiopia. *Journal of Biology, Agriculture and Healthcare*, **7(8):** 22-30.

Bilgin, O., A. Balkan, Z.K. Korkut and Ý. Baþer (2018). Multi-environmental Evaluation of Triticale, Wheat and Barley Genotypes by GGE Biplot Analysis. *Journal of Life Sciences*, **12:** 13-23.

Davis, J.G., D.G. Westfall, J. Martvedt and J.F. Shanahan (2002). Fertilizing winter wheat. Colorado State University, Cooperative. *Ext. Agric*., No. 544.

Dehghani, H., A. Ebadi A. and A. Yousefi (2006). Biplot analysis of genotype by environment interaction for barley yield in Iran. *Agron. J*., **98(2):** 388-393.

El-Sahookie, M.M. and A.F. Al-Mehemdi (2008). Principal component analysis to test stability of cultivars across environments: Atutorial review article. *Iraqi J. Agric. Sci*., **39(1):**102-115.

FAO, (2017). World Wheat market at a glance Food outlook, *Economic Social Dept*., **(1):** 1-7.

Farshadfar, E. and M. Sadeghl (2014). GGE Biplot Analysis of Genotype × Environment Interaction in Wheat-Agropyron Disomic Addition Lines. *Agricultural communications*, **2(3):** 1-7.

Gabriel, K.R. (1971). The biplot graphic display of matrices with application to principal component analysis. *Biometrics*, **58:** 453-467.

Jeberson, M.S., L. Kant, N. Kishore, V. Rana, D.P. Walia and D. Singh (2017). AMMI and GGE Biplot Analysis of Yield Stability and Adaptability of Elite Genotypes of Bread Wheat (*Triticum aestivum* L.) for Northern Hill Zone of India. *International Journal of Bio-resource and Stress Management*, **8(5):** 635-641.

Mehari, M., M. Tesfay, H. Yirga, A. Mesele, T. Abebe, A. Workineh and B. Amare (2015). GGE biplot analysis of genotype-by-environment interaction and grain yield stability of bread wheat genotypes in South Tigray, Ethiopia. *Communications in Biometry and Crop Science*, **10(1):** 17-26.

Mohamed, N.E.M. (2013). Genotype by environment interactions for grain yield in bread wheat (*Triticum aestivum* L.). *Journal of Plant Breeding and Crop Science*, **5(7):** 150-157.

Mohammadi, R., R. Haghparast, A.Amri and S. Ceccarell (2010). Yield stability of rainfed durum wheat and GGE biplot analysis of multi-environment trials. *Crop Pasture Science*, **61(1):** 92-101.

Mohammadi, R., E. Farshadfar and A. Amri (2015). Interpreting genotype × environment interactions for grain yield of rain fed durum wheat in Iran. *The Crop Journal*, **3:** 526-535.

Mohammadi, R. and A. Amri (2012). Analysis of genotype× environment interaction in rain-fed durum wheat of Iran using GGE-biplot and non-parametric methods. *Can. J. Plant Sci.*, **92(4):** 757-770.

Salim, H.A. and S.J. Mahdi (2012). Effect of tillage and chemical herbicides on the control of weeds in wheat crop. *Karkok Univ. J. for Agric. Sci.*, **3(2):** 87-104.

Schafascheck, L., C.D.J. Coelho, B.L. Graczyki, R.S. Hilbert, C.T.S. Dias and R.R. Matiello (2017). Adaptability and Stability of Wheat Genotypes by GGE Biplot Method. *International Journal of Agriculture Innovations and Research*, **6(3):** 2319-1473.

Temesgen, M., S. Alamerew and F. Eticha (2015). GGE Biplot Analysis of Genotype by Environment Interaction and Grain Yield Stability of Bread Wheat Genotypes in South East Ethiopia. *World Journal of Agricultural Sciences*, **11 (4):** 183-190.

Ullah, H., I.H. Khalil., I.A. Khalil and G.S.S. Khattak (2011). Performance of Mung bean enotypes Evaluated in Multi-Environmental Trials Using the GGE Biplot Method. *Atlas J. Biotechn.*,**1:**1-8.

Yan, W. and M.S. Kang (2003). GGE Biplot Analysis: A Graphical Tool for Breeders, Geneticists, and Agronomists Press Boca Raton, FL.USA.

Yan, W. and N. Tanker (2005). An integrated biplot analysis system for displaying, interpreting and exploring genotype-environment interaction. *Crop Sci*., **45:** 1004-1016.

Yan,W., P.L. Cornelius, J. Crossa and L.A. Hunt (2001).Two types of GGE biplots for analyzing multi-environment trial data.*Crop Sci*., **41:** 656-663.

Yan,W. and I. Rajcan (2002). Biplot analysis of test sites and trait relations of soybean in Ontario. *Crop Sci.*, **42:**11-20.

Yan,W. (2002). Singular value partitioning for biplot analysis of multi-environment trial data. *Agron. J.*, **94:** 990-996.