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STABILITY OF GRAIN YIELD IN BREAD WHEAT GENOTYPES UNDER DIFFERENT ENVIRONMENTS

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ABSTRACT: Stability is important indicator in light of climate change in the Mediterranean region. Therefore, thirteen bread wheat genotypes were evaluated for grain yield under eight different environments. The environments were the combinations of four irrigation regimes (normal, mild, moderate and severe stress) × two seasons (2016/2017 and 2017/2018). Results indicated that stability analysis of variance revealed highly significant G x E "linear" for grain yield. Phenotypic stability parameters showed that wheat genotypes Gemmeiza12 and Line 3 were highly adapted to improved environments. On the contrary, wheat genotypes Sakha 95, Line 142 and Line 1 were adapted to water stress environments. Furthermore, wheat genotypes which could be grown under a wide range of environments were Misr 1, Misr 2, Sakha 94, Giza 171, Shandweel 1, Line 26 and Line 6 for grain yield. The most desired and stable genotypes were Misr 1, and Gemmeiza 11 for grain yield. The additive main effect and multiplicative interaction (AMMI) analysis of variance showed that 49.56, 28.90 and 1.79% of the total sum of squares were attributable to environmental, genotypic and genotype x environment interaction (GEI) effects for grain yield, respectively. Both models of **Eberhart and Russell (1966)** and AMMI **(Gauch, 1992)** are consistent in describing the stability of Misr 1 and Gemmeiza 11 for grain yield. These genotypes could be useful in wheat improvement programs for enhancing stability.

Key words: Bread wheat genotypes x environment interaction, phenotypic stability, AMMI model.

INTRODUCTION

Potential impacts of climate change on crop production have received immense attention during the last decades **(Tao *et al.*, 2008)**. Environmental stresses are of the most environmental limitations to wheat yield. Drought continues to be major challenge to agricultural scientists and plant breeders. Therefore, understanding the relationship between environmental stress and crop yield is fundamental to identify possible impacts of future climate and to develop adaptation measures. **Qaseem *et al*. (2019)** found that grain yield was reduced by 56.47%, 53.05% and 44.66% under combined of both heat + drought, heat and drought treatment, respectively.

Genotype x environment (G x E) interaction indicates the impact of environments on the expression of grain yield in wheat genotypes. Genotype x environment interaction analysis presented a certain degree of variation among genotypes; some genotypes displayed wide adaptation while other exhibited specific adaptation either to favorable or unfavorable environments. G x E interactions are of notable importance in the development and evaluation of wheat cultivars. G x E interaction increases with more differences among the cultivars in different environments or from changes in relative ranking of the cultivars **(Allard and Bradshaw, 1964**).

Wheat is the most important cereal crop in Egypt as a major source of nourishment. Increasing production per unit area is very

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important from the point of view of adaptability and stability. This is essential to avoid drought stresses and achieves global food security **(Lamaoui *et al*., 2018)**.

Various statistical procedures have been reported to find out the stability of new cultivars such as joint regression **(Eberhart and Russell, 1966)** and additive main effects and multiplicative interaction, AMMI **(Gauch, 1992)**. **Eberhart and Russell (1966)** suggested that regression coefficient (b_i) and deviation from regression coefficient (S^2d) might predict stable genotype. The genotypes are grouped according to the size of their regression coefficients, less than, equal to, or greater than one and according to the size of the variance of the regression deviations (equal to or different from zero). Those genotypes with regression coefficients greater than one would be more adapted to favorable growth conditions, while those with regression coefficients less than one would be adapted to unfavorable environmental conditions, and those with regression coefficients equal to one would have an average adaptation to all environments. Thus, a genotype with unit regression coefficient ($b_{i\,=}$ 1) and deviation not significantly different from zero ($S^2d = 0$) is said to be the most stable genotype. Many investigators have assessed the phenotypic stability in wheat genotypes under various environments and registered different degrees of stability, **Aly and Awaad (2002), Hamam and Khaled (2009), El-Ameen (2012), Abd El-Shafi *et al*. (2014), Ali (2017), Ali and Abdul-Hamid (2017) and Ahmed *et al*. (2019)**.

The Additive Main effect and Multiplicative Interaction (AMMI) method proposed by **Gauch (1992**) was a significant advance in the analysis and interpretation of G×E interaction. With this method main effects (genotypes and environments) are initially accounted for by a regular analysis of variance, and then the interaction (G×E) is analyzed through a principal component analysis which leads to identification of stable genotypes as well as to widely or specifically adapted genotypes in an easier manner. AMMI has been successfully employed to estimate stability and its heritability, adaptation and G×E elucidation in different crops. Genotypes with first principal-component axis value close to zero indicate general adaptation to environments. The AMMI stability value measure was proposed by **Purchase (1997) and Purchase *et al.* (2000)**. AMMI stability value (ASV) is the distance from zero in a two dimensional scattergam of IPCA 1 score against IPCA 2. A genotype with least ASV is the most stable. In this respect, many investigators used AMMI method for evaluating yield stability. Among them are **Najafian *et al.* (2010), Farshadfar *et al*. (2011), Mohamed *et al.* (2013) Ali (2017), Ali and Abdul-Hamid (2017) and Elbasyoni (2018**), who applied AMMI analysis to the yield data on various environments, and showed specific adaptation for several genotypes to specific environments.

The main purposes of this study are to examine grain yield stability and to characterize the adaptability of 13 bread wheat genotypes grown under eight diverse environments, using the joint regression and the AMMI method.

MATERIALS AND METHODS

Plant Materials and Experimental Layout

Field experiments were conducted at El-Salhiya region using thirteen bread wheat (*Triticum aestivum* L.) genotypes. The pedigree and origin of the bread wheat genotypes are given in Table 1. Bread wheat genotypes Line 1, Line 3 and Line 6 were provided by Prof. Dr. H.A. Awaad, Agronomy Dept., Fac. Agric., Zagazig Univ., Egypt; Line 26 and Line 142 from CIMMYT, while the other varieties were obtained from ARC, Egypt. Bread wheat genotypes were evaluated under eight environments. The environments were the combinations of four water regimes (normal, mild, moderate and severe stress) × two seasons (2016/2017 and 2017/ 2018).

A factorial experiment in a randomized complete block design with three replications was applied. Each plot consisted of 7 rows, 2m long and 15cm apart. Seeds were hand drilled on 24th of November in both seasons. All other cultural practices for wheat production were applied as local recommendation in the experimental area.

Surface irrigation was followed, and amount of water (Table 2) was estimated according to the formula of **Brater *et al*. (1996)** as follows:

$$Q = CA\,(2gh)^{0.5}$$

Where:
Q = discharge rate (cm3/sec.)
C = discharge coefficient of the spile (0.62)
A = cross-sectional orifice area (sq meters)
g = gravitational constant (9.81 cm/s2)
h = total head (8.3 cm)

Table 1. Pedigree and origin of the thirteen bread wheat genotypes used in this study

No.	Genotype	Pedigree	Origin
G1	Misr 1	Oasis/SKAUZ//4×BCN/3/2×PASTOR.CMss00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S	EGYPT
G2	Misr 2	SKAUZ/BAV92. CMss96M03611S-1M-0105Y-010M-010SY-8M-0y-0S.	
G3	Sakha 94	Opata/Rayon//KauZ.CMBW90Y3180-0T0PM-3Y-010M-010Y-10M-15Y-0Y-0AP-0S.	EGYPT
G4	Sakha 95	PASTOR//SITE/MO/3/CHEN/AEGILOPS×SQUARROSA (TAUS)//BCN/4/WBLL1 and CMSA01Y00158S-040P0Y-040M-030ZTM-040SY-26M-0Y-0SY-0S0.	EGYPT
G5	Giza 171	Sakha 93 / Gemmeiza 9 S.6-1GZ-4GZ-1GZ-2GZ-0S N.S.732/Pim/Vee"S"	EGYPT
G6	Gemmeiza 11	Bow"s"/Kz"s"//7C/aeri 82/3/Giza 168/Sakha 61. GM78922-GM-1GM-2GM-1GM-0GM.	EGYPT
G7	Gemmeiza 12	OTUS/3/SARA/THB//VEE.CCMSS97Y00227S-5Y-010M-010Y-010M-2Y-1M-0Y-0GM	EGYPT
G8	Shandweel 1	SITE//MO/4/NAC/TH.AC//3×PVN/3MIRLO/BUC.CMSS93B00567 S-72Y-010M-010Y-010M-0HTY-0SH.	EGYPT
G9	Line 26	GIR WILL-1312×PASTOR-2	CIMMYT
G10	Line 142	WAX WING*2//PBW 343×/ KUKUNA	CIMMYT
G11	Line L1	Gemmeiza9/Pata10//ALD“S”Cr1Zag –Zag190-Zag18-Zag20-Zag12-Zag15- Zag4-0Zag	EGYPT
G12	Line 6	Gemmeiza9/Pata10//ALD“S”Cr2Zag–Zag65-Zag55-Zag22-Zag18-Zag9-Zag12-0Zag	EGYPT
G13	Line 3	Gemmeiza 9/Pata10//ALD “S”Cr1Zag–Zag200-Zag36-Zag54-Zag30-Zag50-Zag27-0Zag	EGYPT

Table 2. Number of irrigations and irrigation quantity as affected by irrigation intervals in 2016/2017 and 2017/2018 seasons

Irrigation interval (day)	No. of irrigations	Irrigation quantity (m^3/fad.)
	2016/2017	
I_1 (8 days)	16	5778.32
I_2 (12 days)	11	4643.01
I_3 (16 days)	9	3304.85
I_4 (20 days)	7	2899.34
	2017/2018	
I_1 (8 days)	15	4959.07
I_2 (12 days)	10	4278.06
I_3 (16 days)	7	3102.10
I_4 (20 days)	6	2788.97

Soil properties of the experimental site are presented in Table 3. Also, monthly total precipitation (mm) and an average of the minimum and maximum temperatures during the growing seasons for the experimental site (El-Salhiya) are given in Table 4.

Combined analyses of variance over environments were conducted as outlined by **Allard (1960)**. Stability parameters for grain yield of the thirteen genotypes were calculated according to the two models of **Eberhart and Russell (1966)** and additive main effects and multiplicative interaction method (AMMI) as proposed by **Gauch (1992).** Differences between genotypes means were determined by revised LSD test at 0.05 level according to **Steel *et al.* (1997)**.

RESULTS AND DISCUSSION

Joint Regression Analysis

Mean square of joint regression analysis of variance for grain yield of the thirteen bread wheat genotypes under the eight environments (Table 5) revealed highly significant differences among genotypes (G) and environments (E). This indicated the presence of genetic and environmental variation regarding the grain yield trait. Environment + Genotype x Environment (E + G x E) had highly significant effects. The G x E interaction was further partitioned into linear and non-linear (pooled deviation) components. Mean squares due to environment (linear) were highly significant, indicating that differences existed between environments and revealed predictable component shared G x E interaction with unpredictable. The linear interaction (G x E linear) was highly significant when tested against pooled deviation, showing genetic differences among genotypes for their regression on the environmental index, so it could be proceeded in the stability analysis **(Eberhart and Russell, 1966)**. The previous highly significant interaction may be to the differences in edaphic and environmental factors for the experimental site (Tables 3 and 4). The non-linear responses as measured by pooled deviations from regressions were insignificant, indicating that differences in linear response among genotypes across environments did account for all the G x E interaction effects. In this concern, highly significant effects for G x Env. Linear interaction effects for wheat grain yield was recorded by **El-Moselhy *et al*. (2015), Hamam *et al*. (2015), Ali (2017)** and **Ali** and **Abdul-Hamid (2017).**

Phenotypic Stability Parameters

Eberhart and Russell (1966) proposed that an ideal genotype is the one which has the highest yield across a broad range of environments, a regression coefficient (b_i) value of 1.0 and deviation mean squares of zero. Thus, a genotype with unit regression coefficient (b_i = 1) and deviation not significantly different from zero (S^2di = 0) is said to be the most stable genotype. The estimates of phenotypic stability parameters according **to Eberhart and Russell (1966)** for thirteen bread wheat genotypes grown under the eight environments for grain yield are given in Table 6.

Phenotypic stability indicated that regression coefficient (b_i) for grain yield of thirteen bread wheat genotypes ranged from 0.81 (Line 142) to 1.27 (Gemmeiza 12), indicating the genetic variability among bread wheat genotypes in their regression response for grain yield (Table 6). The b_i values were deviated significantly from unity (b_i > 1) in Gemmeiza12 and Line 3, indicating relatively suitable in favorable environments, adequate water and other inputs. Meanwhile, the b_i values deviated significantly and less than unity (b_i < 1) in Sakha 95, Line 142 and Line 1. Thus they were adapted to water stress environments. On the other side, wheat genotypes Misr 1, Misr 2, Sakha 94, Giza 171, Shandweel 1 and Line 6 had the b_i values did not deviate significantly from unity. Therefore, these wheat genotypes could be grown under a wide range of environments. The deviations from regression

Table 3. Soil properties of the experimental site (El-Salhiya)

Soil property	
Soil particles distribution	
Sand (%)	88.8
Silt (%)	0.6
Clay (%)	10.6
Soil texture	Sandy loam
Organic matter (g kg^{-1})	0.000
pH	7.6
Soluble cations and anions (mmolc $^{L-1}$) *	
Calcium (Ca^{++})	0.3
Magnesium (Mg^{++})	0.2
Sodium (Na^{+})	0.34
Potassium(K^{+})	0.03
Bicarbonate (HCO_3^{-})	0.2
Chlorine (Cl^{-})	0.4
Sulphate ($SO_4^{=}$)	0.27
Available nutrient (mg kg^{-1} soil)	
Nitrogen (N)	0.008
Phosphorus (P)	0.09

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Table 4. Monthly mean minimum and maximum air temperatures, relative humidity and precipitation during the two wheat growing seasons

Month	Temperature (°C)			Relative humidity (%)	Precipitation (mm)
	Min.	Max.	Mean		
			2016/2017 season		
November	13.30	24.33	18.81	73	4.5
December	12.83	21.00	16.91	88	9.1
January	8.16	14.83	11.49	85	14.2
February	14.83	25.16	19.99	65	4.0
March	15.00	26.50	20.75	60	0.3
April	16.83	32.00	24.41	54	0.1
May	18.33	32.50	25.41	52	0.0
			2017/2018 season		
November	13.00	24.33	19.66	74	4.2
December	11.83	20.50	18.08	80	9.0
January	7.66	14.00	10.83	73	13.5
February	13.66	24.83	19.24	68	4.2
March	14.33	26.16	20.24	70	0.5
April	14.50	29.00	21.75	62	0.0
May	18.50	31.83	25.16	50	0.0

Table 5. Joint regression analysis of variance over eight environments for thirteen bread wheat genotypes for grain yield

Source of variation	d.f.	SS	MS
Model	103	2183.46	258.74**
Genotype (G)	12	786.30	65.53**
Environment (E)	7	1348.47	192.64**
G x E	84	48.68	0.58
E + G x E	91	1397.16	15.35**
Env. (linear)	1	1348.47	1348.47**
G x E (linear)	12	21.03	1.75**
Pooled deviation	78	27.65	0.35
G 1	6	1.06	0.18
G 2	6	5.09	0.85
G 3	6	3.01	0.50
G 4	6	0.87	0.14
G 5	6	2.45	0.41
G 6	6	2.30	0.38
G 7	6	1.31	0.22
G 8	6	0.99	0.16
G 9	6	1.20	0.20
G 10	6	2.58	0.43
G 11	6	1.11	0.19
G 12	6	0.74	0.12
G 13	6	4.92	0.82
Pooled Error	192	497.67	2.59

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Table 6. Genotype means over 8 environments and phenotypic stability parameters of the 13 wheat genotypes for wheat grain yield

Genotypes	Mean	b_i	S^2_{di}
Misr 1	18.98	1.08	0.18
Misr 2	16.68	1.01	0.85
Sakha 94	14.55	1.00	0.50
Sakha 95	16.75	0.87*	0.14
Giza 171	17.10	0.98	0.41
Gemmeiza 11	20.88	0.91	0.38
Gemmeiza 12	15.43	1.27**	0.22
Shandweel 1	15.58	0.98	0.16
Line 26	13.89	1.05	0.20
Line 142	13.44	0.81**	0.43
Line 1	22.17	0.83**	0.19
Line 6	16.77	1.04	0.12
Line 3	21.49	1.17*	0.82
Mean	17.21		
LSD, 0.05	1.57		
CV %	9.36		

(S^2_{di}) for grain yield were insignificant, therefore wheat genotypes were stable. The most desirable and stable wheat genotypes according to the three stability parameters ($\bar{X}$, b_i and S^2_{di}) for grain yield were Misr 1 with a mean yield $\bar{X}$= 18.98, bi=1.08 and the S^2_{di}= 0.18 and Gemmeiza 11 ($\bar{X}$=20.88, bi = 0.91and S^2_{di} =0.38). These previous genotypes gave mean values above grand mean, and their regression coefficients (b_i) did not differ significantly from unity, with minimum deviation mean squares (S^2_{di}).

Additive Main Effects and Multiplicative Interaction Method (AMMI)

The additive main effects and multiplicative interaction (AMMI) model combines the analysis of variance for the genotype and environment main effects with the principal components analysis of the genotypes-environments interaction. It use the standard analysis of variance (ANOVA) procedure, where after the AMMI model separates the additive variance from the multiplicative variance (interaction), and then applies PCA to the interaction (residual) portion from the ANOVA to extract a new set of coordinate axes which account more effectively for the interaction patterns (**Shafii *et al.*, 1992).** A genotype is regarded as stable if its first and second correspondence analysis scores are near zero **(Lopez, 1990; Kang, 2002)**. AMMI analysis of variance showed that environments (E) and wheat genotypes (G) mean squares were highly significant for grain yield (ardab/fad.) (Table 7). The IPCA scores of a wheat genotype in the AMMI and SREG analyses were insignificant except IPCA 1 for SREG model. Variance components (%) of the sum of squares varied from 28.90% for genotypes, 49.56% for environments and 1.79% for GEI. IPCA 1 score had 46.91 %, and IPCA 2 had 32.91% of the total GEI for AMMI models. For SREG model, IPCA 1 score had 94.55 %, and IPCA 2 had 2.73% of the total GGEI. **Elbasyoni (2018)** practical AMMI model and showed that analysis of variance indicated a significant effect of the environments, genotypes, and genotype × environment interaction for grain yield. The variance of the environments attributed to 63.2%, while those due to genotypes was 14.6% and that for genotype × environment interaction being 22.2%.

In respect to ASV for grain yield as given in Table 8 and illustrated in Figs. 1 and 2, Shandweel 1, Line 26, Line 6, Misr1 and Giza 171 were the most desired and stable genotypes valued 0.24, 0.38, 0.41, 0.60 and 0.70, respectively. Otherwise, the other bread wheat genotypes were less stable for and more responsive to the environmental changes.

GE biplot graph for the AMMI model illustrated that environments E_1, E_8 and E_4 were the most differentiating environments for grain yield, they were located far away from the origin (Fig. 1). Whereas, environments E_5, and E_2 were less responsive for grain yield. GGE biplot graph for the SREG model as illustrated in Fig. 2, Gemmeiza 11 (G6) was ideal genotype for grain yield, it had the highest vector length of the high yielding genotypes and with zero GE, as represented by the dot with an arrow pointing to it. A wheat genotype is more desirable if it is located closer to the ideal wheat genotype. Thus Line 1 (G11), Line 3 (G13) and Misr 1 (G1) were desirable genotypes. The environments E_1, M_5, E_6 and E_2 were positively correlated. Whereas, the environment E_1 had negatively correlated with E_8. It is interesting to mention that both models of **Eberhart and Russell (1966) and AMMI (Gauch, 1992)** are consistent in describing stability of Misr 1 and Gemmeiza 11 for grain yield. Many investigators applied the AMMI model to the yield data on various environments for evaluating yield stability, of them **Mohamed *et al.* (2013)** and **Ali (2017)** and they registered specific adaptation for several genotypes to specific environments.

Conclusion

Highly significant G x E “linear” was registered for wheat grain yield. Both models of **Eberhart and Russell (1966)** and AMMI (**Gauch, 1992**) are consistent in describing the stability of Misr 1 and Gemmeiza 11 for grain yield. These genotypes could be useful in wheat improvement programs for enhancing stability.

Table 7. AMMI analysis of variance over eight environments for wheat grain yield

Source of variation	df	AMMI			SREG		
		Sum of square	Mean of square	Percent	Sum of square	Mean of square	Percent
Environment (E)	7	4045.42	577.92**	49.56	4045.42	577.92**	49.56
Reps / Env.	16	119.35	7.46**		119.35	7.46**	
Genotype (G)	12	2358.91	196.58**	28.90	2358.91	196.58**	28.90
G x E	84	146.04	1.74	1.79	146.04	1.74	1.79
IPCA1	18	68.51	3.81	46.91	2368.44	131.58**	94.55
IPCA2	16	48.06	3.00	32.91	68.39	4.27	2.73
IPCA3	14	12.55	0.90	8.59	41.46	2.96	1.66
IPCA4	12	9.39	0.78	6.43	11.27	0.94	0.45
IPCA5	10	3.09	0.31	2.11	8.78	0.88	0.35
IPCA6	8	2.67	0.33	1.83	2.48	0.31	0.10
IPCA7	6	1.78	0.30	1.22	1.03	0.17	0.04
Pooled Error	192	1493.02	7.78		1493.02	7.78	
Total	311	8162.75			8162.75		

Table 8. AMMI stability value over 8 environments of 13 wheat genotypes for grain yield

Genotype	IPCA1	IPCA2	ASV	Rank
Misr 1	-0.35	-0.34	0.60	4
Misr 2	-0.19	-0.98	1.02	9
Sakha 94	0.03	-0.78	0.78	6
Sakha 95	0.66	0.08	0.94	8
Giza 171	0.12	0.68	0.70	5
Gemmeiza 11	0.45	0.58	0.87	7
Gemmeiza 12	-1.28	-0.34	1.85	13
Shandweel 1	0.04	-0.24	0.24	1
Line 26	-0.23	0.19	0.38	2
Line 142	0.94	0.07	1.34	11
Line 1	0.84	-0.23	1.22	10
Line 6	-0.25	0.21	0.41	3
Line 3	-0.79	1.10	1.57	12

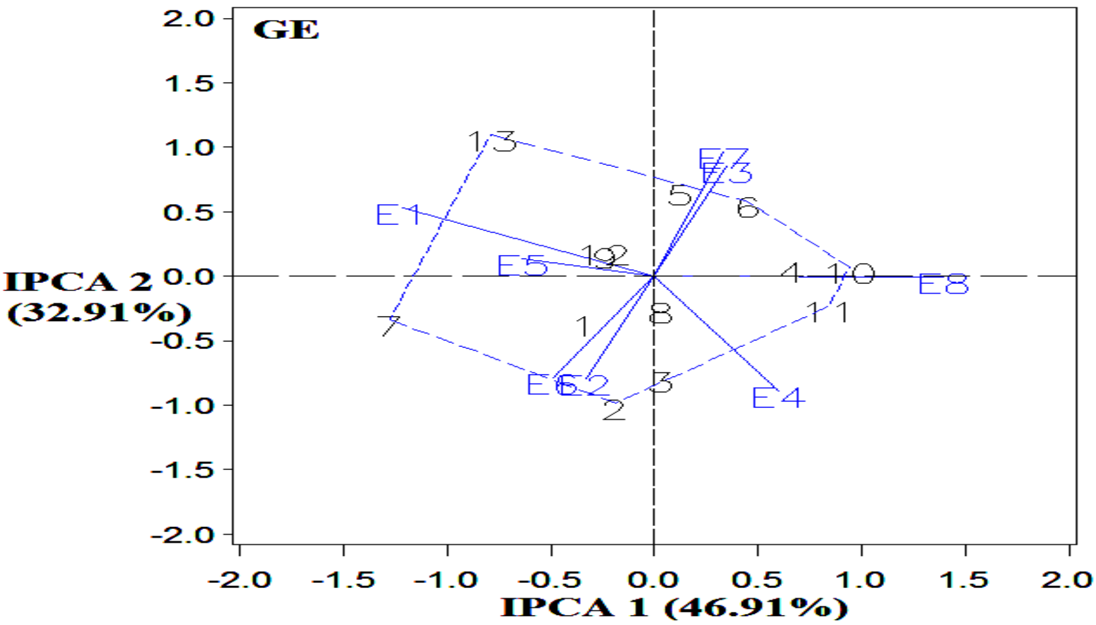

Fig. 1. Graphics display of the GE biplots for thirteen wheat genotypes (assessed G1-G13) and 8 environments (assessed E1-E8) in the AMMI model for grain yield (ardab/fad.)

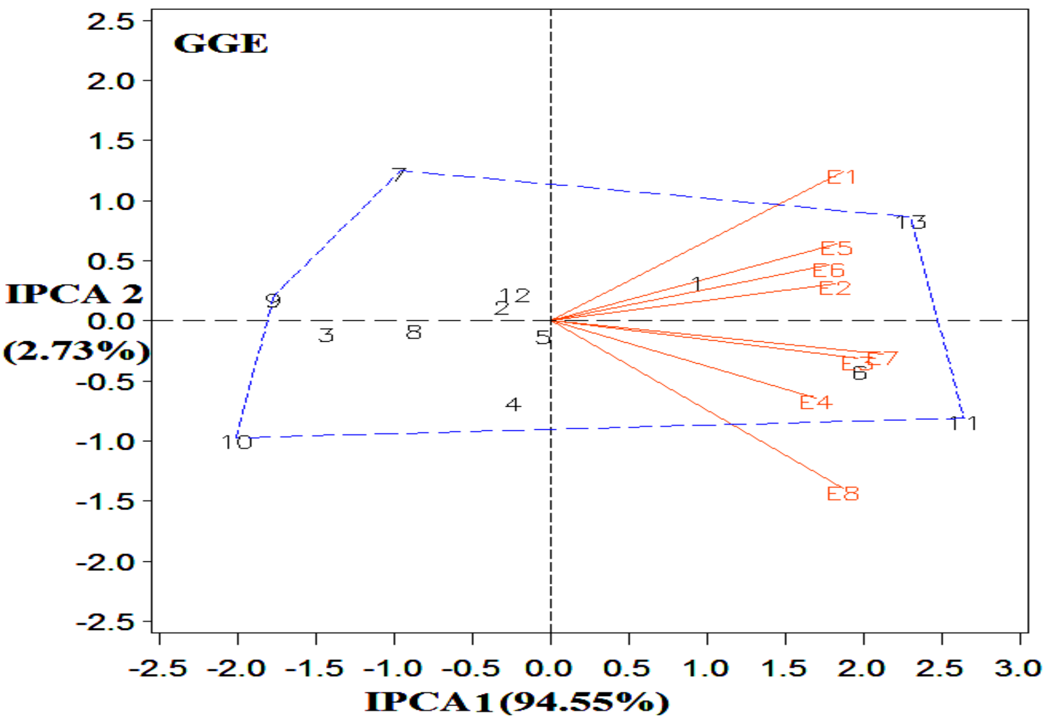

Fig. 2. Graphics display of the GGE biplots for thirteen wheat genotypes (assessed G1-G13) and 8 environments (assessed E1-E8) in the SREG model for grain yield (ardab/fad.)

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ثبات محصول الحبوب للتراكيب الوراثية لقمح الخبز تحت بيئات مختلفة

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أجريت هذه الدراسة بهدف تقييم ثبات ثلاث عشر تركيباً وراثياً من قمح الخبز لمحصول الحبوب فى ثماني بيئات مختلفة عبارة عن أربع معاملات من نظم الري (العادي، المعتدل، المتوسط والقاسي) × موسمين زراعيين (٢٠١٦-٢٠١٧و ٢٠١٧-٢٠١٨)، وقد استخدمت طريقتان مختلفتان لتقدير مقاييس الثبات هما الثبات المظهرى وفقاً لـ **Eberhart and Russell (1966)** وAMMI وفقاً لـ **Gauch (1992)** ويمكن تلخيص أهم النتائج كما يلي: تشير نتائج تحليل الثبات إلى أن التفاعل (الخطي) بين التركيب الوراثي × البيئة كان معنوياً لمحصول الحبوب، في إشارة الي تباين استجابة التراكيب الوراثية للتغيرات البيئية، وأظهرت مقاييس الثبات المظهري تميز الصنف جميزة ١٢ وسلالة ٣ بدرجة عالية من الأقلمة لظروف البيئات الملائمة، بينما يمكن التوصية بزراعة الصنف سخا ٩٥ وسلالة ١٤٢ وسلالة ١ تحت ظروف الاجهاد المائي، كما أشارت النتائج إلى أن أكثر التراكيب الوراثية أقلمة تحت مدى واسع من البيئات هي مصر ١، مصر ٢، سخا ٩٤، جيزة ١٧١، شندويل ١، سلالة ٢٦ وسلالة ٦ لمحصول الحبوب (أردب/فدان)، كما أشارت النتائج إلى أن أكثر الأصناف المرجوة والثابتة تحت مدى واسع من البيئات هي مصر ١ وجميزة ١١، أظهر تحليل التباين لـ AMMI أن ٢٨.٩٠، ٤٩.٥٦ و ١.٧٩% من التباين الكلي كان راجعاً الي تأثير التراكيب الوراثية، البيئات، والتفاعل بين التركيب الوراثي x البيئة، علي الترتيب. وكان أكثر التراكيب الوراثية ثباتاً هي شندويل ١، سلالة ٢٦، سلالة ٦، مصر ١، جيزة ١٧١، سخا٩٤ وجميزة ١١ لصفة محصول الحبوب (أردب/فدان)، وقد توافقت نتائج مؤشرات الثبات المظهري وAMMI على ثبات الأصناف مصر ١ وجميزة ١١ لصفة محصول الحبوب (أردب/فدان).

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