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RANK CORRELATIONS AMONG SOME STABILITY PARAMETERS FOR GRAIN YIELD IN BREAD WHEAT

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ABSTRACT

The present study aimed to evaluate twelve bread wheat genotypes across 9 environments (the combinations of 3 seasons x 3 sowing dates) during 2015/2016, 2016/2017 and 2017/2018 at Kom ombo Agriculture Research Station, Agriculture Research center, Aswan Governorate, Egypt. Significant differences were observed among bread wheat genotypes for grain yield (ton/ha). Combined analysis of variance of grain yield across the nine environments showed a highly significant (p<0.01) mean squares due to genotypes (G), environments (E) and genotypes x environments interaction (GEI), indicating differential response of genotypes across studied environments and the validity of stability analysis. Six parametric of stability statistics were performed ($\overline{X}_i$, b_i , S^2_{di} , R_i^2, W_i^2 and S^2_i). Stability analyses for grain yield of wheat genotypes revealed that the genotypes: Line#2, Sakha 95 and Line#1 were more stable than others, expressed in 5, 4, and 3 out of all 6 stability statistics used, respectively. Thus, these genotypes could be suggested to be more stable than others for these measures. They have a low contribution to GEI. Therefore, the above mentioned genotypes could be recommended as stable and/or incorporated in any future breeding programs aiming to produce lines of bread wheat. Rank correlation among stability measures showed that ecovalance (W^2_i%) was positively correlated with coefficient of regression (b_i), deviation mean squares from regression (S^2_{di}) and coefficient of determination (R^2)

Key words: ***Bread wheat, Triticum aestivum* L.*, Genotype x environment interaction, Stability, Rank correlations.***

INTRODUCTION

In Egypt bread wheat is consider one of the most important cereal crops, where many people depends upon their food. FAO, 2019 reported that Egypt imports about 43% of its need from wheat. Therefore, to reduce the gap between production and consumption increasing wheat production is an important goal (FAO, 2015).

There are two methods to increase the production of wheat first by increasing cultivated area and/or by increasing yield per unit area. Nowadays, in Egypt it is very difficult to increase cultivated area of wheat crop due to many reasons such as competition with other crops and restricted irrigation water supply, etc. So, the only possible way is to increase yield in unit area across introducing high yielding cultivars resistance against environmental stresses and better crop management techniques.

However, when genotypes tested in multiple environments, they usually do not perform in a similar manner. This phenomenon is due to the presence of genotype by environment interaction (GEI), which was defined as the differential genotypic expression across environments. GEI makes identification of superior genotypes complicates. Therefore, a priority for genotypes evaluation and recommendation is to detect the areas in which these genotypes perform similarly (Gauch and Zobel 1997). Moreover, GEI provides information about the effects of different environments on genotypes performance and plays an important role for assessment of performance stability of the breeding materials. So, new wheat genotypes before being released need to be evaluated at different environments for several years. Kang 1998 mentioned that new genotypes with desired traits should be tested for the stability of these traits in the target environments.

High-yielding genotypes can differ in yield stability. Mustatea *et al* (2009) suggested that yield stability and high grain are mutually exclusive. Also, Shah *et al* (2009) found highly significant variances for GEI for all studied traits of ten wheat varieties. Many research have been conducted to investigate stability of wheat genotypes under different environments (Ülker *et al* 2006; Rasul *et al* 2006; Akcura *et al* 2009; Parveen *et al* 2010; Al-Otayk 2010; El-Ameen 2012; Mohamed *et al* 2013 and Abd El-Shafi *et al* 2014).

Many methods have been used to determine stability of a genotype. The first one was by Finlay and Wilkinson (1963), who defined adaptability as the linear relationship of the genotype yield across environments by the regression coefficient (b_i); where a genotype with b_i =1 was considered as adapted. Eberhart and Russell (1966) added regression deviation mean squares (S^2_{di}) as a stability parameter. They mentioned that stability of genotype is expressed in terms of three important parameters: (1) mean performance, (2) slope of regression line (b_i), (3) sum of squares of deviation from regression (S^2_{di}). Thus, a better choice as a stable genotype should be attributed with high mean yield over the environment, regression coefficient equal to one (b=1) and deviation from regression equal not different significantly from zero (S^2_{di} =0). Pinthus 1973 proposed the coefficient of determination (R^2) for measuring response of genotypes and stability of production in different environments, where R^2 measure the proportion of a genotype's production variation that is due to linear regression. Also, Wricke (1962) introduced ecovalance (W^2_i) which reflect GEI for each genotype as a stability parameter. Francis and Kannenberg (1978) proposed environmental variance (S^2_i) and the coefficient of variation (CV_i) of each genotype as stability parameter.

With the presence of these methods of stability parameters breeders need to know if one or more parameters should be obtained for prediction of genotype behavior, and also to choose the best stability parameter(s), therefore, the level of association among stability parameters of different models must be conducted (Duarte and Zimmermann 1995).

The objectives of this study were (1) to evaluate grain yield of twelve bread wheat genotypes under nine environments; (2) to measure the genotype-environment interaction in bread wheat genotypes, for grain yields, and (3) to study the adaptation of twelve genotypes of bread wheat by using six stability parameters; (4) to estimate rank correlations between stability parameters and mean grain yield across all environments used.

MATERIALS AND METHODS

Twelve bread wheat genotypes were evaluated in nine environments (combinations of three seasons and three sowing dates) as follows: three successive seasons 2015/2016, 2016/2017 and 2017/2018 at Kom ombo Agriculture Research Station, Agriculture Research center, Aswan Governorate, with three different sowing dates. Details of genotypes and the nine environments are given in Tables (1) and (2), respectively.

Table 1. Name, pedigree and origin of the studied wheat genotypes.

No.	Name	Pedigree	Origin
G_1	Sids 1	HD 2172/pavon "s" // 1158.57 / Maya 74 "s"	Egypt
G_2	Sids 4	Maya"S"/Man"S"//CMH74A-592/3/Giza157*2	Egypt
G_3	Misr 1	OASIS/SKAUZ//4*BCN/3/2*PASTOR	Egypt
G_4	Misr 2	SKAUZ/BAV92	Egypt
G_5	Shandaweel 1	SITE//M0/4/NAC/TH.AC//3*PVN/3/MIRLO/BUE	Egypt
G_6	Giza 168	MIL/BUC/Seri	Egypt
G_7	Sakha 95	PASTOR//SITE/MO/3/CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/4/WBLL1	Egypt
G_8	Sids 12	BUC//7C/ALD/5/MAYA74/ON//1160,1473 //BB/Gll14/CHAT"s"/6/MAYA/VUL//CMH74A.630/4/ *SX.	Egypt
G_9	Gemmeiza 11	BOW"S"/KVZ//7C/SER182/3/GIZA 168/SAKHA61. GM7892-2GM-1GM-2GM-1GM-0GM.	Egypt
G_{10}	Line#1	WBLL*2/KKTS//KBIRD	CIMMYT
G_{11}	Line#2	PBW343*2/KUKUNA*2//FRTL/PIFED-3	CIMMYT
G_{12}	Line#3	KATILA-15//MNCH/3*BCN	ICARDA

Table 2. The environments used in this study.

Environments	Season	Sowing date
E1	2015/2016	20/11/2015
E2	2015/2016	10/12/2015
E3	2015/2016	30/12/2015
E4	2016/2017	20/11/2016
E5	2016/2017	10/12/2016
E6	2016/2017	30/12/2016
E7	2017/2018	20/11/2017
E8	2017/2018	10/12/2017
E9	2017/2018	30/12/2017

The trials were established in a strip-block design with randomized complete blocks arrangement in 3 replications. Horizontal plots were assigned to the two sowing dates and vertical-plots were assigned to the 12 genotypes. Each experimental unit consisted of 6 rows, 3 m long and 20 cm wide. At harvest the four middle area of each plot was taken to determine grain yield/plot (plot size = 2.4 m^2) and then converted to grain yield (ton/hectare). All other agricultural practices were followed according to the recommendations of ARC, Egypt.

Statistical analyses

In each environment Wilk Shapiro test (Neter *et al* 1996) was used to check out for normality distributions. Also, for each environment analysis of variance (ANOVA) was done separately. Then a combined analysis of variance was done from the mean data of each environment. Homogeneity test of experimental errors variances were done according to Gomez and Gomez (1984).

Six stability parameters were performed to study stability of the studied genotypes across the nine environments as follows:

1) The slope value (b_i) which were proposed by Eberhart and Russell (1966)
2) Deviation from regression parameter (S^2_{di}) which was proposed by Eberhart and Russell (1966)
3) Coefficients of determination (R_i^2) by Pinthus (1973).
4) Ecovalance (W^2_i) by Wricke (1962)
5) Environmental variance (S^2_i) by Francis and Kannenberg's (1978),
6) Mean performance across environments ($\overline{X}_i$).

Moreover, for each pair of the possible pair-wise comparisons of the stability parameters a Spearman's rank correlation coefficients were estimated and the significance of the rank correlation coefficient was tested according to Steel *et al* (1997). All statistical analyses were carried out using MSTAT-C software package (Freed *et al* 1989), GENES computer software (Cruz, 2013) and MS Excel.

RESULTS AND DISCUSSION

Analysis of variance

Combined analysis of variance for grain yield is presented in Table (3). Results of combined analysis showed that differences among environments were highly significant for grain yield, indicating that the nine environments are different in their conditions. Highly significant ($p<0.01$) differences among genotypes and genotype x environments interaction (GEI) were detected for grain yield. Significant mean squares due to GEI indicated that genotypes performed differently at different environments.

Table 3. Combined analysis of variance for grain yield of 12 bread wheat genotypes tested across nine environments.

SOV	df	Mean squares	P-value
Environments (E)	8	49.265 **	0.0000
Replicates/E	18	0.6010	
Genotypes (G)	11	28.350 **	0.0000
G x E	88	0.645 **	0.0001
Error	198	0.3380	

**** significant at 0.01 probability level.**

It is clear from previous results that the studied genotypes must be tested under different environments.

Mean performance

The mean performance of the twelve genotypes for grain yield at each environment and their combined means are presented in Table (4). Mean grain yield under the nine environments was 6.893, 5.540, 4.347, 7.288, 5.856, 4.644, 5.776, 4.642 and 3.804 ton/ha, respectively. The overall mean for grain yield of the twelve genotypes across the nine environments was 5.406 ton/ha, while, mean yield of the studied genotypes were ranged from 3.872 (Line#3) to 6.945 (Misr 2). However, there were insignificant differences for grain yield between Misr 1 and Gemmiza 11, and among Gemmiza 11, Giza 168, Sids 12 and Sakha 95 and also between Shandaweel1 and Line#2, and between Line#1 and Sids 4.

Table 4. Mean grain yield (ton/ha) for twelve bread wheat genotypes and their combined means across nine environments.

Genotypes	E1	E2	E3	E4	E5	E6	E7	E8	E9	Combined
Sids 1	7.535	5.359	4.143	6.854	5.217	4.851	5.921	4.884	4.000	5.418 e
Sids 4	5.376	3.710	3.042	5.150	4.876	3.650	5.143	4.074	2.917	4.215 g
Misr 1	8.127	6.538	6.031	8.744	7.377	6.261	6.614	5.242	4.141	6.564 b
Misr 2	8.881	6.942	6.102	8.959	7.645	6.344	6.421	5.819	5.441	6.950 a
Shandaweel 1	6.570	4.868	3.893	5.474	4.680	3.986	5.290	3.859	3.787	4.712 f
Giza 168	7.558	5.887	4.756	8.959	6.168	5.301	6.341	5.441	4.301	6.079 cd
Sakha 95	6.963	5.795	4.690	7.818	6.398	4.737	6.451	5.268	4.141	5.807 d
Sids 12	7.237	5.826	4.669	9.592	6.235	4.569	6.616	5.268	4.045	6.006 cd
Gemmeiza 11	8.176	6.793	5.135	8.021	7.284	5.758	6.557	5.043	3.945	6.301 bc
Line#1	5.354	4.203	3.064	6.867	4.754	3.184	4.461	3.641	3.106	4.293 g
Line#2	6.236	4.963	3.566	6.251	5.131	3.942	4.973	3.825	2.977	4.652 f
Line#3	4.708	3.977	3.078	4.766	4.511	3.142	4.523	3.337	2.844	3.876 h
Mean	6.893	5.405	4.347	7.288	5.856	4.644	5.776	4.642	3.804	5.406

Stability of tested genotypes

Pooled analysis of variance for grain yield across the nine environments is presented in Table (5). The results in Table 5 reflected significant differences among the studied genotypes for grain yield, which indicated that the genotypes varied with respect to yield performance. Joint regression analysis of variance revealed that the mean squares due to genotypes (G), environments (E) and GEI were significant for grain yield, indicating that the studied genotypes and environments had a wide variability among each other. The significant mean square of GEI suggested that grain yield was unstable with change in environments. These findings are in agreement with those obtained by Ülker *et a.* (2006), Rasul *et al* (2006), Akcura *et al* (2009), Parveen *et al* (2010), Al-Otayk (2010), El-Ameen (2012), Mohamed *et al* (2013), and Abd El-Shafi *et al.* (2014).

Table 5. Joint regression analysis of variance for grain yield of the 12 genotypes tested in nine environments.

SOV	df	Mean squares	P-value
Total	**107**	**2.376 ****	**0.00000**
Genotypes (G)	**11**	**9.450 ****	**0.00000**
Environments (E)	**8**	**16.421 ****	**0.00000**
GE	**88**	**0.215 ****	**0.00010**
Env.+(Genotypes*Env.)	**96**	**1.566 ****	**0.00000**
Environment (Linear)	**1**	**131.371 ****	**0.00000**
Genotype*Environment(Linear)	**11**	**0.525 ****	**0.00000**
Pooled deviation	**84**	**0.157 ***	**0.032633**
Pooled Error	**198**	**0.113**	

*** and ** significant at 0.01 and 0.05 probability level, respectively.**

The GEI divided into linear and non-linear components and mean squares for them were significant, suggesting that predictable (linear response) and un-predictable (non-linear or deviation from linear response) components were involved in the differential response of stability for grain yield. Samiliar findings were obtained by Ülker *et al* (2006), Rasul *et al* (2006), Akcura *et al* (2009), Parveen *et al* (2010), Al-Otayk (2010), El-Ameen (2012), Mohamed *et al* (2013), and Abd El-Shafi *et al* (2014).

Abd El-Shafi *et al* (2014) reported that significant environment (linear) variance implies linear variation among environments for grain yield. The G x E (linear) interaction was significant against pooled deviation, suggesting the possibility of the variation for grain yield and indicated the presence of genetic differences among genotypes for their regression on the environmental index. The linear component of GEI was found to be more than the non-linear component (pooled deviation).

The estimates of the six stability parameters for 12 bread wheat genotypes grain yield (ton/ha) and their ranks tested across the nine environments are presented in Table (6).

Table 6. Mean values of grain yield (ton/ha) and 5 measures of stability and their rank for 12 bread wheat genotypes studied under 9 environments.

Genotypes	$\overline{X}$	Rank	b_i	Rank	S^2_{di}	Rank	R^2_i	Rank	W^2_i%	Rank	S^2_i	Rank	Fr
Sids 1	5.42	7	0.951	5	0.057	4	0.89	10	6.411	4	0.533	8	
Sids 4	4.22	11	0.73	10	0.080	8	0.81	11	11.348	10	0.426	5	
Misr 1	6.56	2	1.142	6	0.113	11	0.90	8	9.519	8	1.13	11	1
Misr 2	6.95	1	1.042	4	0.069	7	0.90	7	6.835	6	0.711	9	1
Shandaweel 1	4.71	8	0.736	11	0.087	9	0.81	12	11.716	11	0.446	7	1
Giza 168	6.08	4	1.206	8	0.012	1	0.95	3	6.829	5	0.226	4	2
Sakha 95	5.81	6	1.013	2	-0.060	5	0.97	2	1.98	2	-1.84	2	4
Sids 12	6.01	5	1.382 *	11	0.198	12	0.91	6	19.923	12	2.106	12	
Gemmeiza 11	6.3	3	1.183	7	0.062	6	0.93	4	8.387	7	0.838	10	1
Line#1	4.29	10	1.037	3	0.035	2	0.92	5	5.52	3	0.427	6	3
Line#2	4.65	9	0.988	1	-0.090	3	0.98	1	1.07	1	-4.72	1	5
Line#3	3.88	12	0.631 *	12	-0.040	10	0.90	9	10.462	9	-0.43	3	1

*** Significantly different from 1.0 for the regression coefficients and from 0.0 for the deviation mean squares at the 0.05 and 0.01 levels of probability, respectively. *Fr.* =frequency of the number of stability parameters showing stability for each genotype, if a genotype had six values of *Fr.*, it could be considered most stable.**

Concerning the mean performance of grain yield as the first parameter for evaluating the genotypes, Misr 2, Misr 1, Gemmiza 11, Giza 168 and Sakha 95 gave the best mean yields while Sids 4 and Line#3 had the lowest mean yields across environments (Table 6). Mean grain yield across the nine environments showed serious differences in ranks among the tested genotypes, indicating a high GEI (Baker 1998 and Abd El-Shafi *et al* 2014).

Genotypes with general adaptability are those with average stability (a regression coefficient (b_i = 1.0) when associated with high mean yield across tested environment (Finlay and Wilkinson, 1963). Moreover, the ideal genotype is the one which has the highest yield across different environments, a regression coefficient (b_i) value of 1.0 and deviation mean squares of zero (Eberhart and Russell, 1966**).** Therefore, regression coefficient value close to 1.00 indicates low affecting to environmental changes, and then exhibiting more adaptiveness. By other words, a genotype with regression coefficient (b_i=1) and deviation not significantly different form zero (S^2_{di}=0) appear to be the most stable genotype. A wide range of regression coefficients (b_i), (0.630 to 1.380) for grain yield in Table 6, showed that the twelve genotypes had different responses to environmental effects. 10 of studied genotypes (83%) had regression slopes for grain yield that did not differ from 1.0, indicating that yield response under studied environments for tested genotypes with good potential. Based on previous results of (b_i), the genotypes Sids 1, Sids 4, Misr 1, Misr 2, Shandaweel 1, Giza 168, Sakha 95, Gemmiza 11, Line#2, and Line#3 were classified as highly stable across studied environments. However, Sids 12 showed that regression slopes for grain yield differ significantly from 1.0, indicating that this genotype was response under desired environments. Moreover, the S^2_{di} values (Table 6) of all studied genotypes were not significantly different from zero. So it may be considered as of good stable across studied environments. The genotypes Sakha 95 and Line#1 had insignificant b_i value, indicating high sensitivity to environmental effects and they may be suitable in favorable environments.

Results in Table 6 for the coefficient of determination (R_i^2), showed that the range of R_i^2 was from 0.805 to 0.982, these results revealed that 81% to 98% of the mean grain yield variation can be explained by genotype response across environments and also showed stability differences among genotypes. As R_i^2 values ranges from 0 to 1, therefore it considered a better index for measuring the validity of the linear regression than S^2_{di}. To identify the predictability and repeatability of the performance within environments, we have to measure the dispersion around the regression line and the suitable method for that will be coefficient of determination (R_i^2) (Bilbro and Ray, 1976). Results in Table (6) revealed that the coefficient of determination (R_i^2) values for LINE#2, G7, Giza 168, Gemmiza 11, Line#1 and G7 were 98%, 97%, 95% , 93% , 92% and 90%, respectively indicating the reliability of the linear response of these genotypes.

Wricke (1962) suggested ecovalence (W^2_i) as an indicator to the contribution of each genotype to the GEI. Genotypes with low (W^2_i) contributed the least to the GEI, therefore they are more stable. Results in Table (6) for W^2_i%, showed that Line#2 followed by G7 were the lowest ecovalence and considered to be stable. However, Sakha 95, and Shandaweel 1 were the highest W^2_i% and considered to be unstable and had the highest contribution to GEI.

Finally, environmental variance (S^2_i) is used as stability parameter which reported by Francis and Kannenberg (1978). Lin *et al* 1986 mentioned that genotypes exhibiting low environmental variance (S^2_i) are considered to be stable. Results in Table (6) shows that Line#2, G7, and Line#3 had lowest (S^2_i) compare to remain genotypes for grain yield, considered to be stable. Similar results were obtained by Lin *et al* 1986, Ortiz *et al* (2001) and Abd El-Shafi *et al* (2014).

In summary, stability analysis for grain yield of bread wheat genotypes revealed that genotypes Line#2, G7 and Line#1 were more stable, expressed in 5, 4 and 3 out of all 6 studied stability parameters, respectively. Thus, these genotypes were more stable than the others for these parameters. Also, these genotypes had a low contribution to the GEI. Therefore, Line#2, G7 and Line#1 may be recommended as commercially stable genotypes and/or incorporated in any future breeding programs.

Interrelationships among stability parameters

To study the relationships between mean yield and stability parameters, as well as among studied stability parameters the rank correlation analysis was used. The ranks of each genotype across 9 environments after applying the method of stability analysis, were used for rank correlation (Table 6). These ranks were used to calculate rank correlation (Sperman`s correlation coefficient) in Table (7).

The results of Spearman's coefficient of rank correlations showed that mean yield was statistically significant ($P<0.05$) and negatively correlated with environmental variance (S^2_i) parameter (r = -0.601*). The results in Table (7) showed that b_i was positively correlated with S^2_{di}, R^2_i and W_i^2%. These results were in harmony with those obtained by Shah *et al* ,(2009) and Abd El-Shafi *et al* (2014). Deviations from regression (S^2_{di}) exhibited a positive and highly significant correlation (r=0.825**) with W_i^2%. Also, Coefficent of determination (R^2_i) exhibited a positive and significant correlation (r=0.678*) with W_i^2%. These findings agree with other researchers (Letta 2007 and Shah *et al* 2009 and Abd El-Shafi *et a*, 2014).

Table 7. Estimates of rank correlation coefficients among grain yield and stability parameters.

Parameters	Mean	b_i	S^2_{di}	R^2_i	W^2_i%	S^2_i
Mean	**1.000**	**0.175**	**-0.077**	**0.252**	**0.007**	**-0.601 ***
b_i		**1.000**	**0.608 ***	**0.608 ***	**0.902 ****	**0.245**
S^2_{di}			**1.000**	**0.545**	**0.825 ****	**0.524**
R^2_i				**1.000**	**0.678 ***	**0.343**
W^2_i%					**1.000**	**0.545**
S^2_i						**1.000**

***, ** Correlation coefficients are significantly different from zero at 0.05 and 0.01 level of probability, respectively.**

CONCLUSION

These results showed that significant GEI has an impact on the grain yield of studied genotypes. Therefore, there is a necessity need for multiple testing of these genotypes through different environments. These studies may help to identify which genotypes manifest relatively low GEI with stable yields in test environments. Moreover, it is advisable to test new genotypes in the environments of intended use before release to farmers. Genotypes Line#2, Sakha 95 and Line#1 are likely to be stable and may be recommended for cultivation in different locations as they had high stability.

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الارتباط الرتبى بين بعض مقاييس الثبات لمحصول الحبوب في قمح الخبز

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تهدف هذه الدراسة الى تقييم اثنى عشر تراكيب وراثية من قمح الخبز من خلال ٩ بيئات (توليفات من ٣ سنوات × ٣ مواعيد زراعة) خلال مواسم ٢٠١٦/٢٠١٥ و ٢٠١٧/٢٠١٦ و ٢٠١٨/٢٠١٧ في محطة بحوث كوم امبو، مركز البحوث الزراعية، (محافظة اسوان). وقد اظهرت النتائج وجود فروق معنوية بين التراكيب الوراثية لقمح الخبز لصفة محصول الحبوب (طن / هكتار) . وكذلك أظهر تحليل التباين التجميعى لمحصول الحبوب عبر التسعة بيئات وجود تباينات معنوية عالية ($P<0.01$) راجعة للتراكيب الوراثية و البيئات والتفاعل بينهما مما يشير إلى اختلاف الاستجابة بين التراكيب الوراثية عبر البيئات المستخدمة مع امكانية عمل تحليل الثبات. تم استخدم ستة مقاييس احصائية للثبات b_i , S^2_{di} , R_i^2, W_i^2 .and S^2_i)**.** ($\overline{X}_i$ **وكشف تحليل الثبات لمحصول الحبوب ان التراكيب Line#2 ،سخا ٩٥، Line#1 كانت الاكثر ثباتا من خلال ٥، ٤، و ٣ من الستة مقاييس للثبات المستخدمة على التوالي . كما انها اعطت مساهمة منخفضة فى التفاعل بين التراكيب الوراثية و البيئة. وبالتالي فان التراكيب الوراثية السابق ذكرها يمكن اعتبارها الاكثر ثباتا كما يمكن استخدمها فى برامج التربية المستقبلية لقمح الخبز. معامل الارتباط الرتبى بين مقاييس الثبات اشار الى وجود ارتباط معنوى موجب بين معامل ecovalance (W^2_i%) وبين كل من معامل الانحدار ,(b_i) والانحراف عن الانحدار (S^2_{di}) ومعامل التقدير (R^2).**