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GENOTYPE X ENVIRONMENT INTERACTION AND YIELD STABILITY ANALYSIS OF SESAME (SESAMUM INDICUM L.) GENOTYPES

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ABSTRACT: Thirteen sesame genotypes were evaluated seed yield/fad., under eight different environments i.e. These environments are the combinations between two different locations in Egypt, Ismailia Research Station and Shandawel Research Station. during four successive summer seasons of 2018 to 2021. The results showed that Mean performance for seed yield/fed ranged from 6.08ard/fed for genotype M575 to 4.7 ard/fed for line 59-3-5 in Ismailia location, while Shandawell location seed yield ranged from 7.86 ard/fed for LOCAL 219 to 6.17 ard/fed for Shandawell 3. Pooled analysis of variance revealed that the mean squares among the genotypes were highly significant for seed yield. Stability analysis indicated that, genotype x environment (GxE) "linear" was significant for seed yield, indicating that genotypes differed in their response to changes in the environments. G x E was also significant when tested against pooled deviation for seed yield/fad., suggesting that the linear regression and the deviation from linearity were important for describing stability for seed yield. Stability parameters analysis was assessed using regression coefficient (bi), mean squares of deviation from regression (S^2d), Genetic superiority index (pi), determination coefficient values (R2) and coefficient of variability (C.V). The correlation coefficients of relations between the mean seed yield and different stability parameters, mean seed yield and Pi were highly significantly positive correlation (r = 0.92**). The genotypes Shandawel 3, Line53-3 and Line59-3-5 could be considered stable genotype in terms of most studied traits.

Key words Sesame, phenotypic, genotypic, stability, correlation coefficients.

INTRODUCTION

Sesame (*Sesamum indicums* L.) is an important oilseed crop grown for local consumption in Egypt, Decorticated sesame seeds have a composition of 45-63% oil, 19-31% proteins, about 14% carbohydrates and about 3% ash Anilakumar *et al.,* (2010). Sesame oil is rich in oleic and linoleic fatty acids Sharar *et al.,* (2010), it has wide useing in the pharmaceutical and cosmetic industries due to its antioxidant compounds. Mathew *et al.* (2013) and Baraki *et al.* (2016) has reported average yield of sesame between 614.3−926.8 kg ha^{-1}. Breeding for high yielding and stable Genotypes has always been a very important objective of all plant breeding programs. Seed yield is a complex character and sensitive to environmental changes. Plant breeder aimed to produce high yielding and stable Genotypes. Genotype-environment interactions are often described as inconsistent differences among genotypes from one environment to another especially when varieties are compared over series of environments. Most of the quality characteristics are polygenically inherited and will therefore be influenced by the environment to a large extent Labuschangne *et al.,* (2002).

Hereby the relative ranking of genotype, usually differ as a result of edaphic variation between locations and changes in the environmental circumstances. Thus, a large G x E interaction led to reduce any actual progress from selection Comstock and Moll, (1963). A genotype is stable if, at a given environmental or plant population it exhibits very little fluctuation in seed yield from year to year.

Phenotypic and genotypic stability of yield performance and some attributes of sesame genotypes have been assessed by many investigators. In this respect, significant G x E

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interaction between genotype x location and genotype x sowing methods were detected for seed yield and its components by El-Serogy *et al.,* (1997).

The use of regression coefficients in determination of stability has been adopted by many researchers., an approach originally proposed by Yates and Cochram (1938) and later modified by Finlay and Wilkinson (1963) and Eberhart and Russel (1966). Eberhart and Russell (1966) stated that the deviations from the regressions calculated from the environmental averages of genotypes should also be considered as a stability parameter. Finlay and Wilkinson (1963) defined a stable genotype is one with a regression coefficient close to the average regression coefficient. The same researchers emphasised that if the regression coefficient of a genotype is close to 1.0, the genotype has average stability over all environments.

Other univariate stability parameters include regression coefficient (bi) and deviation from regression (Sd^2i) Eberhart and Russel, (1966), coefficient of variation, CV_i (Francis and Kannenberg (1978) and genotypic superiority index Pi Lin and Binns (1988).

Various statistical approaches have been so far to measure the stability of genotypes over environments. However, it was shown that no single method can adequately explain cultivar performance across environments Dehghani *et al.,* (2006). The stability parameters are not informative and useful in selection unless they are combined with mean performance of genotypes. Thus, stability must be used along with performance measurements to give reliable results.

An ideal sesame genotype selection is therefore one that combines high seed yield and stable performance in most of the ecological environments where it is cultivated. Therefore, the present work was conducted to determine the stability of seed yield in different genotypes and field traits performance in some sesame genotypes grown in Egypt under eight environments and selection genotypes that performed well under such environments.

MATERIALS AND METHODS

1. Plant material and environments

Thirteen sesame lines viza Shandawel 3, line 53-3, Line 10-66, Line 111-9, N.A 575, N.A 261, Line 107-7, N.A 585, Line 112-2, Line 133-4, LOCAL 219 and Line 59-3-5. source obtained from the Agriculture Research Center (ARC), Giza, Egypt. Seeds of the 13 sesame genotypes were grown under eight environments. These environments are the combinations between two different locations in Egypt, Ismailia Research Station and Shandawel Research Station, Sohag (Table 1). during four successive summer seasons from 2018 to 2021.

2. Experiment Design

Using randomized complete block design with three replications for each environment (2 locations X 4 years). Plot area was 9 m2 and included 6 rows of 3 m long and 50 cm apart. After full emergence the seedlings were thinned to secure one plant/hill. The recommended cultural practices for sesame production under each location were applied.

3. Data recorded

At maturity, Plots were hand harvested, then seeds were cleaned and weighed to determine Seed yield/fed was recorded on plot mean basis.

4. Statistical Analysis

The data were subjected to analyses of variance (ANOVA) using statically analysis system (SPSS) version 22. Bartlett’s test Steel and Torrie (1980) indicated heterogeneity of error variance for seed yield/fed in each of two locations for four years and then the data was log transformed to proceed further for pooled analysis. Analysis of variance was conducted using Eberhart and Russell (1966). to estimate various stability parameters used the statistical models were Joint linear regression coefficients model (bi) and (S^2di) Eberhart and Russell (1966); Finlay and Wilkinson (1963), Lin and

Binns cultivar superiority measure (P_i), Lin and Binns, (1988) determination coefficient value (R^2) of genotypes. Stability by coefficient of variance (CV) coefficient of variability, stable genotypes are those showing lower CV with higher yield. According to Francis and Kannenbergs (1978). Genotypic stability Tai, (1971) was used for comparing and ranking the studied sesame genotypes regarding their stability.

RESULTS AND DISCUSSION

1. Mean performance for seed yield.

According to the results, mean performance for seed yield/fed during the four years for thirteen sesame lines (Fig.1.) ranged from 6.08 ard/fed for line N.A575 to 4.7 ard/fed for line Line 59A3-5 in Ismailia location, while Shandawel location seed yield ranged from 7.86 ard /fed for line LOCAL 219 to 6.17 ard/fed for line Shandawel 3. Different response between thirteen sesame genotypes in two locations were shown due to the different environmental variations and soil conditions for the two locations, indicating that sesame seed yield was affected by environmental conditions prevailed in the two locations, also providing evidence for the necessity of testing studied genotypes in multiple environments and Stability measurement, therefore the stability parameters for each genotype. Similar finding results was obtained by Bhardwaj *et al. (*2014), Eryigit *et al.* (2016) and Kashani *et al.* (2015). While Anastasi *et al.* (2017) determined sesame seed yields between 1900 to 3500 kg ha^{-1}. These values are higher than the seed yield in this study.

Table (1): Description of experimental sites.

No	Location	Latitude	Longitude	Altitude
1	Ismailia Station	30° 36′ N	32° 14′ E	647
2	Shandawel Station	26° 37′ N	31° 39′ E	720

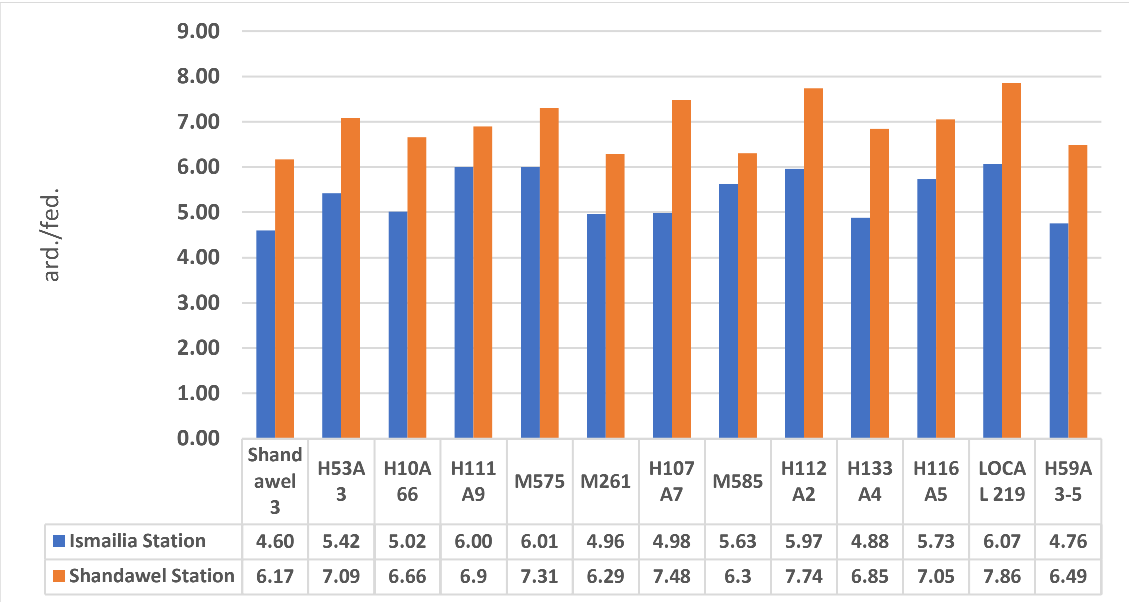

Fig.1. Mean performance for seed yield ard/fed of 13 sesame lines in two different locations during four seasons of 2018 to 2021.

2. Stability Analysis

2.1. Analysis of variance

Pooled analysis of variance also exhibited highly significant mean squares ($P < 0.05$) due to the genotypes, environments, and genotypes × environment for Seed yield/fed (Table 2).

Eberhart and Russell (1966) model of stability analysis was used for the assessment of environmental influence, genotypes and varieties x environmental interaction for each trait. When the genotypes x environment interactions were significant for the traits, then partitioning of total sum of squares due to genotypes x environment interactions into predictable and unpredictable source of variations.

Results of analysis of variance for thirteen sesame genotypes over eight environments of Finlay-Wilkinson regressions for Seed yield/fed are presented in Table (3). An analysis of variance for stability revealed highly significant differences ($P < 0.01$) for seed yield among genotypes and environment + (G x E). This reveals that not only the amount of variability existed among environments but also the presence of genetic variability among the genotypes**,** provides evidence for highly significant mean squares of genotypes for Seed yield/fed, suggesting that sesame genotypes were genetically different for genes controlling these characters. Highly significant environment + (genotype x environment) component was recorded for Seed yield/fed. Also, highly significant effect of environments (linear) was reported, indicating that the studied characters were highly influenced by the combination of environmental components (years and locations). Genotype x environment (linear) item was highly significant for the studied characters, suggesting that the tested sesame genotypes differed in their response to environments.

The significance of (G x E linear) component gave the chance to continue the estimation of the stability parameters. In addition to the significance of the mean squares of G x E interaction (linear), the pooled deviation item was found to be highly significant, suggesting differential response of genotypes to the various environments. Significant G x E interaction (linear) against the pooled deviation was observed for Seed yield/fed, suggesting that differences in linear response among genotypes across environments had occurred, and the linear regression and the deviation from linearity were the main components for differences in stability for most studied characters among genotypes. In this respect, G x E interaction was found to be highly significant for seed yield and some related characters (John *et al.*, 2001). These results of the significant differences for seed yield among genotypes, environment and G×E interaction are in agrees with the finding of Zenebe and Hussien (2009), Mekonen (2012), Daba *et al.* (2014) and Mekonnen *et al.* (2015).

Table (2): Pooled analysis of variance of Seed yield/fed. for 13 sesame genotypes grown in 8 Environments.

Source	D.F	M.S
Genotypes (G)	12	5.85**
Environments (E)	7	27.23**
G x E	84	0.52**
Error	208	0.288
TOTAL	311	

** = Significant at 5% probability level.

Table (3): Stability analysis of Seed yield/fed. for 13 sesame genotypes grown in 8 Environments.

Source	D.F	**M.S** Seed yield ard/fed
Total	103	
Varieties (V)	12	1.95**
Env. + (V. x Env.)	91	0.86**
Env. (Linear)	1	63.54**
V x Env (Linear)	12	0.40**
Pooled devation	78	0.13**
Shandawel 3	6	0.12**
Line 53-3	6	0.08
Line 10-66	6	0.15**
Line111-9	6	0.22**
N.A 575	6	0.06
N.A 261	6	0.05
Line 107-7	6	0.21**
N.A 585	6	0.19**
Line 112-2	6	0.13**
Line 133-4	6	0.24**
Line 116-5	6	0.14**
LOCAL 219	6	0.01
Line 59-3-5	6	0.09*
Pooled Error	192	0.30

** = Significant at 5% probability level.

2.2. Phenotypic stability parameters.

According to Eberhart and Russel (1966), a genotype considered as stable should meet criteria of high mean performance, the mean performance coupled with the regression coefficient values provides as useful parameter for studying the adaptation of genotypes ,the genotypes with regression coefficient (bi) equal or close to 1.0 and minimum deviation from regression mean square (S^2d=0) were considered to be stable (adaptable to all environments); a genotype with a regression coefficient significantly greater than 1 and small deviation mean square was considered as unstable, (adaptable to high-yielding environments); and a genotype with a regression coefficient significantly lower than one and a small deviation mean square it indicates genotype better yielder in low yielding environment and more adaptive.

A genotype may be considered to be stable (1) if its among-environment variance is small, (2) if the residual mean square from a regression model on the environmental index is small, or (3) if its response to environments is parallel to the mean response of all genotypes in the trial. In first concept, Becker, and Léon, (1988) called this a static of stability.

The stability parameters bi and S^2d Table (4) for seed yield, the regression coefficient (bi) genotypes ranged from 0.46 to 1.57, the deviation mean square (S^2d) ranged from -0.089 to 0.138. Using these criteria, seed yield of genotypes Shandawel 3, Line 53-3, Line10-66 and Line59-3-5 with regression coefficients of 1.01, 1.08, 1.02 and 1.08 respectively, S^2d approaching zero could be considered widely adapted and stable.

The genotypes Line 107-7 and Line133-4 showed significant regression coefficient and more than unity and it considered as unstable with adaptability to normal conditions. On the other hand, the genotype N.A585 showed non-significant regression coefficient less than unity and it considered as unstable with adaptability to stress environments. However, if the bi value of a genotype is more than 1, the genotype will perform at a higher level in good environmental conditions Akgun and Altindag, (2011).

If the regression coefficient measures less than 1, it indicates that the plant can show adaptation to poor environmental conditions. Explained Mekonnen *et al.* (2015) that regression coefficients (bi) ranged 0.25 to 1.44. The results showed similarities with the experimental findings the reported by Mirza *et al*. (2013), Daba *et al*. (2014), Mekonnen *et al.* (2015) and Raikwar (2016).

According to Lin and Binns (1988) model was used the Genetic superiority index (Pi) characterizes genotypes. stability and productivity and defines a superior genotype with performance near the maximum in various environments. The genotypes Shandawel 3 and Line 59-3-5 showed smaller value of Pi (-0.77 and -0.55) respectively Table (5), smaller value of Pi indicates less distance and maximum yield resulting better genotype and stable.

Generally, the univariate stability estimates it was observed that the two genotypes Shandawel 3, -and Line59-3-5 were the most stable and highly productive in terms of sugar yield to be considered for cultivation in the studied environments. These measurements of stability were used in determination of stability of sesame genotypes and other crops (Adebisi,2004; Adebisi *et al.*,2005).

Francis and Kannenberg's coefficient of variability (C.V) According to Francis and Kannenberg's coefficient of variability, Promising genotypes Line 107-7, Line 133-4 and Line112-2 differed from the other genotypes by higher C.V. % values, but the promising genotypes N.A585, Line59--3-5 and -had lower C.V.% . Ortiz *et al.* (2001) suggested that it may be possible to select simultaneously for high and stable genotypes are those with below average C.V and with above average yield. In this regard genotypes with their C.V below the average (15.62) were N.A585, Line 59-3-5, Line53-3, Line111-9, Shandawel 3, N.A575, N.A 261 and Line 10-66 (Table 4).

The determination coefficient (R2) was also used as another stability parameter. The determination coefficient value (R2) is accepted as an important statistic because it allows of the comparison of the stability of genotypes evaluated in different trials and in different measures Bibro and Roy, (1976). An expression coefficient close to one indicates that the genotypes is stable. The determination coefficient (R2) among genotypes ranged from 0.45 to 0.98. In this regard genotypes with their determination coefficient close to 1 were LOCAL 219, Line53-3, Shandawel 3 and Line59-3-5 indicates that the genotypes is stable (Table 4). Similar conclusion was reported by Mehmet (2018).

2.3. Genotypic stability parameters.

The genotypic stability, Tai (1971) partitioned G x E interaction effect of a variety into two components i.e. "α" static measures the linear response to environmental effects and "λ" static which measure the deviation from the linear response. A perfect stable variety has $\alpha = -1$, $\lambda = 1$. However, the average stable genotype has $\alpha = 0$, $\lambda = 1$, whereas the above average stable genotype should have an estimate of $\alpha < 0$, $\lambda = 1$ and the values $\alpha > 0$ and $\lambda = 1$ described as below average stable one.

The estimates of genotypic stability parameters α and λ for seed yield (Table 4) indicated that sesame genotypes, Shandawel 3, Line53-3 and Line59-3-5 had average degree of stability as they had α values not deviated from zero with λ approached near unity. However, the other sesame genotypes were unstable.

Genotypic stability for seed yield have been assessed by genotypic stability for seed yield have been assessed by El-Hashash and Agwa (2018). they reported significant differences among genotypes, environments and their interactions for seed yield. Therefore, studying the performance and stability of various sesame genotypes over old and newly reclaimed environments may provide reliable information for recommendation of some cultivars to be grown under specific environments or to assist sesame breeders for planning breeding programs.

3. Correlations coefficients

Study on the correlations among stability statistics is essential to make any recommendations of a crop variety Karimzadeh *et al.,* (2013). The correlation coefficients of relations between the mean seed yield and different stability parameters are presented in Table (5). The most reliable one is the one easy to be calculated and gave unbiased estimation for seed yield stability. Mean seed yield and Pi were highly significantly positive correlation (r = 0.92**). In agreement with this result, Pourdad (2011) was obtained strong positive rank correlation of mean seed yield with Pi in safflower. Mean seed yield was generally quite poorly correlated with the rest of the parameters.

Table (4): Estimates of phenotypic and genotypic stability parameters for Seed yield/fed. of 13 sesame genotypes grown in 8 environments.

Character Parameter / Genotype	Seed yield (ard. /fad.)							
	$\bar{x}_i$	bi	S^2d_i	Pi	C.V	R^2	α	λ
Shandawel 3	5.38	1.01**	-0.033	-0.77	14.5	0.94	0.00	0.88
Line53-3	6.25	1.08**	-0.020	0.09	13.36	0.96	0.03	0.79
Line10-66	5.83	1.02**	0.050	-0.32	15.44	0.75	0.01	1.39
Line111-9	6.45	0.58*	0.116	0.28	13.52	0.45	-0.17	2.79
N.A575	6.65	0.87**	-0.037	0.49	14.73	0.80	-0.05	0.66
N.A261	5.62	0.84**	-0.054	-0.53	14.56	0.82	-0.06	0.55
Line107-7	6.23	1.57**	0.108	0.07	22.64	0.80	0.23	3.38
N.A585	5.96	0.46 ns	0.088	-0.19	12.07	0.47	-0.22	3.07
Line112-2	6.85	1.19**	0.033	0.69	17.76	0.79	0.08	1.40
Line133-4	5.86	1.24**	0.138	-0.29	19.77	0.84	0.10	2.47
Line116-5	6.39	0.89**	0.043	0.23	15.15	0.81	-0.04	1.37
LOCAL 219	6.96	1.16**	-0.089	0.11	16.36	0.98	0.06	0.23
Line59-3-5	5.62	1.08**	-0.007	-0.55	13.14	0.93	0.03	0.93
Grand mean L.S.D 0.05	6.16				15.62			

Where, mean = Seed yield; Bi = Linear regression coefficient(slope); S^2d =Mean square deviation from regression; Pi = Genetic superiority index; CV = coefficient of variation, R^2 = coefficients of determination; genotypic stability; α and λ Tai's (1971).

Table (5): Correlation coefficients between mean seed yield and the studied stability parameters.

Stability parameters	$\bar{x}_i$	bi	S^2d_i	Pi	C.V
$\bar{x}_i$	1.00	0.09	-0.08	0.92**	0.20
bi		1.00	-0.01	0.03	0.82**
S^2d_i			1.00	0.12	0.37
Pi				1.00	0.21
C.V					1.00

** = Significant at 1% probability level.

Correlation of mean seed yield with bi was positive but no significant. On the other hand, Mekonnen *et al.* (2015) observed positive and significant correlation between seed yield and bi. It was negatively correlated with S^2d (-0.08). The regression coefficient (bi) displayed highly significantly positive correlation with coefficient of variation (0.82**), It was negatively correlated with S^2d (-0.01). Despite existence of highly significant correlations, it is obvious that each stability parameter and especially those belonging to different groups, describe different aspects of genotypes x environment interaction according to Lin *et al.* (1986) and Mustãţea1 *et al.* (2009).

Conclusion

This study showed the significant variations of the genotypes, environments and their interaction indicated that the response of the genotypes was highly variable and fluctuated in the seed yield. This signifies the need to select genotypes well adapted to specific environment and exceptionally for broadly adapted genotypes. Genotypes that showed stability but were poor in mean performance can be involved in crosses with agronomically desirable genotypes for respective characters, in a compensating manner in order to give constant performance of the trait. three genotypes viz. Shandawel 3, Line53-3 and Line59-3-5 were identified as desirable. Study on the correlations among stability statistics is essential to make any recommendations of a crop variety These genotypes may be recommended to be released for commercial sesame production which they performed better under all environments.

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تحليل الثبات والتفاعل بين التراكيب الوراثية والبيئة لمحصول السمسم

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الملخص العربي

تم تقييم محصول البذور لثلاث عشر تركيب وراثي من السمسم في ٨ بيئات (موقعين مختلفين بمحطه بحوث الاسماعيليه ومحطه بحوث شندويل) خلال ٤ مواسم من عام ٢٠١٨ الي ٢٠٢١) وقد تم تقدير مكونات الثبات المظهري يطريقه ابراهارت وراسل (١٩٦٦) والوراثي بطريقه تاي (١٩٧١). وقد أظهرت النتائج أن متوسط محصول البذور من ٦,٠٨ اردب/فدان للتركيب الوراثي المستورد ٥٧٥ الي ٤,٧ اردب/فدان للسلاله ٥٩-٣-٥ بمحطه بحوث الاسماعيليه بينما تراوح محصول البذور من ٧,٨٦ اردب/فدان للسلاله محلي ٢١٩ الي ٦,١٧ اردب/فدان للصنف شندويل٣.

وقد أظهر تحليل التباين المعنويه العاليه بين التراكيب الوراثيه للمحصول . وقد أظهر تحليل الثبات معنويه التفاعل بين التراكيب الوراثيه والبيئه (التركيب الوراثي × البيئه) لصفه محصول البذور وهذا يدل علي الاختلاف بين التراكيب في استجابتها للبيئات المختلفه. وقد أظهر أيضا التفاعل بين التراكيب الوراثيه والبيئه معنويه حين اختبارها لمحصول البذور اردب/الفدان. وهذا يوضح أن الانحدار الخطي والاختلافات كان مهم لتوصيف ثبات التركيب الوراثي لصفه المحصول. وقد أظهرت التراكيب الوراثيه شندويل٣ و السلاله ٥٣-٣ و السلاله ٥٩-٣-٥ ثبات لصفه محصول البذور.