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Stability Analysis for Root Yield and Quality Characters of Some Sugar Beet Genotypes

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ABSTRACT

This study aimed to evaluate the genotype × environment (G × E) interaction and stability parameters for yield and quality traits in sugar beet. Eight genotypes Baikal, Universe, Avantga, Serenada, Capel, Bts 301, Athos poly, and Saucona were tested in a randomized complete block design with three replications across nine environments. These environments consisted of three sowing dates (1st September, 1st October, and 1st November) over three growing seasons (2015/2016, 2016/2017, and 2017/2018), resulting in a total of nine distinct growing conditions. Pooled analysis of variance showed highly significant differences among genotypes for growth, yield, and quality traits. The G × E interactions and environmental linear effects were also highly significant, indicating that the performance of sugar beet genotypes was strongly influenced by varying environmental conditions. Stability analysis revealed that some genotypes exhibited phenotypic and genotypic stability for most traits, with varying adaptability across environments. Among them, Bts 301 consistently outperformed other genotypes, recording the highest mean values for most traits. Additionally, Saucona, Serenada, Capel, and Universe demonstrated stability for root yield, top yield, and sugar-related traits based on multiple statistical measures (mean, bi, s^2di, λi, and αi). Based on these findings, the study recommends Saucona, Serenada, Capel, Universe, and Bts 301 for cultivation due to their stability and high yields in root and sugar production. These genotypes are well-suited for different planting dates under the agro-climatic conditions of the Fayoum region.

Keywords: Stability parameters, genotypic x environments, sugar beet, yield and quality traits.

1. Introduction

Sugar beet (*Beta vulgaris* L.) serves as one of the world's most important sources of sugar, accounting for approximately one-third of worldwide sugar production, with particular significance in dry land farming areas (Wu *et al*., 2013). FAO statistics in 2023 indicate that, the global cultivation area for sugar beet spanned 4.52 million hectares, yielding 281.19 million tons of produce at an average productivity rate of nearly 62.2 tons per hectare. The leading producers of this vital crop include major agricultural regions such as the European Union nations, Russia, and the United States. In Egypt, sugar beet production in 2023 amounted to 12.8 million tons from 243.3 thousand hectares, yielding 52.6 tons per hectare. This crop contributed 1.3 million tons of sugar, accounting for nearly 50% of Egypt's domestic sugar production (FAO, 2023). For a sugar beet variety to be commercially successful, it must exhibit high yield potential along with desirable agronomic traits. Additionally, its performance must remain stable across diverse environmental conditions to ensure consistent productivity. According to research by Yan and Tinker (2006), genotype × environment interactions were analyzed across multiple environments, revealing significant effects for several key traits. Their findings indicated that root fresh weight per plant, as well as root and sugar yields per hectare, showed statistically significant G × E interactions. However, other measured characteristics, including root length, diameter, sucrose content, and purity percentage, did not demonstrate significant genotype-environment interactions. Previous studies in Egypt have highlighted the significant influence of genotype × environment (G × E)

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interactions on sugar beet performance. Shalaby *et al*. (2008) reported highly significant variations among sugar beet genotypes when grown under different environmental conditions. Similarly, Reza *et al*. (2009) found notable differences in key traits such as root length, root diameter, sugar yield, sucrose content, and purity among tested sugar beet varieties. Their analysis of variance further confirmed significant genotypic and environmental effects on grain yield, with the presence of G × E interactions indicating differential genotype performance across locations (Moradi *et al.*, 2012; Dewdar *et al*., 2008; Dewdar, 2013). Stability analysis methods have been developed to quantify these interactions. Wricke (1962, 1964) introduced the concept of ecovalence, which measures a genotype's contribution to the total G × E interaction sum of squares. Lower ecovalence values indicate greater stability, a desirable trait in crop production. Expanding on this, Tai (1971) proposed a model that partitions G × E effects into two components:

α (alpha): Reflects the genotype's linear response to environmental changes.

λ (lambda): Captures deviations from this linear response, indicating unpredictable variability.

These statistical approaches help breeders identify genotypes with consistent performance across diverse environments**.** He concluded that a variety with the values α = -1 and λ =1 will be referred to as perfectly stable, while the one with the values α = 0.0 and λ =1 as average stable, and values of the α< 0.0 and λ =1 as above average stable. In this respect, Dewdar *et al.* (2008), in their study on stability parameters, phenotypic and genotypic of cotton genotypes, reported that (bi, s^2d, λ, and α) differed in their efficiency in determining the stability of cotton genotypes across environments. In the same time, Al Jbawi *et al* (2016), evaluated fourteen monogerm cultivars of sugar beet in three years 2009, 2010 and 2011, their studies indicated that three monogerm sugar beet varieties—Rafal, Agora, and Sherif demonstrated stable performance in terms of sucrose content (%), purity (%), root yield, and sugar yield, as reflected in their yield stability statistics (Ysi). Additionally, Sanghera *et al*. (2017) reported that the Magnolia and Cauvery genotypes had higher root yields but below-average stability (bi < 1.0), while the Calixta genotype showed the highest sucrose content with a regression coefficient exceeding unity (bi > 1.0) along with significant regression deviation. This study aimed to: quantify genotype × environment interaction effects and assess stability parameters for various agronomic and quality characteristics on eight genotypes of sugar beet.

2. Materials and Methods

This investigation was conducted at the Agricultural Experiment Station of El-Fayoum University, Egypt, spanning three consecutive agronomic seasons (2015/16, 2016/17 and 2017/18). The experimental materials comprised multiple sugar beet genotypes, whose details are provided in Table 1.

Table 1: Origin and type of eight sugar beet genotypes.

No.	Genotypes	Type	Origin
1	Baikal	Monogerm	Germany
2	Universe	Monogerm	Germany
3	Avantga	Monogerm	France
4	Serenada	Monogerm	Germany
5	Capel	Multigerm	France
6	Bts 301	Multigerm	Germany
7	Athos poly	Multigerm	Netherland
8	Saucona	Multigerm	France

The evaluated traits included

Growth traits: root length, root diameter, Root fresh weight and tops, and leaf area index. Yield and yield components: root yield, top yield, and sugar yield. Quality traits: sucrose (%), brix (%), and purity (%) . (as shown in Table 4).

Seeds of the mentioned varieties were sown in three sowing dates (1st September, 1st October, and 1st November) in the three successive seasons (2015/2016, 2016/2017, and 2017/2018). Nine environments (three sowing dates by three seasons) were done. In each sowing date, the experimental design was a randomized complete block design (RCBD) with three replications. All recommended agronomic practices were applied. Each plot consisted of five ridges spaced 60 cm apart, with each ridge measuring 3.5 meters in length (equivalent to 1/400 fed.). Meteorological data for the three growing seasons are presented in Table 2.

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Table 2: Degree of maximum, minimum temperature (C°) and humidity (%) at Fayoum Governorate in 2015/2016, 2016//2017, and 2017/2018 growing seasons.

Season	Meteo. Data	September	October	November	December	January	February	March	April	May	June
2015/ 2016	Max. temp.	38.50	35.50	27.70	21.10	20.20	24.60	28.00	31.10	34.90	40.30
	Min. temp.	24.20	22.80	15.70	9.90	8.40	9.50	13.40	17.00	18.20	24.30
	Humidity	37.00	41.00	41.00	43.00	43.00	41.00	39.00	35.00	33.00	34.00
2016/ 2017	Max. temp.	38.20	33.00	29.17	22.10	22.45	23.60	28.80	32.80	36.00	41.20
	Min. temp.	23.60	21.60	17.11	9.50	10.30	10.50	14.90	15.70	19.80	23.80
	Humidity	37.00	34.00	42.00	43.00	44.00	41.00	38.00	34.00	32.00	35.00
2017/ 2018	Max. temp.	38.30	36.30	26.20	25.60	21.30	23.40	29.40	31.90	37.30	39.70
	Min. temp.	23.80	18.60	13.10	11.70	9.40	9.70	12.70	13.30	21.30	23.40
	Humidity	39.00	35.00	41.00	43.00	43.00	41.00	37.00	33.00	35.00	36.00

*Meteorology Station of the Agricultural Research Center in Giza

The experiment followed a randomized complete block design (RCBD) with three replications. Before the combined ANOVA, Bartlett's test for homogeneity and normality tests were performed using SPSS software to verify the assumptions of variance homogeneity across environments. Treatment means were compared using the Least Significant Difference (LSD) method (Gomez and Gomez, 1984) at significance levels of 5% and 1%. For stability analysis, phenotypic and genotypic stability were assessed based on Tai's model (Tai, 1971).

2.2. Phenotypic stability

Phenotypic stability was assessed using the stability model developed by Eberhart and Russell (1966), which evaluates stability parameters for all studied traits. In this model, both genotypes and environments were considered fixed factors. The analysis followed the statistical approach described by Eberhart and Russell (1966), applying their stability model to the experimental data.

The model is expressed as:

$$Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}$$

Where:

Y_{ij} = mean performance of the ith genotype in the jth environment (i = 1, 2, ..., v; j = 1, 2, ..., n),

μ_i = overall mean of the ith genotype across all environments.

β_i = regression coefficient indicating the ith genotype's response to environmental changes,

I_j = environmental index, calculated as the mean of all genotypes in the jth environment minus the grand mean:

$$I_j = (\sum Y_{ij} / v) - (\sum\sum Y_{ij} / vn), \text{ where } \sum I_j = 0$$

δ_{ij} = deviation from regression for the ith genotype in the jth environment.

Eberhart and Russell (1966) defined two key stability parameters:

Regression coefficient (b_i): Measures the genotype's adaptability to different environments.

$$b_i = \sum Y_{ij} I_j / \sum I_j^2$$

Deviation from regression (S^2d_i): Indicates stability variance around the regression line.

$$S^2d_i = (\sum \delta_{ij}^2 / (n-2)) - (\overline{S^2}_e / r)$$

An ANOVA (Table 3) was performed to partition the variance into components attributable to environments (linear), genotypes (linear), genotype × environment interactions (linear), and deviations from the regression model.

Table 3: Analysis of variance of combined data for multi-environmental data when stability parameters are estimated according to Eberhart and Russell's model (1966).

Source of variation	D.F.	S.S.
Genotypes (G)	g – 1	$\Sigma_i y^2_i / n - CF$
Environments (E) + G x E	g (n – 1)	$\Sigma_i \Sigma_j y^2_{ij} - (\Sigma_i y^2_{i.}/n)$
Environment (linear)	(1)	$[(\Sigma_j y_{.j} I_j)^2/g] / \Sigma_j I^2_j$
Genotypes x Environments (Linear)	(g-1)	$\Sigma_i (\Sigma_j y_{ij} I_j)^2/\Sigma_j I^2_j$ –E. (linear) S.S.
Pooled deviations	g (n – 2)	$\Sigma_i \Sigma_j \delta^2_{ij}$
Genotype 1	n – 2	$\Sigma_j \delta^2_{1j}$
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Genotype g	n – 2	$\Sigma_j \delta^2_{1g}$
Pooled error	n (g-1) (r-1)	M e = pooled $\sigma^2 e/r$

Where: C.F. = Correction factor, r, n, and g refer to the number of replications, environments, and genotypes, respectively.

2.3. Genotypic stability

Tai's model for estimating genotypic stability

The stability analysis was conducted following Tai's model (1971), which decomposes genotype × environment (G×E) interaction effects into two distinct statistical components for each genotype:

α (alpha) - representing the linear responsiveness to environmental variation

λ (lambda) - quantifying deviations from linearity through error variance estimation

This analytical approach provides a comprehensive assessment of genotype stability by evaluating both the predictable (α) and unpredictable (λ) components of environmental adaptation.

$$\alpha = \frac{S_i(\mathrm{gL})_i}{\mathrm{MSL{-}MSB/mp}}$$

$$\lambda = \frac{S^2(gL)_{i-\alpha S_{i.}}(gL)_i}{(M-1)MSE/mp}$$

Where:

$S_i\,(gE)_i$ is the simple covariance between the environment and the interaction effect.

$S^2\,(gE)_i$ is the sample variance of the interaction effects of the i^{th} genotype in the n environments.

MSE is the mean square of the environmental effect.

MSB is the mean square of the replicates within environments.

MSE is the mean square of the error deviates.

m is the number of genotypes.

p is the number of replications.

3. Results and Discussion

3.1. Analysis of variance

Statistical analysis revealed highly significant ($p<0.01$) genotypic variations for all eleven measured traits (as shown in Table 4). The significant genotype × environment (G×E) interaction for root length, root diameter, fresh weight parameters, and leaf area index demonstrated that phenotypic expression of these traits was substantially influenced by environmental conditions. Further decomposition of variance components showed that environmental linear effects (E. linear) contributed most significantly to the observed interactions, with mean square values of 117.38, 42.79, 2.89, 1.37, and 364.49 for the respective growth traits, while G×E linear effects showed comparatively smaller contributions. These findings align with Comstock and Moll's (1963) assertion that significant G×E interactions can compromise selection efficiency and are consistent with previous research by Al Jbawi (2016), El Hashash and Agwa (2018), and Whaley and Eskandari (2019).

3.2. Phenotypic and genotypic stability

3.2.1. Growth traits

3.2.1.1. Root length

About root length, the means averaged over environment and phenotypic and genotypic stability parameters are given in Table 5 and Figure 1. Regression coefficients (bi) for the two genotypes No.7 (Athos poly) and No. 8 (Saucona) were insignificant and differed from unity; the minimum deviation from regression (S^2di) was detected and had high mean values indicating that these genotypes are phenotypically stable over the environments studied. The reminder genotypes No. 1, 2, 3, 4, 5 and 6 which were differed significantly from unity. For genotypic stability parameter were not significantly differed from α = zero for all genotypes at all the probability levels, except for genotypes 5 and 6. The estimated λ statistics were not significantly differ from unity (λ= 1) for all genotypes except for genotype no 1 and 6. These results indicated that sugar beet genotypes No. 8 (Saucona) showed below average degree of genetic stability. However, genotypes No. 2 (Universe), No. 3 (Avantga), No. 4 (Baikal) and No. 7 (Athos poly) showed above genetically stable. Similar results were obtained by Akura *et al* (2005) and Sanghera *et al* (2017).

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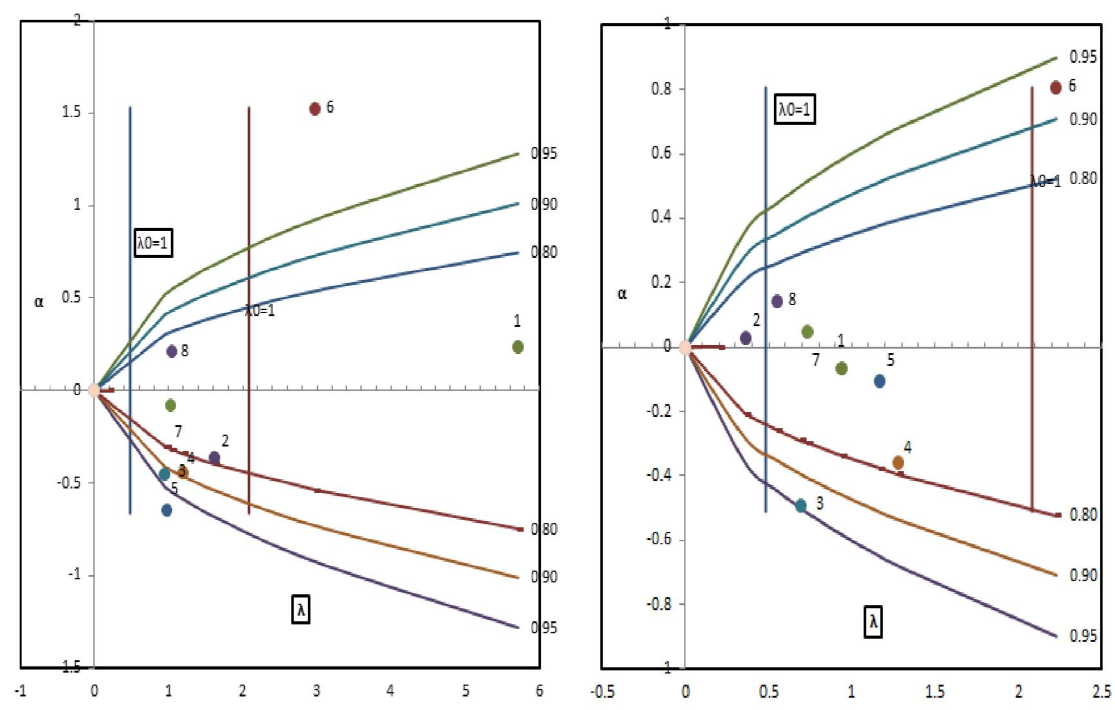
Table 4: Analysis of variance for growth, yield and quality traits in eight sugar beet varieties over nine environments.

S.O.V.	D.F.	Root length	Root diameter	Root fresh weight	Top fresh weight	LAI	Root yield	Top yield	Sugar yield	Brix %	Sugar %	Purity %
Genotypes (G)	7	61.176**	14.808**	0.590**	0.130**	24.840**	126.380**	26.320**	10.540**	10.360**	11.880**	8.500**
Environments + G x E	64	3.522**	0.974**	0.054**	0.090**	6.290**	7.960**	3.940**	0.510**	0.670**	0.668**	1.400**
Environments (linear)	1	117.381**	42.796**	2.895**	1.371**	364.490**	281.160**	190.130**	17.000**	22.920**	24.460**	74.800**
G x E (linear)	7	5.884**	0.662*	0.026**	0.382**	4.270**	8.040*	2.930**	1.310**	0.811	1.657**	0.132
Pooled deviations	56	1.193	0.266	0.006	0.031	0.149	3.070	0.740	0.118	0.261	0.119	0.252
Baikal (G1)	7	3.317**	0.243	0.003	0.198*	0.271	1.880	0.210	0.089	0.121	0.108	0.047
Universe (G2)	7	0.962	0.093	0.008	0.004	0.196	2.900	0.362	0.138	0.232*	0.161	0.026
Avantga (G3)	7	0.584	0.196	0.007	0.008	0.072	2.300	0.264	0.062	0.044	0.049	0.081
Serenada (G4)	7	0.722	0.339	0.006	0.003	0.033	5.500	0.639	0.219	0.156	0.099	0.012
Capel (G5)	7	0.637	0.304	0.002	0.002	0.178	3.070	0.350	0.083	0.114	0.058	0.146*
Bts 301 (G6)	7	2.113**	0.621*	0.016*	0.007	0.319	3.530	2.787**	0.188	1.290**	0.390**	1.510**
Athos poly (G7)	7	0.600	0.190	0.002	0.006	0.049	1.960	0.580	0.067	0.091	0.056	0.134*
Saucona (G8)	7	0.613	0.144	0.006	0.015	0.078	3.410	0.702	0.097	0.039	0.033	0.049
Pooled error	126	0.579	0.259	0.004	0.076	0.301	3.230	0.424	0.114	0.102	0.092	0.054

Table 5 and Figure 1: Phenotypic and genotypic stability parameters for root length and diameter traits in eight sugar beet genotypes.

Genotypes	Root length (cm)					Root diameter (cm)				
	Mean	bi	S^2di	α	λ	Mean	b_i	S^2di	α	λ
Serenada	22.96	1.22	2.65**	0.24	5.71	12.68	0.94	-0.05	-0.07	0.94
Universe	22.63	0.67*	0.29	-0.36	1.62	12.00	1.03	-0.20	0.03	0.36
Avantga	22.79	0.59*	-0.08	-0.45	0.95	12.1 7	0.55*	-0.10	-0.49	0.69
Baikal	23.04	0.60*	0.05	-0.44	1.19	12.20	0.68*	0.05	-0.36	1.28
Capel	22.55	0.41*	-0.03	-0.64	0.98	11.91	0.90	0.01	-0.11	1.17
Bts 301	30.06	2.39*	1.45**	1.52	2.98	15.74	1.73*	0.33*	0.81	2.23
Athos poly	22.33	0.93	-0.07	-0.08	1.03	12.16	1.04	-0.10	0.05	0.73
Saucona	22.69	1.19	-0.05	0.21	1.05	12.07	1.13	-0.15	0.14	0.55



Numbers 1, 2, 3, 4, 5, 6, 7, and 8 refer to eight genotypes studied: Baikal, Universe, Avantga, Serenada, Capel, Bts 301, Athos poly, and Saucona.

3.2.1.2. Root diameter

Concerning root diameter, the genotypes' mean values over environments and stability for this trait are presented in Table 6 and Figure 1; estimates of the regression coefficient (bi) for all genotypes were insignificantly different from unity, except for genotypes No. 3 (Avantga), No. 4 (Baikal), and No. 6 (Bts 301). Concerning the second stability parameters (S^2di), sugar beet genotypes had insignificant deviation from regression; these results indicated that these genotypes would be classified as being stable. Also, these results suggest that only genotype No. 1 (Serenada) are stable for this trait and it gave high value than grand mean (12.68 cm) followed by genotypes No. 2 (Universe), No. 5 (Capel), No. 7 (Athos poly) and No. 8 (Saucona), where, had insignificant bi and S^2di, but it gave low values than grand mean. The genotypic stability parameters are presented in (Table 6 and Figure 1), it could be noticed that the average stability area in the figure contained genotypes No. 2 (Universe), No. 7 (Athos poly) and No. 8 (Saucona) had stable for this trait and were below average stable, while the genotypes; No.1 (Serenada), No. 3 (Avantga), No. 4(Baikal) and No. 5 (Capel) showed above genetically stable. Similar results were obtained by Sanghera *et al*. (2017).

3.2.1.3. Root fresh weight

Concerning root fresh weight, the highest mean performance was observed in genotype No. 6 (Bts 301), while genotype No. 3 (Avantga) had the minimum value (1.06 kg). Six genotypes were found to be stable for the root fresh weight trait. These genotypes, No. 2 (Universe), No. 8 (Saucona), had non-significant values for regression coefficient (bi) and deviation from regression coefficient (S^2di), and may do better in all the environments.

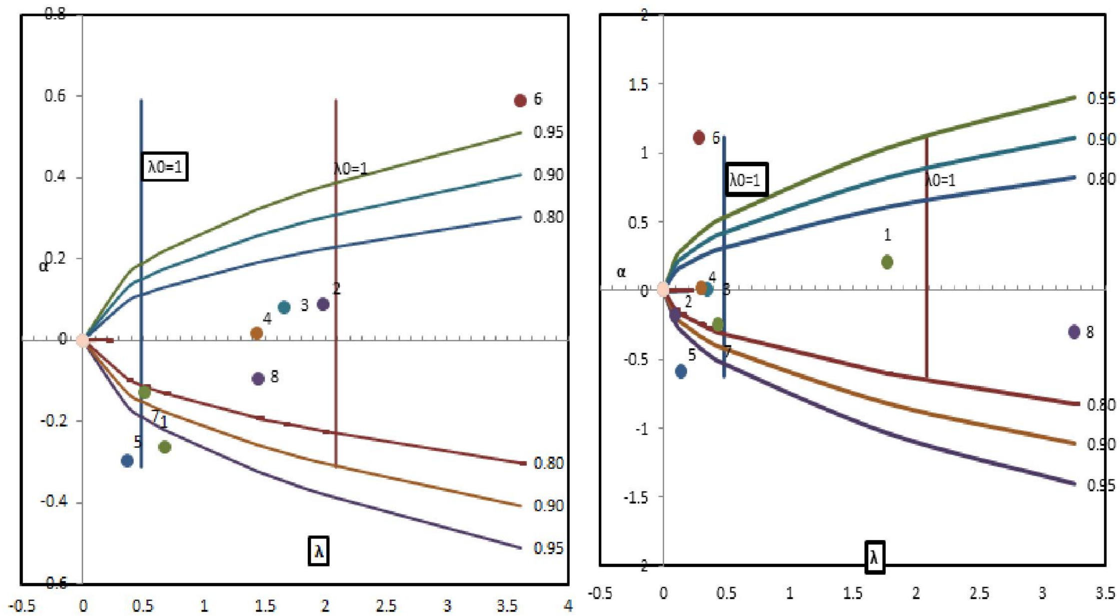
Data in Table 6 and Figure 2 showed that genotypic stability parameters α were not significantly different from zero for all the probability levels, except for genotypes No. 1 (Serenada), No. 5 (Capel), and No. 6 (Bts 301). The estimated statistics were insignificantly different from λ =1 for the studied genotypes, except for genotype No. 5 (Capel) and No. 6 (Bts 301). These results indicated that sugar beet genotypes No. 2 (Universe), No.3 (Avantga), and No.4 (Baikal) showed the average degree of genotypic stability. While genotypes No. 7 (Athos poly) and No. 8 (Saucona) showed above are genetically stable. Also, the phenotypic stability was detected for previous genotypes No. 2 (Universe), No. 3(Avantga), No. 4 (Baikal), No. 7 (Athos poly), and No.8 (Saucona). These results agree with those obtained by Okasha and Mubarak (2018).

3.2.1.4. Top fresh weight

Stability parameters of b_i, S^2di, α, and λ for eight genotypes with the mean of this trait are given in Table 7 and Figure 2. For phenotypic stability significant difference in bi values for all genotypes studied, except for genotypes No. 4 (Baikal) and No. 6 (Bts301). While the estimates of S^2di were not significantly different from zero for all genotypes, except for genotype No.1 (Serenada). The graphic analysis illustrated that the genotype No. 1 (Baikal) has a degree of below stability; however, the genotypes No. 3 (Avantga) and No. 4 (Serenada) were spotted in the average stability area. At the same time, the genotypes No. 2 (Universe) and No. 7 (Athos poly) gave above genetic stability, while the reminder genotypes were unstable for this trait.

Table 6 and Fig. 2: Phenotypic and genotypic stability parameters for root and top fresh weight traits in eight sugar beet genotypes.

Genotypes	Root fresh weight (kg)					Top fresh weight (Kg)				
	Mean	bi	S^2di	α	λ	Mean	bi	S^2di	α	λ
Serenada	1.12	0.74*	0.00	-0.26	0.67	0.85	4.66*	0.12*	0.20	1.78
Universe	1.09	1.09	0.00	0.09	1.98	0.58	0.45*	-0.07	-0.18	0.10
Avantga	1.06	1.08	0.00	0.08	1.66	0.57	0.44*	-0.07	0.00	0.35
Baikal	1.13	1.02	0.00	0.02	1.43	0.57	0.64	-0.07	0.01	0.31
Capel	1.08	0.71*	0.00	-0.30	0.37	0.55	0.30*	-0.07	-0.59	0.15
Bts 301	1.82	1.57*	0.01*	0.59	3.60	0.81	0.90	-0.07	1.11	0.29
Athos poly	1.13	0.88	0.00	-0.13	0.51	0.57	0.34*	-0.07	-0.25	0.44
Saucona	1.09	0.91	0.00	-0.09	1.45	0.60	0.27*	-0.06	-0.30	3.25



Numbers 1, 2, 3, 4, 5, 6, 7, and 8 refer to eight genotypes studied: Baikal, Universe, Avantga, Serenada, Capel, Bts 301, Athos poly, and Saucona.

3.2.1. 5. Leaf area index

The results presented in Table 7 and Figure 3, the regression coefficient (b_i) was significantly different from unity for all studied genotypes, except for genotypes No. 3 (Avantga) and No. 5 (Capel) gave an insignificant value for unity. Also, the second parameter of phenotypic stability values was insignificantly different from zero ($S^2di = 0$), indicating that these genotypes were more stable under the studied environments for this trait. For genotypic stability, the results showed that stability parameter α was significantly different from zero for all genotypes at all the probability levels, except for genotypes No.2 (Universe), No.3 (Avantga), and No. 5 (Capel), which gave insignificant differences from α= 0 and λ= 1. The genotype No. 2 (Universe) showed below average degree of genotypic stability. However, the genotype No. 5 (Capel) showed the average degree of stability at all probability levels for this trait at the same time, while genotype No. 3 (Avantga) showed genotypic stability above. Further, the phenotypic stability was detected for the previous genotypes No. 3 (Avantga) and No. 5 (Capel).

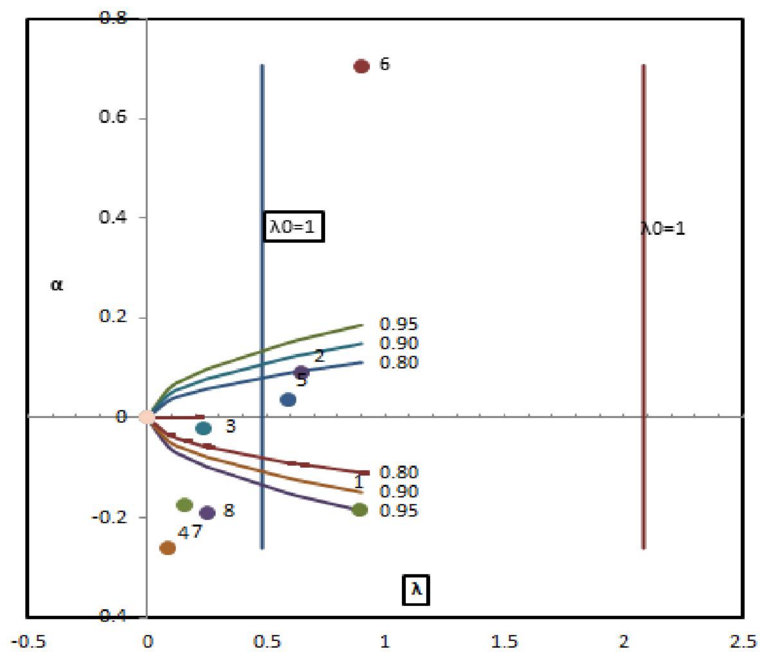
3.3. Yield and yield components

3.3.1. Root yield

The analysis of root yield performance across genotypes (Tables 8 and Figure 4) revealed statistically comparable mean values among all studied varieties. Notably, genotypes Universe (No. 2; 28.65 ton/fad), Baikal (No. 4; 28.06 ton/fad), and Capel (No. 5; 28.67 ton/fad) demonstrated superior yields coupled with below-average stability (bi<1), suggesting their potential suitability for challenging growing conditions. Application of Eberhart and Russell's (1966) stability parameters showed considerable variation in environmental responsiveness, with regression coefficients (bi) ranging from 0.47 (Avantga, No. 3) to 1.99 (Bts 301, No. 6). Among the eight genotypes evaluated, four exhibited regression slopes statistically equivalent to 1.0, indicating consistent yield performance across diverse environments. Further analysis identified Universe (No. 2), Baikal (No. 4), Capel (No. 5), and Saucona (No. 8) as particularly adaptable to varying planting dates, as evidenced by their non-significant deviation from unity in regression coefficients and minimal deviation from regression (S^2di). These findings corroborate previous research by Sanghera *et al.* (2017), supporting the utility of stability parameters in genotype evaluation and selection.

Table 7 and Figure 3: Phenotypic and genotypic stability parameters for leaf area index trait in eight sugar beet genotypes.

Genotypes	Leaf area index				
	Mean	bi	S^2di	α	λ
Serenada	5.55	0.82*	-0.08	-0.18	0.89
Universe	5.76	1.09*	-0.15	0.09	0.65
Avantga	5.58	0.98	-0.28	-0.02	0.24
Baikal	5.28	0.74*	-0.32	-0.26	0.09
Capel	5.90	1.04	-0.17	0.04	0.59
Bts 301	10.26	1.70*	-0.03	0.71	0.90
Athos poly	5.83	0.83*	-0.30	-0.17	0.15
Saucona	5.32	0.81*	-0.27	-0.19	0.25



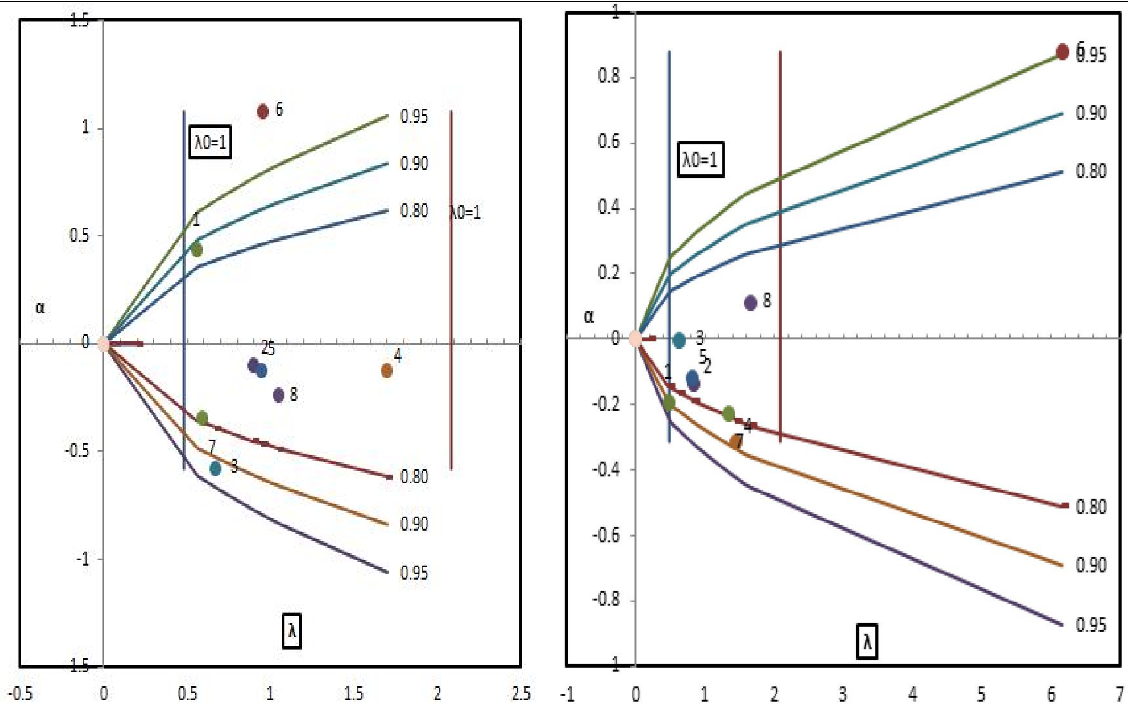
Numbers 1, 2, 3, 4, 5, 6, 7, and 8 refer to eight genotypes studied: Baikal, Universe, Avantga, Serenada, Capel, Bts 301, Athos poly, and Saucona.

3.3.2. Top yield

Table 9 and Figure 4 present mean values of the top yield trait, bi, and S^2di parameters for eight genotypes. The bi values were did not differed significantly than one and insignificant S^2di values than zero for four out eight genotypes studied No. 2 (Universe), No. 3 (Avantga), No. 5 (Capel) and No. 8 (Saucona) indicating that these genotypes had the most stable performance and these genotypes are phenotypically stable over the studied environments.

Table 8 and Figure 4: Phenotypic and genotypic stability parameters for root and top yield traits in eight sugar beet genotypes.

Genotypes	Root yield (ton\fad.)					Top yield ton\fad.)				
	Mean	bi	S^2di	α	λ	Mean	bi	S^2di	α	λ
Serenada	26.91	1.40*	-1.31	0.44	0.56	5.60	0.82*	-0.38	-0.20	0.47
Universe	28.65	0.91	-0.30	-0.10	0.90	5.69	0.87	-0.22	-0.14	0.84
Avantga	26.95	0.47*	-0.90	-0.58	0.67	5.64	1.00	-0.32	0.00	0.62
Baikal	28.06	0.89	2.31	-0.12	1.70	5.66	0.71*	0.05	-0.31	1.45
Capel	28.67	0.89	-0.12	-0.13	0.95	5.99	0.89	-0.24	-0.12	0.82
Bts 301	37.81	1.99*	0.34	1.08	0.96	10.52	1.82*	2.20**	0.88	6.16
Athos poly	26.82	0.68*	-1.23	-0.35	0.59	5.37	0.79*	-0.01	-0.22	1.34
Saucona	26.41	0.78	0.22	-0.24	1.05	6.33	1.10	0.12	0.11	1.65



Numbers 1, 2, 3, 4, 5, 6, 7, and 8 refer to eight genotypes studied: Baikal, Universe, Avantga, Serenada, Capel, Bts 301, Athos poly, and Saucona.

Graphical analysis revealed that genotype No. 3 (Avantga) exhibited average stability across probability levels (0.20, 0.10, and 0.05). This genotype approached full stability, as its position nearly intersected the midpoint of the λ confidence interval. In contrast, genotypes No. 6 (Bts 301) and No. 8 (Saucona) demonstrated below-average genetic stability. The remaining genotypes displayed intermediate stability levels.

3.3.3. Sugar yield

Mean performance pooled over environments, regression coefficients (bi) and deviation from regression (S^2di) for this trait are given in Table 9and Figure 5. Concerning the environment, sugar yield of environments over genotypes, it's clear that the earliness of planting date in the three seasons was associated with increased in sugar yield (ton/fad) and vice versa for lateness in planting date of the three seasons (1st Nov. at 2015/2016, 2016/2017 and 2017/2018). The genotypes ranged from 4.51 tons/fad. For genotype No. 8 (Saucona) to 7.73 tons/fad. For genotype No. 6 (Bts 301). The results indicated that all genotypes were not differ from zero for the second stability parameter (S^2di) which mean that those genotypes can be classified as stable genotypes, while the first stability parameter (bi) was significant for four out eight genotypes No. 1, 3, 6 and 7, indicating that these variations were unstable according the regression coefficient (Eberhart and Russell, 1966). Similar results were reported by Ranji *et al* (2005) and Ebrahimian *et al* (2008). The findings indicated that the genotype No. 1 (Serenada) had below average stability ($\alpha > 0$) and ($\lambda = 1$). Genotypes No.2 (Universe), No. 4 (Baikal), No. 5 (Capel), and No. 8 (Saucona) have a degree of above average stability ($\alpha < 0$) and ($\lambda = 1$) with probability 0.90, while the other genotypes were unstable according to Tai (1971).

3.4. Quality traits

3.4.1. Sugar percentage

The average sugar percentages across different environments, along with phenotypic and genotypic parameters for this trait, are displayed in Table 9 and Figure 5. The regression coefficients (b_i) varied significantly from one, except for genotypes No. 1 (Serenada) and No. 8 (Saucona). However, the deviation from regression (S^2d_i) was not significantly different from zero for most genotypes, except

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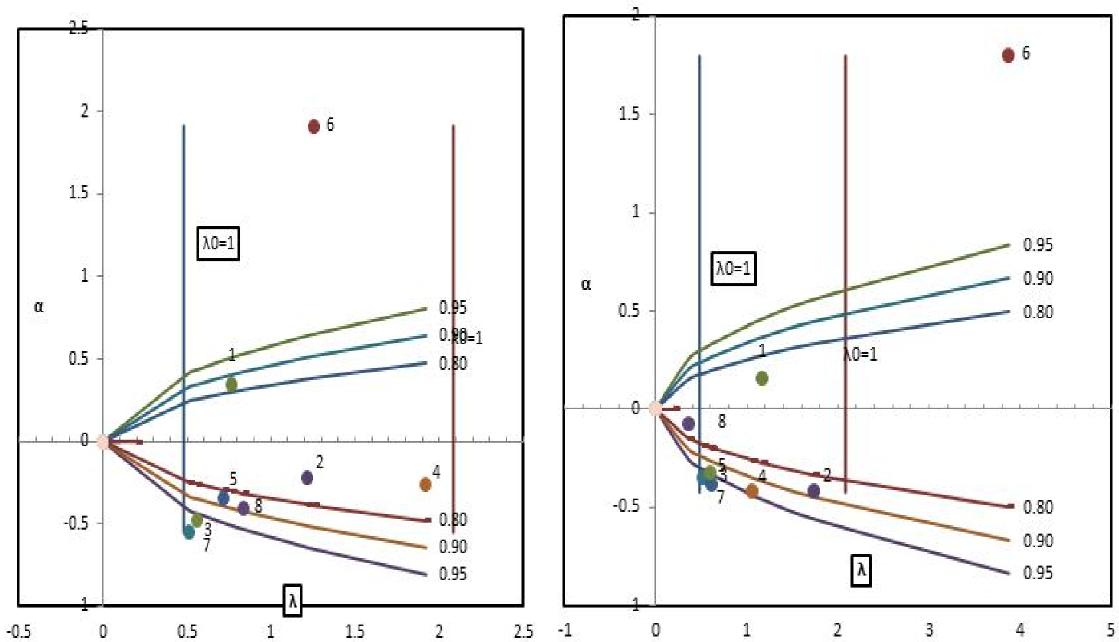
for No. 5 (Capel), which also exhibited a high mean value. This suggests that these genotypes are phenotypically stable across the tested environments.

Regarding genotypic stability, the stability parameter (α_i) did not significantly deviate from zero at any probability level, except for genotype No. 6 (Bts 301). Additionally, the estimated statistics (λ) were not significantly different from one for all genotypes, except No. 8 (Saucona). These findings indicate that genotype No. 1 (Serenada) had below-average genetic stability, while genotypes No. 2 (Universe), No. 3 (Avantga), No. 4 (Baikal), No. 5 (Capel), and No. 7 (Athos poly) demonstrated above-average genetic stability.

Table 9 and Figure 5: Phenotypic and genotypic stability parameters for sugar yield and sugar percentage traits in eight sugar beet genotypes.

Genotypes	Sugar yield (ton\fad.)					Sugar percentage				
	Mean	bi	S^2di	α	λ	Mean	bi	S^2di	α	λ
Serenada	4.69	1.34*	-0.02	0.35	0.76	17.35	1.15	0.02	0.16	1.17
Universe	4.90	0.79	0.03	-0.22	1.21	17.09	0.60*	0.07	-0.42	1.73
Avantga	4.58	0.47*	-0.05	-0.55	0.51	16.98	0.66*	-0.04	-0.35	0.52
Baikal	4.83	0.75*	0.11	-0.26	1.92	17.19	0.59*	0.01	-0.42	1.05
Capel	4.85	0.67*	-0.03	-0.35	0.72	16.94	0.63*	-0.03	-0.38	0.62
Bts 301	7.73	2.83*	0.08	1.91	1.25	20.30	2.76*	0.30*	1.80	3.86
Athos poly	4.54	0.55*	-0.05	-0.48	0.56	16.90	0.68*	-0.03	-0.32	0.60
Saucona	4.51	0.61*	-0.01	-0.40	0.83	17.07	0.93	-0.06	-0.07	0.36



Numbers 1, 2, 3, 4, 5, 6, 7, and 8 refer to eight genotypes studied: Baikal, Universe, Avantga, Serenada, Capel, Bts 301, Athos poly, and Saucona.

3.4.2. Brix percentage

Table 10) and Figure 6 showed that the genotypic stability parameter α was insignificantly different from zero for all studied genotypes at all the probability levels. The genotype No. 8 (Saucona) was spotted in the average stability area at the probability levels. The genotype No. 2 (Universe) showed a below-average degree of genotypic stability. However, the reminder genotypes shown above are genotypically stable.

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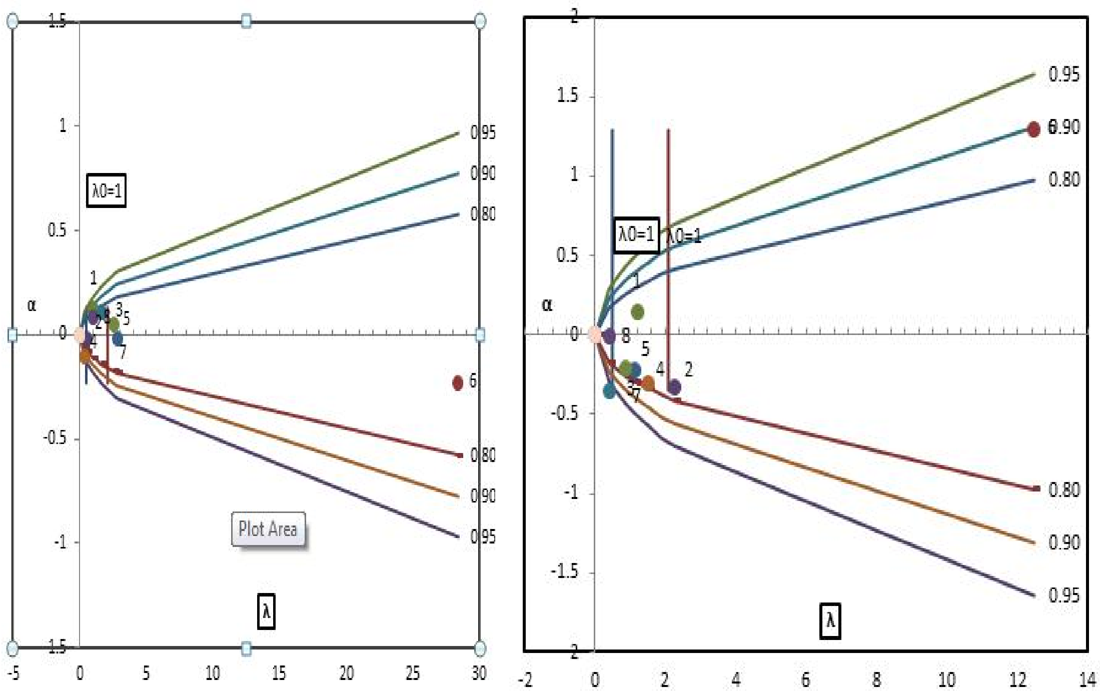
Table 10 and Figure 6: Phenotypic and genotypic stability parameters for purity and brix percentage traits in eight sugar beet genotypes.

Genotypes	Purity %					Brix %				
	Mean	Bi	S^2di	α	λ	Mean	b_i	S^2di	α	λ
Serenada	86.02	1.13	-0.01	0.13	1.00	20.17	1.139	0.021	0.14	1.18
Universe	85.99	0.98	-0.03	-0.02	0.56	19.88	0.683	0.132*	-0.33	2.26
Avantga	85.94	1.11	0.02	0.11	1.60	19.75	0.658	-0.056	-0.35	0.42
Baikal	85.97	0.90	-0.05	-0.10	0.31	19.99	0.700	0.056	-0.31	1.52
Capel	85.89	0.98	0.09*	-0.02	2.78	19.72	0.787	0.015	-0.22	1.12
Bts 301	88.66	0.77*	1.46**	-0.23	28.05	22.87	2.252	1.191**	1.29	12.47
Athos poly	85.82	1.05	0.08*	0.05	2.55	19.69	0.795	-0.009	-0.21	0.89
Saucona	85.86	1.08	-0.01	0.08	0.98	19.88	0.987	-0.061	-0.01	0.38



Numbers 1, 2, 3, 4, 5, 6, 7, and 8 refer to eight genotypes studied: Baikal, Universe, Avantga, Serenada, Capel, Bts 301, Athos poly, and Saucona.

3.4.3. Purity percentage

The environmental mean values and phenotypic stability parameters are summarized in Table 10. Analysis revealed that regression coefficients (bi) remained statistically equivalent to unity for the majority of genotypes, except for genotype No. 6 (Bts 301). Evaluation of the second stability parameter (S^2di) identified significant deviations from regression in genotypes No. 5 (Capel), No. 6 (Bts 301), and No. 7 (Athos poly), indicating phenotypic instability. The remaining genotypes demonstrated stability for this characteristic.

Visual representation of the data (Figure 6) supported these findings, showing no significant departure of the genotypic stability parameter (α) from zero across all probability levels. Statistical analysis revealed that λ values did not differ significantly from 1 for most genotypes, except for No. 3 (Avantga), No. 5 (Capel), No. 6 (Bts 301), and No. 7 (Athos poly). These results classify sugar beet genotypes into distinct stability categories: No. 1 (Serenada), No. 2 (Universe), and No. 8 (Saucona) displayed below-average genetic stability, while No. 4 (Baikal) exhibited above-average stability. Phenotypic stability followed similar patterns for these genotypes.

According to Tai's (1971) stability model, ideal stability is characterized by parameters ($\alpha = -1$ and $\lambda = 1$). Genotypes with average stability show values ($\alpha = 0$ and $\lambda = 1$), while those with above- average stability demonstrate ($\alpha < 0$ and $\lambda = 1$). Cultivars displaying below-average stability are identified by ($\alpha > 0$ and $\lambda = 1$).

4. Conclusion

Our findings reveal significant variations in sugar beet performance across different growing conditions, with clear genotype × environment interactions affecting both yield and quality. Among the tested varieties, Saucona, Serenada, Capel and Universe demonstrated remarkable stability, consistently performing well regardless of planting date or season, making them particularly suitable for Fayoum's variable conditions. While Bts 301 stood out for its exceptional yield potential, its performance proved more dependent on specific environmental factors. These results give farmers and breeders crucial guidance for variety selection for sugar beet cultivation in Fayoum region.

References

Akura, M., Y. Kaya and S. Taner, 2005. Genotype-environment interaction and phenotypic stability analysis for grain yield of durum wheat in the central Anatolian region. J Agric., 29: 369-375.

Al Jbawi, E.M., A.F. Al Raei, A.A. Ali and H. Al Zubi, 2016. Genotype – Environment interaction study in sugar beet (*Beta vulgaris* L.) International J. of Environ. 3 (5): 71-86.

Comstock, R.E. and R.H. Moll, 1963. Genotype x Environment Interactions. Symposium on Statistical Genetics and Plant Breeding. National Academy of Science National Research Council, Washington, D C. 164-196.

Dewdar, M.D.H., 2013. Stability analysis and genotype x environment interactions of some Egyptian cotton cultivars. African Journal of Agricultural Research Vol. 8(41): 5156-5160.

Dewdar, M.D.H., S.K.A. Ismail and A.A.M. Atia, 2008. Genotypic and phenotypic stability of five Egyptian cotton varieties. Egypt J. Plant Breed., 12(1): 279-292.

Eberhart, S.A. and W.A. Russell, 1966. Stability parameters for comparing varieties. Crop Sci., 6:36-40.

Ebrahimian, H.R., S.Y. Sadeghian, M.R. Jahadakbar and Z. Abasi, 2008. Study of adaptability and stability of sugar beet monogerm cultivars in different locations of Iran. J. Sugar Beet, 24: 1-13.

El Hashash, E.F. and A.M. Agwa, 2018. Comparison of parametric stability statistics for grain yield in barley under different drought stress severities. Merit Research Journal of Agricultural Science and Soil Sciences. 6 (7): 098-111.

Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. 2nd Edition, John Wiley and Sons, New York, 680.

Moradi, F., H. Safari and A. Jalilian, 2012. Study of genotype ×environment interaction for sugar beet monogerm cultivars using AMMI method. J. Sugar Beet. 28(1): 29-35.

Okasha, S.A. and M.H. Mobarak, 2018. Genotype x environment interactions and stability analysis for root yield and quality traits in sugar beet (*Beta vulgaris* L.). Egypt. J. Plant Breed. 22 (3): 469– 486.

Ranji, Z., M. Mesbah, R. Amiri and S. Vahedi, 2005. Study on the efficiency of AMMI method and pattern analysis for determination of stability in sugar beet varieties. Iranian J. of Crop Sci., 7(1):1-21.

Reza, E.H., S.Y. Sadeghian, M.R. Jahadakbarand and A. Zahra, 2009. Study of adaptability and stability of sugar beet monogerm cultivars in different locations of Iran. Journal of Sugar Beet, 24:1-13.

Sanghera, G.S., K.S. Thind, , N. Singh, R.P. Singh and V. Tyagi, 2017. Genotype x environment interactions and stability analysis for root yield and quality traits in sugar beet (*Beta vulgaris* L.). Ann. Agric. Res. New Series, 38 (2) : 235-241.

Shalaby, N.M.S., I.E. El-Beiall, A.H.S. Al-Labbody and S.H.M. Abd-El-Haleem, 2008. Studies on stability of sugar beet genotypes under old and new reclaimed lands. Pakistan Journal of Biotec., 4(2):73-91.

Tai, G.C.C., 1971. Genotypic stability analysis and its application to potato regional trials. Crop.Sci. 11:184-190.

Whaley, R. and M. Eskandari, 2019. Genotypic main effect and genotype by environment interaction effect on seed protein concentration and yield in food grade soybeans (*Glycine max* L.). Euphytica, 215:33. https://doi.org/10.1007/s10681-019-2344-2.

Wricke, G., 1962. Ueber eine methode zur Erfassungder Oekolo-streubreite in feld versuchen. Z. Pflanzenzuchtg, 47: 92-96.

Wricke, G., 1964. Zur Berechung der ökovalenz bei Sommerweizen und Hafer Z F Pflanzenuchtug 52: 127-38.

Wu, G.Q., N. Liang, R.J. Feng and J.J. Zhang, 2013. Evaluation of salinity tolerance in seedlings of sugar beet (*Beta vulgaris L.*) genotypes using proline, soluble sugars and cation accumulation criteria. Acta Physiol. Plant, 5:2665–2674 doi:10. 1007/s11738- 013-1298-6.

Yan, W. and N.A. Tinker, 2006. Biplot analysis of multi-environment trial data principles and applications. Can. J. Plant Sci. 86(3):623-645.