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GENOTYPE × ENVIRONMENT INTERACTION FOR CHARACTERISTICS OF SOME SUGAR BEET GENOTYPES

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ABSTRACT

In order to study the effect of genotype × environment interaction and stability of sugar beet genotypes for seven cultivars, viz Lilly, DS 9004, Gazella, Oscar Poly, Pather, Toro and Hercule. A field trail was sown in eight environments as major four locations (Sakha, Giza, El-Fayoum and Malawy) for two years (2011/12 and 2012/13) using a randomized complete block design, with three replications. Analysis of variance for root yield, sugar yield and sugar content showed that the environment and genotype and genotype × environment interaction (GEI) were significant. GEI were evaluated by two methods (phenotypic stability and AMMI model).

According to phenotypic stability analysis results, genotype (Lilly) was the most stable for sugar content and root and sugar yield. This genotype recorded the highest root and sugar yield (30.34 and 5.22 ton/fed, respectively) across environments, and Sakha environment had the highest mean values of environments followed by El-Fayoum environment.

AMMI model explained most of the genotype × environment interaction (85.97%, 83.34 % and 86.47 %) for root yield, sugar content and, sugar yield, respectively. Lilly was the best genotype based on the biplot, and showed specific adaptation to Sakha and El-Fayoum location. The varieties Pather, Hercule and Toro were the lowest variety among the evaluated varieties and it is better not to use it in the studied areas. The genotypes Gazella, Oscar poly and DS9004 had an average genetic potential for the studied traits, but its high general adaptability, then it could be introduced for all areas. Among the locations, Sakha was the best location, and was more similar to El-Fayoum. Meanwhile, Malawy was the poorest location.

Therefore, two stability methods confirmed that Sakha and El-Fayoum are recommended as suitable regions for sowing sugar beet and Lilly variety could be suggested as the best genotype for these locations. Meanwhile, AMMI method showed new information.

Keywords: Phenotypic stability, AMMI, genotype × environment interaction, stability, sugar beet.

INTRODUCTION

Sugar beet is considered one of important winter sugar crop in Egypt. So, it is preferable to evaluate sugar beet verities under Egyptian conditions to select the best ones characterized with high yield and quality traits to improve their productivity as an urgent demand to meet sugar consumption or at least to decrease the Egyptian gap from sugar (Al-Labbody 2012).

In plant breeding programs, many potential genotypes are usually evaluated in different environments (locations and years) before selecting desirable genotypes. A genotype × Environment interaction (GEI) is the differential genotypes response evaluated under different environmental conditions. GEI is of major importance, because they provide information about the effects of different environments on cultivar performance and play a key role for assessment of performance stability of the breeding materials (Moldovan *et al.,* 2000). Stable genotypes have the same reactions with high yield or performance (Björnsson, 2002). Since analysis of the ordinary methods such as using combined variance analysis tables gives just information about the presence or absence of interactions between genotype and environment, Campbell and Kern (1982) used this analysis to study the stability of 10sugar beet. Researchers have evaluated different methods of stability and each one has suggested a method (Rostayee *et al.* 2003).

Various studies have been done in evaluating the stability of various sugar beet varieties in different areas through using the methods of parametric univariate (Ggyllenspetz 1998, Keshavarz *et al.* 2001 and Ebrahimian *et al.* 2008), regression analysis is certainly the most popular method for stability analysis due to its simplicity and the fact that its information on adaptive response is easily applicable to locations. Also using multivariate methods and AMMI model (Paul *et al.* 1993 and Ranji *et al.* 2005). The method AMMI (Additive main Effect and Multiplicative Interaction) is one of the most capable methods of stability analysis in regional trials (Crossa 1990). In this method the existence of the first 2 significant components is the best state for the evaluation of interaction of genotype and environment (Akura *et al.* 2005).

The reason for the extensive use of AMMI is that the model could justify a major part of the total deviation of interaction and differentiate the main and interactions from each other (Ebdon and Gauch 2002). The evaluation of the rank correlation coefficients among stability parameters, calculated for root yield and sugar content in sugar beet varieties, showed that the information derived from analysis of AMMI, in most cases, were more stable than other methods of stability analysis and also the new information are obtained through this method, which otherwise cannot be identified by other methods (Ranji *et al.* 2005). Considering the fact that in sugar beet, varieties with high yield, in comparison to the varieties with average yield have less stability (Ggyllenspetz 1998), evaluation of field stability of sugar beet varieties in different areas in order to find the high yielding and stable varieties, is one of the important issues in the sugar beet breeding programs.

The purpose of this investigation is to identify of the interaction of genotype × environment and determines the relative importance of two methods of stability adaptation of sugar beet genotypes under different areas.

MATERIALS AND METHODS

Seven sugar beet cultivars (Lilly, DS 9004, Gazella, Oscar Poly, Pather, Toro and Hercule) were evaluated in an experiment based on a randomized complete block design with 3 replications in two successive seasons (2011/12 and 2012/13) and four locations (Sakha research station, Giza research station, El-Fayoum and Malawy) across North and middle Egypt.

The experiment was done in different locations. Sawing dates were took place at the first week of October in the first and second season. Each plot included 4 rows with 50 cm distance and 10 m length. At harvest plants of the plots were harvested and weighed. A sample of 5-roots from each plot were randomly selected in order to determine the following characteristics: root length (cm), root diameter (cm), root weight/plant (Kg), No. of root cycles, sucrose%, total soluble solids percentage (TSS %) was determined using hand refractometer, purity% = sucrose% ×100 / TSS%, root yield (ton/fed), tops yield (ton/fed) and sugar yield (ton/fed) = root yield × sucrose %.

The recorded data were statistically analyzed according to Keshavarz *et al.* 2001). Least significant difference test at 5% level of probability was used to compare means. On the other hand, Bartlett's homogeneity test was used to satisfy the assumption of homogeneity of variances before running the combined analysis on the seven genotypes and eight environments (four locations and two years).

Data were analyzed across all locations and years using pooled data by Eberhart and Russell (1966) as ordinary or traditional method to characterize phenotypic stability, based on the regression coefficient. They indicated a stable variety as having unit regression over the environments (b_i = 1.0) and minimum deviation from the regression (σ_i = 0). Therefore a variety with a high mean yield over the environments, unit regression coefficient (b_i = 1.0) and deviation from regression as small as possible (σ_i = 0), will be a better choice as a stable variety.

For analysis of interaction of genotype × environment, the AMMI model equation according to Gauch, and Zobel, (1996). To determine genotypes stability, the first and second main components were used and in order to relate the different genotypes to the different environments the biplot diagrams were utilized (Gabriel 1971). For statistical analysis and drawing the diagrams, the statistical software of GenStat were used and for AMMI analysis.

RESULTS AND DISCUSSION

Bartlett's test indicated homogenous error variance for the traits in each of eight environments and allowed to proceed further for pooled analysis across environment. Genotype, environment variance and genotype × environment interaction were significant for all traits except total soluble solids% for genotypes (Table 1).The existence of significant difference among the varieties was the representation of the difference of genetic potentiality of the varieties for the evaluated characteristics; also, the existence of significant difference among the studied regions represents the significant variety effect in the additive structure of data for the evaluated characteristics among the regions. Similar results were reported by Ranji *et al.* (2005) and Ebrahimian *et al.* (2008).

Table (1): Combined analysis of variance of evaluated genotypes over different environments.

Source of variance	df	Root length	Root diameter	Root weight	No. of root cycles	TSS %	Sucrose %	Purity %	Root yield	Sugar yield	Foliage yield
Genotypes(G)	6	327.09**	2.65**	0.31**	6.21**	1.39	11.23**	209.64**	69.85**	3.32**	4.45**
Environments(E)	7	112.88**	9.35**	0.21**	19.82**	23.36**	8.37**	293.86**	184.66**	5.84**	84.42**
G x E	42	45.35**	6.09**	0.07*	2.02**	1.53*	1.22**	39.92*	19.10**	0.64**	16.84**
Error	112	14.11	1.08	0.04	0.85	1.03	0.63	26.21	3.67	0.17	2.64
Total	167										

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

Mean performance of genotypes for ten studied traits was shown in Table (2). Results revealed that the studied traits varied from 25.42 to 34.11 cm with an average of 31.08 cm for root length, from 9.78 to 10.91 cm with an average of 10.34 cm for root diameter, from 0.86to 1.19 Kg with an average of 1.05 for root weight, from 7.45 to 8.62 with an average of 8.19 for no. of root cycles, from 20.35 to 21.09 % with an average of 20.83% for total soluble solids %, from 77.48 to 84.77 % with an average of 81.69 % for purity %, from 6.41 to7.68 ton/fed with an average of 6.85 ton/fed for tops yield, from 25.25 to 30.34 ton/fed with an average of 26.87 ton/fed for root yield, from 15.97 to 17.72% with an average of 16.96 % for sucrose % and from 4.11 to 5.22 ton/fed with an average of 4.56 ton/fed for sugar yield. Therefore, Lilly genotype produced the highest values for root length, root weight, root yield and sugar yield.

Regarding to environments, (Table 2) showed significant effects on the studied traits, indicating a wide range of environmental effects. Giza environment had the highest mean values of environments for root length (2nd years), root diameter (both years), TSS % (both year), sugar content % and tops yield (both year). Meanwhile, El-Fayoum environment had the highest mean values of environments for root weight /plant (2nd year) and purity % (both year). Sakha environment had the highest mean values of environments for No. of root cycles (2nd year), root yield (1st year) and sugar yield (both years). The reverse trend was true for different traits and environments. In this connection, some investigators emphasized that environments had great effects on sugar beet genotypes traits (El-Hinnawy *et al*., 2002 and El-Sheikh *et al.* 2008). Therefore, Sakha environment had the highest mean values of environments for root and sugar yield followed by El-Fayoum environment.

-Phenotypic stability:-

The remarkable difference between yielding environment may indicate that the genotypes were subjected to wide range of environmental conditions under the present investigation. Significant differences among genotypes under study were observed in combined analysis of variance for stability of sugar beet yield traits (root yield, sugar content and sugar yield) (Table 3). Significance environment (linear) indicated that environments differ in their effect to different genotypes when tested with pooled deviation. Significance genotype x environment (linear) interaction and pooled deviation regression indicates that the genotypes differed in the predictable (linear) and unpredictable (non-linear) response to change in environments for yield traits.

This may lead to conclusion that it is essential to determine the degree of stability for each genotype. The obtained results are partly in agreement with those reported by Al-Assily *et al* (2002). A major portion of the genotype x environment interaction was accounted for the linear component which suggest that the difference could be due to the presence of genetic variability among the studied genotypes (some genotypes were more stable in yield performance than others over environments). On the other hand, Oscar Poly, Pather and Toro had significance genotypes for root yield and sugar yield.

Table (2):Mean performance of studied traits over different environments.

Trait	Env. code / Genotypes	Sakha 2012 Env.1	Sakha 2013 Env.2	Giza 2012 Env.3	Giza 2013 Env.4	El-Fayoum 2012 Env.5	El-Fayoum 2013 Env.6	Malawy 2012 Env.7	Malawy 2013 Env.8	Mean
root length (cm)	Lilly	31.70	28.13	38.33	39.33	32.67	33.33	35.97	33.40	34.11^{a}
	DS 9004	29.10	24.43	36.67	43.67	34.00	35.00	33.20	31.87	33.49^{a}
	Gazella	27.63	29.03	35.67	38.67	35.00	32.33	31.40	38.23	33.50^{a}
	Oscar Poly	26.37	32.67	35.67	37.00	35.00	32.00	30.73	34.33	32.97^{a}
	Pather	25.93	27.17	35.33	36.00	34.00	33.00	32.03	32.10	31.95^{a}
	Toro	26.67	25.67	25.33	22.33	29.33	30.33	24.00	25.33	26.13^{b}
	Hercule	26.00	31.00	19.33	19.00	31.00	33.00	18.33	25.67	25.42^{b}
	Mean	27.63^{c}	28.30^{c}	32.33^{a}	33.71^{a}	33.00^{a}	32.71^{a}	29.38^{bc}	31.56^{ab}	31.08
root diameter (cm)	Lilly	9.70	10.40	11.13	11.20	11.17	11.07	8.30	10.40	10.42^{ab}
	DS 9004	11.60	9.50	11.30	11.80	10.50	10.77	7.60	9.30	10.30^{ab}
	Gazella	9.70	10.30	11.10	12.90	10.93	10.30	6.63	10.20	10.26^{ab}
	Oscar Poly	11.03	10.20	10.83	12.00	9.53	9.90	7.43	11.40	10.29^{ab}
	Pather	9.93	10.80	10.93	12.13	10.47	10.13	8.43	10.53	10.42^{ab}
	Toro	8.87	10.40	12.00	8.00	10.67	10.00	11.00	7.33	9.78^{b}
	Hercule	9.10	10.03	11.00	9.67	10.33	9.50	14.00	13.67	10.91^{a}
	Mean	9.99^{b}	10.23^{b}	11.19^{a}	11.10^{a}	10.51^{ab}	10.24^{b}	9.06^{c}	10.40^{b}	10.34
root weight /plant (Kg)	Lilly	1.09	1.04	0.98	1.17	1.49	1.37	1.12	1.23	1.19^{a}
	DS 9004	0.98	1.01	1.03	1.13	1.29	1.14	1.01	0.88	1.06^{a}
	Gazella	0.96	0.87	1.22	1.10	1.48	1.31	0.96	1.00	1.11^{a}
	Oscar Poly	1.03	1.17	1.07	1.22	0.92	1.00	0.99	1.25	1.08^{a}
	Pather	1.05	0.94	1.17	1.06	1.45	1.16	1.11	1.00	1.12^{a}
	Toro	0.99	1.02	0.77	0.74	1.17	1.00	0.74	1.09	0.94^{b}
	Hercule	0.96	0.93	0.69	0.59	0.93	0.89	0.62	1.27	0.86^{b}
	Mean	1.01^{cd}	1.00^{cd}	0.99^{d}	1.00^{cd}	1.25^{a}	1.13^{b}	0.94^{d}	1.10^{bc}	1.05
no. of root cycles	Lilly	8.23	10.50	9.30	8.47	5.87	7.20	7.30	9.50	8.30^{a}
	DS 9004	9.00	10.37	8.47	8.87	6.40	7.63	7.87	9.20	8.48^{a}
	Gazella	8.67	10.50	8.80	9.33	5.97	7.63	7.77	9.87	8.57^{a}
	Oscar Poly	8.33	11.20	9.27	8.20	6.30	7.50	8.17	8.53	8.44^{a}
	Pather	8.60	10.47	9.47	8.33	7.97	6.93	8.10	9.10	8.62^{a}
	Toro	6.30	7.40	7.83	9.20	6.73	7.03	8.77	6.50	7.47^{b}
	Hercule	7.53	7.77	8.43	7.83	6.33	7.30	8.30	6.07	7.45^{b}
	Mean	8.10^{bc}	9.74^{a}	8.80^{ab}	8.60^{b}	6.51^{d}	7.32^{bc}	8.04^{bc}	8.40^{b}	8.19
total soluble solids %	Lilly	20.10	21.03	23.17	22.33	19.00	19.17	21.17	21.33	20.91^{ab}
	DS 9004	20.63	21.13	23.50	20.33	20.00	20.20	21.00	21.00	20.97^{ab}
	Gazella	20.07	20.57	22.33	21.50	18.33	18.67	20.67	20.67	20.35^{b}
	Oscar Poly	21.23	21.30	23.17	20.50	20.00	19.83	21.33	21.33	21.09^{a}
	Pather	21.13	22.27	22.17	21.33	20.00	19.30	20.67	20.00	20.86^{ab}
	Toro	20.67	20.67	23.00	22.00	19.00	20.00	22.00	18.33	20.71^{ab}
	Hercule	20.00	21.33	22.00	21.67	21.00	19.67	22.00	19.67	20.92^{ab}
	Mean	20.55^{cd}	21.19^{bc}	22.76^{a}	21.38^{b}	19.62^{e}	19.55^{e}	21.26^{bc}	20.33^{d}	20.83

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Trait	Env. code	Sakha		Giza		El-Fayoum		Malawy		Mean
	Genotypes	2012 Env.1	2013 Env.2	2012 Env.3	2013 Env.4	2012 Env.5	2013 Env.6	2012 Env.7	2013 Env.8	
Purity %	Lilly	82.28	78.72	78.56	86.40	87.36	91.50	77.05	79.14	82.63^{a}
	DS 9004	86.00	86.83	77.61	96.09	87.80	87.99	74.90	80.90	84.77^{a}
	Gazella	89.33	81.49	76.11	84.99	85.43	86.08	79.67	76.59	82.46^{a}
	Oscar Poly	84.54	81.83	76.85	91.92	82.17	85.18	79.12	80.94	82.82^{a}
	Pather	84.76	80.27	79.48	88.23	86.00	89.97	79.09	84.99	84.10^{a}
	Toro	78.40	81.98	70.04	71.41	85.84	75.31	75.75	82.11	77.60^{b}
	Hercule	79.62	79.21	74.47	76.01	79.27	82.77	70.24	78.26	77.48^{b}
	Mean	83.56^{ab}	81.48^{ab}	76.16^{c}	85.01^{ab}	84.84^{ab}	85.54^{a}	76.55^{c}	80.42^{bc}	81.69
tops yield (ton/fed)	Lilly	3.67	4.57	10.98	13.60	3.47	5.35	4.60	6.11	6.54^{b}
	DS 9004	5.37	5.32	11.86	10.50	3.49	7.18	5.78	4.24	6.72^{b}
	Gazella	5.17	5.33	10.21	11.10	3.44	7.62	5.59	4.51	6.62^{b}
	Oscar Poly	5.07	6.22	11.23	13.40	2.82	8.08	5.28	4.49	7.07^{ab}
	Pather	5.07	4.30	8.71	9.97	4.01	9.11	4.18	5.93	6.41^{b}
	Toro	9.00	8.67	3.81	4.49	4.10	10.00	5.75	9.58	6.92^{ab}
	Hercule	10.00	10.67	5.26	6.52	3.80	8.67	8.19	8.37	7.68^{a}
	Mean	6.19^{bc}	6.44^{bc}	8.87^{a}	9.94^{a}	3.59^{d}	8.00^{ab}	5.63^{c}	6.18^{bc}	6.85
root yield (ton/fed)	Lilly	34.43	31.83	29.64	28.20	31.64	34.64	24.75	27.59	30.34^{a}
	DS 9004	29.25	28.83	25.58	23.53	27.22	29.38	25.24	22.71	26.47^{b}
	Gazella	29.20	26.72	26.33	25.75	28.83	30.84	25.48	24.03	27.15^{b}
	Oscar Poly	32.07	29.87	24.15	24.21	28.59	27.83	27.17	23.53	27.18^{b}
	Pather	24.70	23.63	28.24	26.85	24.98	25.32	23.77	24.51	25.25^{c}
	Toro	33.63	30.77	25.28	19.50	31.97	29.43	17.60	22.50	26.34^{b}
	Hercule	31.60	29.62	26.72	17.97	26.22	30.65	19.53	20.84	25.39^{c}
	Mean	30.70^{a}	28.75^{ab}	26.56^{b}	23.72^{c}	28.49^{ab}	29.73^{a}	23.36^{c}	23.67^{c}	26.87
Sucrose %	Lilly	16.53	16.53	18.20	19.30	16.60	17.53	16.30	16.77	17.22^{b}
	DS 9004	17.73	18.33	18.23	19.53	17.55	17.77	15.67	16.97	17.72^{a}
	Gazella	17.93	16.77	17.00	18.27	15.64	16.07	16.43	15.77	16.73^{c}
	Oscar Poly	17.93	17.43	17.80	18.80	16.43	16.90	16.83	17.20	17.42^{ab}
	Pather	17.90	17.87	17.60	18.80	17.05	17.37	16.33	16.97	17.49^{ab}
	Toro	16.20	16.93	16.11	15.68	16.27	15.07	16.64	14.85	15.97^{d}
	Hercule	15.93	16.87	16.38	16.40	16.61	16.28	15.43	15.37	16.16^{d}
	Mean	17.17^{abc}	17.25^{abc}	17.33^{ab}	18.11^{a}	16.59^{bc}	16.71^{bc}	16.23^{c}	16.27^{c}	16.96
sugar yield (ton/fed)	Lilly	5.69	5.27	5.40	5.43	5.26	6.08	4.04	4.63	5.22^{a}
	DS 9004	5.19	5.29	4.67	4.60	4.78	5.22	3.97	3.85	4.70^{bc}
	Gazella	5.24	4.49	4.48	4.70	4.50	4.97	4.22	3.78	4.55^{cd}
	Oscar Poly	5.74	5.20	4.30	4.55	4.71	4.71	4.58	4.06	4.73^{b}
	Pather	4.43	4.22	4.98	5.05	4.25	4.40	3.88	4.16	4.42^{d}
	Toro	5.45	5.21	4.06	3.05	5.20	4.43	2.93	3.34	4.21^{e}
	Hercule	5.03	5.00	4.37	2.94	4.35	5.00	3.02	3.20	4.11^{e}
	Mean	5.25^{a}	4.95^{ab}	4.61^{bc}	4.33^{cd}	4.72^{abc}	4.97^{ab}	3.80^{d}	3.86^{d}	4.56

Table (3): Combined analysis of variance for stability of sugar beet yield traits for seven genotypes over eight environments.

Sugar yield (ton/fed)	Sugar content (%)	Root yield (ton/fed)	df	Source of variance
0.53	1.07	15.24	55	Total
1.11**	3.75**	23.28**	6	Genotypes
0.46**	0.75**	14.25**	49	Env. + (Genotypes x Env.)
13.63**	19.52**	430.87**	1	Environment (linear)
0.54**	0.70	27.88**	6	Genotype x Environment (linear)
0.14**	0.31**	2.38**	42	pooled deviation
0.12	0.45	1.23	6	Lilly
0.02	0.24	1.00	6	DS 9004
0.07	0.32	1.49	6	Gazella
0.14*	0.15	4.06**	6	Oscar Poly
0.18**	0.06	2.84*	6	Pather
0.27**	0.60*	3.81**	6	Toro
0.15*	0.22	2.24	6	Hercule
0.06	0.21	1.22	112	pooled error

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

Estimates of stability and adaptability parameters of evaluated sugar beet genotypes for sugar content and root and sugar yield at 8 environments were shown in Table (4). The mean root yield of seven sugar beet genotypes ranged from 25.25 to 30.34 ton/fed and from4.11 to 5.22 ton/fed for sugar yield. The highest yield was obtained from Lilly (30.34 and 5.22 ton/fed, respectively). It was emphasized that both linear (b_i) and non-linear (σ_{ij}) components of G × E interactions are necessary for judging the stability of a genotype. A regression coefficient (b_i) approximately 1.0 coupled with a σ_{ij} of zero indicated average stability (Eberhart and Russell, 1966). Regression values above 1.0 describe genotypes with higher sensitivity to environmental change (below average stability) and greater specificity of adaptability to high yielding environments.

Table (4):Estimates of stability and adaptability parameters of evaluated sugar beet genotypes for sugar content and root and sugar yield at 8 environments.

Sugar yield (ton/fed)			Sugar content (S %)			Root yield (ton/fed)			Genotypes
S^2_d	B_i	$\bar{x}$	S^2_d	B_i	$\bar{x}$	S^2_d	B_i	$\bar{x}$	
0.07	1.02	5.22^a	0.33	1.27	17.22^b	0.01	1.10	30.34^a	Lilly
-0.03	1.01	4.70^{bc}	0.03	1.62**	17.72^a	-0.22	0.82	26.47^b	DS 9004
0.01	0.70**	4.55^{cd}	0.11	1.28	16.73^c	0.26	0.66**	27.15^b	Gazella
0.08*	0.76	4.73^b	-0.06	1.04	17.42^{ab}	2.83**	0.81**	27.18^b	Oscar Poly
0.12**	0.19**	4.42^d	-0.15	1.12	17.49^{ab}	1.61*	-0.06**	25.25^c	Pather
0.21**	1.71**	4.21^e	0.39*	0.16**	15.97^d	2.58**	1.93**	26.34^b	Toro
0.09*	1.61**	4.11^e	0.01	0.50**	16.16^d	1.01	1.72**	25.39^c	Hercule
	1	4.56		1	16.96		1	26.87	mean
	0.26	0.14		0.33	0.21		0.19	0.58	SE

The same letters in each column, on the basis of Duncan test have no significant differences at 5% level.

A regression coefficient below1.0 provides a measurement of greater resistance to environmental change (above average stability) and this increases the specificity to adaptability to low yielding environments. Finlay and Wilkinson (1963) found that linear response is the positively associated with mean performance. Eberhart and Russel (1966) emphasized that both linear (b_i) and nonlinear (σ_{ij}) components of G × E interaction should be considered in judging the phenotypic stability of a particular genotype and their responses were independent from each other.

Linear regression for the average root and sugar yield of a single genotype on the average yield of all genotypes in each environments resulted in regression coefficient (b_i values) ranging from -0.06 to 1.93 and 0.19 to 1.71 for root and sugar yield, respectively (Table 4). This large variation in regression coefficient explains different responses of genotypes to environmental changes (Akura *et al*., 2005). The regression coefficients of Lilly for root and sugar yield was non-significant (b_i =1.0) and had a small deviation from regression (σ_{ij}) and this possessed fair stability. Genotypes with high mean yield, a regression coefficient equal to the unity (b_i =1.0) and small deviation from regression (σ_{ij} =0) are considered stable (Finlay and Wilkinson, 1963; Eberhart and Russel, 1966). Higher values of σ_{ij} explained to us that there is high senstivity to environmental changes. These varieties gave quite good yield when environmental conditions were conductive. Lilly was the most stable for the root and sugar yield. Because its regression coefficient was close to unity and they had low deviation from regression.

Among these genotypes, genotype (Lilly) could be considered the most stable ones followed by DS 9004 for sugar yield (ton/fed), but had low mean. Meanwhile, Oscar Poly and Pather could be considered the stable ones for sugar content (%) only. Other genotypes are sensitive to environmental changes and have adapted to the poor environments. The stable genotype (Lilly) should be recommended for a wide range of environments, while the genotype, which proved to be suitable for high yielding or low yielding environments, should be recommended for the respective areas.

The same seven sugar beet genotypes over eight environments (four locations and two years) were analyzed through AMMI. The results of variance analysis of the traits showed that the main effects of environment and genotype were highly significant (Table 5). The existence of highly significant difference among the genotypes was the representation of the difference of genetic potentiality of the varieties for the evaluated yield traits; also, the existence of highly significant difference among the studied environments represents the significant genotype effect in the additive structure of data for the yield traits among the environments. Similar results were reported by Ebrahimian *et al*. (2008) and Ranji *et al*. (2005). The interaction of genotype × environment was highly significant for the evaluated traits. The genotype contribution to total sum of squares for root yield, sugar content and sugar yield were 16.67%, 38.07% and 22.72% and the environment contribution were estimated to be 51.42%, 33.08%, 46.57%, respectively, and for the interaction of genotype × environment, these quantities were 31.91%, 28.85%, 30.72%, respectively. The existence of high genotype and environment share of the total sum of squares percentages is representative of the difference in the genetic potential of varieties and also the difference in the productivity potential of various environments (Aghayee Sarbarzeh *et al.* 2007).

Table (5): Analysis of AMMI of the ten studied traits for seven sugar beet genotypes over eight environments (2011/12-2012/13).

Sugar yield			Sugar content (S %)			Root yield			df	Source of variance
Ms	Explained SS%	SS	Ms	Explained SS%	SS	Ms	Explained SS%	SS		
3.32**	22.72[a]	19.94	11.24**	38.07[a]	67.41	45.70**	16.67[a]	419.10	6	Genotypes (G)
5.84**	46.57[a]	40.88	8.37**	33.08[a]	58.57	69.86**	51.42[a]	1292.40	7	Environment (E)
0.64**	30.72[a]	26.97	1.22**	28.85[a]	51.08	184.63**	31.91[a]	802.10	42	(G) x (E)
1.54**	68.34[b]	18.43	2.42**	56.81[b]	29.02	19.10**	70.51[b]	565.6	12	$IPCA_1$
0.49**	18.13[b]	4.89	1.36**	26.53[b]	13.55	47.14**	15.46[b]	124.00	10	$IPCA_2$
0.18**	13.53[b]	3.65	0.43	16.66[b]	8.51	12.40**	14.01[b]	112.40	20	Residuals
1.60**		87.78	3.22**		177.05	5.62**		2513.60	55	Total

*** and ** significant at 0.05 and 0.01 probability levels, respectively.**
[a] and [b] are the percentage of sum of squares and the sum of squares of treatment × environment Interaction, respectively.

The interaction of genotype × environment was separated into 2 main components. The first main component share of the interaction for root yield, sugar content, sugar yield, from the variance of interaction of genotype × environment were 70.51 %, 56.81 %, 68.34 % and for the second main component were 15.46%, 26.53%, 18.13%, respectively (Table 5). The explanation of high percentage of variance of interaction of genotype × environment with the first 2 components of the interaction represents this fact that these 2 components well described the significant interaction of genotype × environment, caused by the multiplicative structure of the data. Farshadfar *et al*. (2010) stated that the AMMI method is suitable for the stability analysis, paying attention to the fact that it justifies 89.30 % of genotype × environment interaction changes with the first two main components.

The first and second Interaction Principal Components Score (IPCS) for genotypes and environments has been represented in Tables 6 and 7. The comparison of means, through Duncan method, for the main effects and interaction of environment × genotype were shown in the same Table. It was found that among the studied environments, Sakha and El-Fayoum had the favorite quantities for each root yield and sugar yield (2.93 and 1.57, and 1.21 and 2.33 for 1st and 2nd season, respectively), in comparison to other areas, but Sakha and Giza had the favorite quantities for sugar content, whereas Malawy showed the weakest quantities (-2.11and -2.50,-2.73 and -1.69 and -2.88 and -3.05 for 1st and 2nd year, respectively) for the all traits. Among the varieties, Lilly had the highest quantities, for root yield and sugar yield (2.64 and 3.44, respectively); in this case Pather, Hercule and/or Toro were the most unfavorable genotypes for all traits.

Table (6): Quantities of the first and second components of interaction and means of characteristics for the evaluated genotypes (2011/12-2012/13)

Sugar yield			Sugar content (S %)			Root yield			Genotype
$IPCA_2$	$IPCA_1$	Mean	$IPCA_2$	$IPCA_1$	Mean	$IPCA_2$	$IPCA_1$	Mean	
1.11	3.44	5.22[a]	0.27	0.79	17.22[b]	2.71	2.64	30.34[a]	Lilly
0.41	0.51	4.70[bc]	1.42	2.88	17.72[a]	-0.31	-0.66	26.47[b]	DS 9004
-1.04	0.03	4.55[cd]	1.54	-1.11	16.73[c]	0.78	-0.49	27.15[b]	Gazella
0.56	0.56	4.73[b]	1.48	1.16	17.42[ab]	-0.25	-0.09	27.18[b]	Oscar Poly
-3.13	-0.08	4.42[d]	0.01	1.70	17.49[ab]	1.08	-3.20	25.25[c]	Pather
1.88	-2.17	4.21[e]	0.04	-3.34	15.97[d]	-1.94	1.65	26.34[b]	Toro
0.21	-2.28	4.11[e]	-1.92	-2.08	16.16[d]	-2.07	0.15	25.39[c]	Hercule

The same letters in each column, on the basis of Duncan test have no significant differences at 5% level.

Table (7): Quantities of the first and second components of interaction and means of traits for the evaluated environments (2011/12-2012/13).

Sugar yield			Sugar content (S %)			Root yield			Environment	
$IPCA_2$	$IPCA_1$	Mean	$IPCA_2$	$IPCA_1$	Mean	$IPCA_2$	$IPCA_1$	Mean		
-0.58	2.93	5.25[a]	0.12	0.70	17.17[abc]	-0.26	2.93	30.70[a]	E1	Sakha
-1.11	1.52	4.95[ab]	1.98	0.58	17.25[abc]	-1.05	1.57	28.75[ab]	E2	
1.40	-0.07	4.61[bc]	0.05	1.08	17.33[ab]	1.92	-0.92	26.56[b]	E3	Giza
2.09	-0.75	4.33[cd]	-0.74	3.91	18.11[a]	0.77	-2.51	23.72[c]	E4	
-0.64	0.49	4.72[abc]	1.13	-1.40	16.59[bc]	-0.01	1.21	28.49[ab]	E5	El-Fayoum
0.42	1.81	4.97[ab]	-0.78	-0.45	16.71[bc]	0.69	2.33	29.73[a]	E6	
1.21	-2.88	3.80[d]	0.13	-2.73	16.23[c]	-1.57	-2.11	23.36[c]	E7	Malawy
-0.36	-3.05	3.86[d]	-1.89	-1.69	16.27[c]	-0.49	-2.50	23.67[c]	E8	

The same letters in each column, on the basis of Duncan test have no significant differences at 5% level.

The study of root yield biplot (Figure 1) shows that the genotypes of Lilly and Pather had the highest and lowest root yield (30.70 and 25.25 t/fed), respectively. On the other hand, Lilly and Hercule had the highest and lowest sugar yield (5.22 and 4.11 t/fed). Among the areas, Sakha (Env 1 and 2) and El-Fayoum (Env 5 and 6) had the highest root and sugar yield in two years.

In biplot, it is favorable to use the 2 components having the highest variance explained (Zali *et al*. 2007).The interpretation of structure of genotype × environment interaction by using the biplot resulting from the first and second components of the interaction (using the $AMMI_2$model) was reported in various studies (Kaya *et al*. 2002 and Danyaie *et al*. 2011). The biplot of root yield, in the Figure 1, was the representative of the close relationships with the environment for 2 years of the same area of Sakha

(Env 1 and 2) and El-Fayoum (Env 5 and 6). Also, varieties Gazella, Oscar Poly and DS9004 had specific adaptation of o the area of (Env 3) Giza 1st year. On the basis of sugar content biplot (Figure 1), all areas had the close environmental relationship and most the varieties had the specific adaptation to the areas for similarity the values. The biplot of sugar content also showed that the area of Sakha (Env 1 and 2) and the area El-Fayoum (Env 5 and 6) had the highest environmental closeness and the varieties DS9004, Oscar Poly and Gazella had the specific adaptation with area of (Env 3) Giza 1st year and (Env 7 and 8) Malawy.

Considering the relative correspondence of distribution of varieties and the area vectors in the biplot resulted from root yield and sugar yield, it can be described that the trend of the rank differences of the varieties in the studied areas for the two traits are the same. In other words, in this study, sugar yield was more influenced by root yield than by sugar content (Moradi *et al*., 2012 and Ggyllenspetz 1998).

In general, considering the main effect of additivity for the varieties (mean comparison), and also evaluation of the multiplicative interaction of varieties × areas, the variety Lilly had a high genetic potential for the studied traits, but it had a less general adaptability in some areas, and because of its specific adaptability with the areas of Sakha and El-Fayoum, it is capable of being introduced to these areas. Varieties Pather, Hercule and Toro were the lowest among the evaluated varieties and it is better not to use it in the studied areas. Varieties Gazella, Oscar poly and DS9004 had an average genetic potential for the studied traits, but its high general adaptability, then it can be introduced for all areas. Therefore, the highest general adaptability belonged to the variety, which had average quantities for traits. The point that in sugar beet the varieties with average yield have higher stability of yield in the areas has been reported earlier (El-Sheikh *et al*., 2008 and Moradi *et al*., 2012).

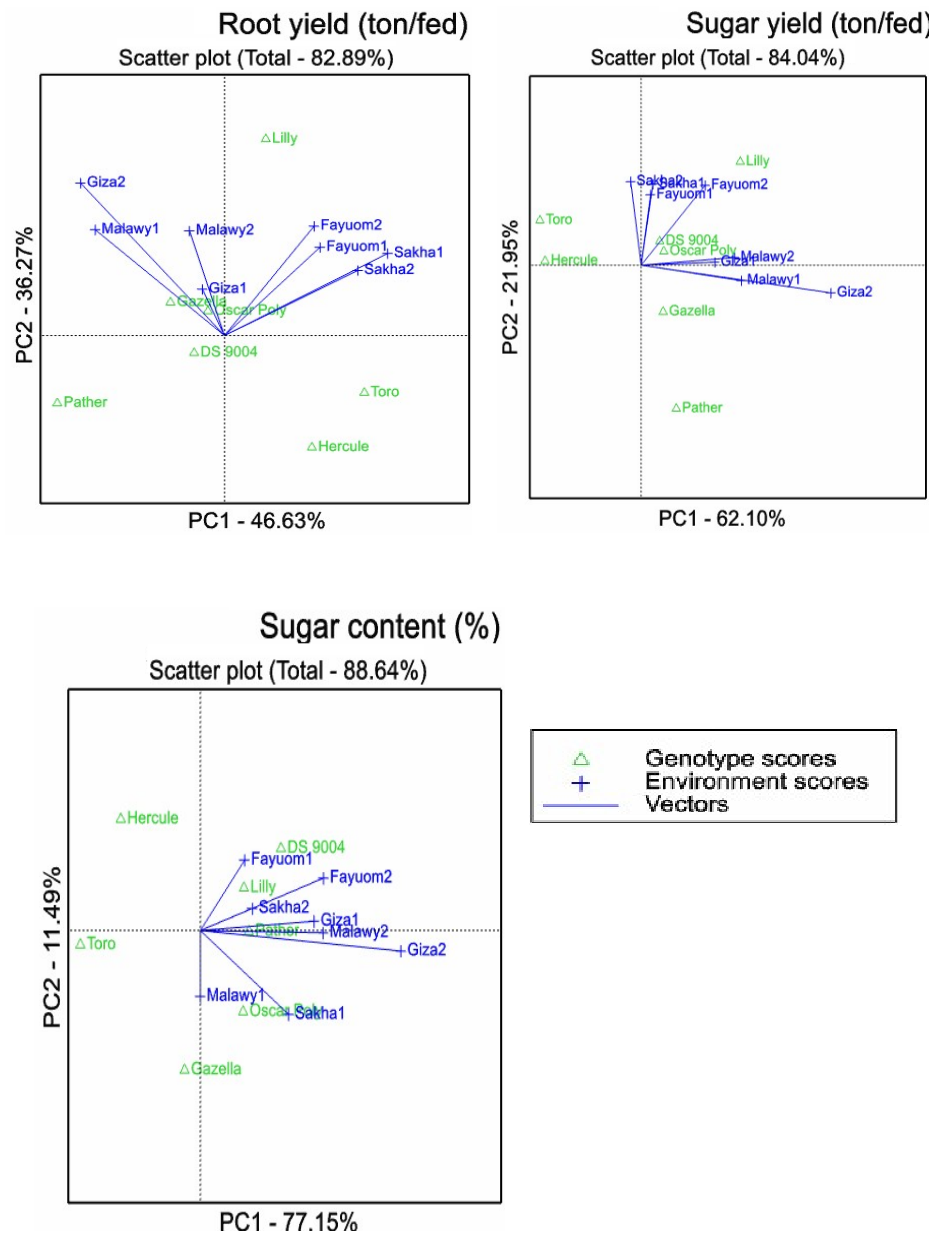

Figure (1): Bi-plot diagram of the first main components of interaction with mean genotypes and environments for the studied traits of sugar beet (2011/12-2012/13).

It could be concluded that two stability methods confirmed that Sakha and El-Fayoum are recommended as suitable places for sowing sugar beet and Lilly is suggested as the best genotype for these locations. Meanwhile, AMMI method showed new information.

REFERENCES

Aghayee-Sarbarzeh M., H. Safari, M. Rostaei, K. Nadermahmoodi, M.M. Pour Siabidi, A. Hesami, K. Solaimani, M.M. Ahmadi, and R. Mohammadi (2007). Study of general and specific adaptation in dry land advance wheat (*Triticum aestivum* L.) lines using GE biplot based on AMMI model. Pajouhesh and sazandegi. 77:41-48. (in Persian)

Akura, M., Y. Kaya and S. Taner (2005). Genotype-environment interaction and phenotypic stability analysis for grain yield of durum wheat in Central Anatolian Region. Turkish J. Agric. For., 29: 369–375

Al-Assily, Kh. A., S. R. Saleeb, S. H. Mansour and M. S. Mohamed (2002). Stability parameters for soybean genotypes as criteria for response to environmental conditions. Minufia J. Agric. Res., 27(2): 169-180.

Al-Labbody, A.H.S. (2012).Performance of some sugar beet varieties under different sowing dates. Fayoum J. Agric. Res. and Dev. 26 (1): 86 –92.

Björnsson, J., (2002). Stability Analysis Towards Understanding Genotype x Environment Interaction. Plant agriculture department of university of Guelph, Ontorio, Canada, www. genfys. slue.se/staff/deg/nova 02 (Accessed on 10 Nov 2004)

Campbell L.G., J.J. Kern (1982). Cultivar x environment interactions in sugarbeet yield trials*.Crop Sci. 22*: 932-935.

Crossa, J. (1990). Statistical analyses of multilocation trials. Advances in Agronomy. 44: 55-85.

Danyaie A., S.R. Tabaei-Aghdaei, A.A. Jafari, M. Matinizadeh, and A. Mousavi (2011). Additive main effect and multiplicative interaction analysis of flower yield in various Rosa damascena Mill. genotypes across * environments in Iran. J. of Food, Agric. & Env.. 9(2): 464-468.

Ebdon J.S., and H.G. Gauch (2002). Additive main effect and multiplicative interaction analysis of natural turf grass performance trials. Crop Sci. 42: 497-506.

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. Journal of Sugar Beet. 24(2): 1-13.

El-Hinnawy, H.H., E.A. Mahmoud, B.S.H. Ramadan, M.A. Farag and E.M. Al-Jbawi (2002). Phenotypic stability for some sugar beet genotypes. Proceedings of the 2nd Congress on Recent Technologies in Agriculture, Fac. of Agric., Cairo Univ., 28-30 Oct., Vol.4:1051-1058.

El-Sheikh S. R. E.,S. A.A. Enan and Maha M. El-Zeni (2008). Stability analysis of some sugar beet varieties under different environment conditions. Egypt J. of Appl. Sci. 23 (11):102-121.

Farshadfar M., F. Moradi, A. Mohebi, and H. Safari (2010). Investigation of yield stability of 18 agropyron elongatum genotypes in stress and non-stress environments, using AMMI model. Iranian J. of Rang lands and Forests Plant Breeding and Genetic Research. 18(1):45-54.

Finlay, K.W. and G.N. Wilkinson (1963). The analysis of adaptation in a plant-breeding programme. Australian J. Agric. Res., 14: 742–754.

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

Ggyllenspetz U. (1998). Genotype × environment interaction and stability of diploid and triploid sugar beet (Beta vulgaris L.) varieties. Sveriges Lantbruksuniv, Uppsala (Sweden). pp19.

Gauch, H. G. and R. W. Zobel (1996). AMMI analysis of yield trials. Pages 1–40 *in* M. S. Kang and H. G. Gauch, eds. Genotype by environment interaction. CRC Press, Boca Raton, FL.

Kaya Y., C. Palta, and S. Taner (2002). Additive main effects and multiplicative interactions analysis of yield performances in bread wheat genotypes across environments. Turk J. Agric. 26: 275-279.

Keshavarz S., M. Mesbah, Z. Ranji, R. Amiri (2001). Study on stability parameters for determining the adaptation of sugar beet commercial varieties in different areas of IRAN. J. of Sugar Beet. 17(1): 15-36.

Moldovan,V., M. Moldovan and R. Kadar (2000). Item from Romania. SCA Agricultural Res. Stat. Turda, 3350 Str. Agriculturii 27. Jud. Chuj.

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

Paul H., F.A. Van Eeuwijk, and W. Heijbroek, (1993). Multiplicative models for cultivar by location interaction in testing sugar beets for resistance to beet necrotic yellow vein virus. Euphytica. 71: 63-74.

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 Journal of crop sciences. 7(1): 1-21.

Rostaee M., D. Sadeghzadeh Ahari, A. Hesami, K. Soleimani, H. Pashahpoure, K. Nader Mahmodi, Porsiabidi M.M. Ahmadi, M. Hasanpor Hasani, and A. Abedi Asel (2003). Study of adaptability and stability of grain yield of bread wheat in cold and moderate – cold dry land areas. 19(2):263-280.

Zali H., S.H. Sbaghpour, P. Pezeshkpor, M. Safikhani, R. Sarparast, and A. Hashembaigi (2007). Stability Analysis of Yield in Chickpea Genotypes using Additive Main effects and multiplicative interaction effects (AMMI). J. of Sci. and Tech. of Agriculture and Natural Resources. 11(42):173-180.

تـأثير تفاعل التركيب الـوراثى × البيئـة علـى صـفات المحصـول لـبعض التراكيـب الوراثية لبنجر السكر

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من أجل دراسة تأثير التفاعل بين التركيب الوراثي × البيئة و ثبات التراكيب الوراثية لسبعة أصناف من بنجر السكر ، ، منها الصنف المنزرع Lilly ، DS9004، Gazella ، Oscar Poly ، Pather ، Toro و Hercule في ثمانية بيئات كأربعة مواقع رئيسية (سخا ، الجيزة ، الفيوم و ملوى) لمدة عامين (٢٠١٢-٢٠١٣) باستخدام تصميم قطاعات كاملة العشوائية ، فى ثلاث مكررات. أظهر تحليل التباين لصفات محصول الجذر، السكر و محتوى السكر أن التأثيرات الرئيسية للتفاعل بين التركيب الوراثي × البيئة معنوية. وقد تم تقدير هذا التفاعل بطريقتين هما (الثبات المظهرى ونموذج AMMI).

وفقا لنتائج التحليل المظهري للثبات ، كان الصنف المنزرع (Lilly) أكثر ثباتا لمحصول الجذر والسكر يليه الصنف DS9004. حيث سجل هذا الصنف(Lilly) أعلى القيم المتحصل عليها لصفات محصول الجذر والسكر من هذا الصنف (٣٠.٣٤ و ٥.٢٢ طن / فدان) على التوالى ، وسجلت بيئة سخا أعلى القيم بين مختلف البيئات لمحصول الجذر و السكر تليها بيئة الفيوم.

أوضح نموذج AMMI أن التفاعل بين التركيب الوراثي × البيئة قد سجل (٨٥.٩٧ ٪ ، ٨٣.٣٤ ٪ و ٨٦.٤٧ ٪) لمحصول الجذر، و محتوى السكر ، ومحصول السكر على التوالي. وكان الصنف (Lilly) أفضل تركيب وراثى على أساس biplot ، ولكن كان أقل تكيفاً للبيئات و أظهر تكيفاً محدوداً لبيئتى سخا و الفيوم. وكانت أصناف Pather ، Hercule و Toro أقل الأصناف تكيفا بين الأصناف المدروسة و من الأفضل عدم استخدامها في المناطق التي شملتها الدراسة.أما الأصناف Gazella ، Oscar poly و DS9004 كانت متوسطة بالنسبة للصفات المدروسة ، ولكن ذات قدرة عالية على التكيف ، ومن ثم يمكن زراعتها بجميع البيئات المدروسة . أما البيئات.. فكانت بيئة سخا أفضل البيئات ، و كانت الفيوم أكثر البيئات قربا لها . بينما كانت بيئة ملوي أفقر البيئات.

لذا... أكدت طريقتى تحليل الثبات أن أكثر البيئات المناسبة لزراعة بنجر السكر سخا و الفيوم على النحو الموصى به، كما يعتبر الصنف (Lilly) كأفضل التراكيب الوراثية لهذه البيئات. فى حين أن طريقة AMMI تمدنا بمعلومات أكثر.