Egypt. J. Plant Breed. 28(1):155– 165(2024)

HETEROSIS IN SUGAR BEET FOR SOME ROOT TRAITS

K.E.M. Bayomi
Plant Breeding Unit, Genetic Resources Dept., DRC, Cairo, Egypt.
khmegahed@yahoo.com, khaled.megahed75@gmail

ABSTRACT

Hybrid production under Egyptian conditions comes in the first order for Plant Breeding and Conservation Program of Desert Research Center (DRC). A Line × Tester design was used to evaluate heterosis for growth, yield, and quality traits. Three parents (monogerm) with one taster (multigerm) and three hybrids of sugar beet were evaluated during season 2023-2024 at Kafer El-Sheikh governorate. The experimental design was randomized complete block design with three replicates. The results indicated existence of significant differences for most studied traits of sugar beet genotypes. P_3 and P_4 were the best in most of traits. Heterosis was present for root yield and quality traits of hybrids. $P_3 \times P_4$ expressed highly significant and positive heterosis to mid parent for root length and root diameter (7.62 and 3.62%, respectively). $P_2 \times P_4$ expressed highly significant and positive heterosis to mid parent for sucrose percentage (3.19%). Heritability in broad-sense was high for all studied traits, except sucrose percentage was moderate.

Key words: ***Beta vulgaris L., Genetic parameters, Heritability, Quality traits.***

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is resulted from the plant breeding effort, and is one of the few crops that did not exist in the ancient times as the age of sugar beet in the world is only about 200 years. The sugar beet grew up in Europe by selection of plants that had higher sucrose content from strains of fodder beet (Poehlman1979).

Today, sugar beet represents about 45% of the total sugar produced in the world, and is considered the main source of sugar in Europe. Sugar is one of the most important strategic commodities in Egypt, and sugar beet is the first source for the production of sugar in the country before the sugar cane. (Report of the Board of Sugar Crops; January 2023).

Line × Tester technique is an important tool to calculate both specific and general combining ability (GCA and SCA) and to estimate gene actions in both parents. It is an efficient technique for evaluation of inbred or pure lines. This technique also helps the breeder to isolate the segregating genotypes and to select best genotypes for hybridization procedures (Kempthorne, 1957). Ghura (1995) evaluated some sugar beet monogerm lines and estimated the general and specific combining ability. She found that significant heterosis for root yield and sugar yield. Stancic (1995) studied the heterosis in root yield, sugar content and yield of polarized sugar in triploid hybrids. He revealed that crosses involving multigerm pollinators and CMS line 51-60 were the best. Ghura *et al*. (1997) studied broad and narrow sense heritability for some characters of sugar beet and found that high values of narrow sense

heritability were obtained for total soluble solids percent (T.S.S.%) and root diameter, which were suggested to be controlled by additive gene effects, while moderate narrow sense heritability was estimated for root length, root weight and T.S.S.%, and it was influenced by the effect of non-additive genes. Ahmadi and Assad (1998) estimating genetic parameters of agronomic and quality traits in a diallel cross of sugar beet and found that mean squares of GCA were significant for all traits. However, SCA mean squares were significant only for root yield, sugar percentage, impure sugar yield, recoverable sugar yield and white sugar yield. A significant ratio of GCA/SCA mean squares for sugar percentage indicated that additive variance was most important in determining this trait. Broad-sense heritability values ranged from 0.38 for white sugar yield to 0.73 for potassium percentage. Ogata *et al*. (2003) found that narrow sense heritability value of root weight was 42.0%. On the other hand, narrow sense heritability for sugar content and K were 92.1% and 90.4%, respectively. Ghura (2006) studied characters of five sugar beet crosses. She found that, narrow sense estimate for total soluble solids was proven to be very high for the two crosses Sp22-o× C46/2 and Sp22-o× C39, since they recorded 99%. Kikindonov (2011) found that all the tested semi-sugar beet hybrids have positive values of the heterosis effect. Bayomi (2013) carried out a study on natural flowering and seed production of sugar beet and found that the mean squares of seven genotypes were significant for seed characters and root characters in both seasons. Line FC723cms recorded the highest sucrose % (17.07% and 18.60%) in two locations. Three crosses for root length showed positive and highly significant heterosis over the mid-parents and the better parent. All the crosses for root diameter and root weight showed positive and significant or highly significant heterosis over the mid-parents. Only, one cross for total soluble solids percentage showed positive and significant or highly significant heterosis over the mid-parent and the better parent. Only, one cross for alpha-amino nitrogen showed negative and significant heterosis over the mid-parents. He found that heritability estimates in broad sense were moderate for all studied traits and heritability estimates in narrow sense were low for some traits. The objective of this

study was the evaluation of seven genotypes of sugar beet (4 parents + 3 hybrids) for some root and quality traits.

MATERIALS AND METHODS

The trial was set up during two seasons. The first (2022/2023) for hybrids production to four genotypes of sugar beet was carried out at garden local community in protected Saint Catherine of South Sinai. The second (2023/2024) to evaluated seven genotypes of sugar beet (4 parents + 3 hybrids) was carried out at Kafer El-Sheikh governorate.

Sugar beet genotypes obtained from plant breeding and conservation program of Desert Research Center (DRC) were three monogerm (SKC59-5/3/3, SKH43-5/1/3 and FC723-6/1/3) and one multigerm (SKT48-5/3/3). Three single crosses were made under St. Catherine condition by using three monogerm genotypes as females, namely SKC59-5/3/3(P_1), SKH43-5/1/3(P_2) and FC723-6/1/3(P_3), while the multigerm genotype SKT48-5/3/3(P_4) was used as tester.

Sugar beet genotypes (4 parents + 3 hybrids) were planted in a randomized complete blocks design with three replications. Each replicate contained 7 experimental plots. Plot area was 7.5 m^2 including 3 rows (5 m long and 50 cm wide) and 20 cm between plants. Seed drilling was done in the 15th of September 2023 in Kafer El-Sheikh location. Normal agricultural treatments were applied. Harvesting was occurred after 210 days (15th of April 2024). Data of root characters (Root length (cm), Root diameter (cm) and Root weight (g)) and quality characters (Sucrose %, Potassium, Sodium, Alpha Amino nitrogen and Purity%) were recorded on five randomly selected plants from each plot. Sucrose percentage was determined using Saccharimeter on a lead acetate basis according to the procedure of Delta Sugar Company (Le-Docte, 1927). Potassium and sodium were determined using Flame photometer according to Brown and Lilliand (1964). Alpha-amino nitrogen was determined according to Pergl (1945). Purity % was calculated according to the following equation: Purity% = Sucrose%/T.S.S.% x 100. Analysis of variance was done according to Cochran and Cox (1957). The treatment means were compared using least significant difference test at 5% and 1% levels of significance

(Steel and Torrie, 1980). The phenotypic and genotypic coefficients of variation were estimated by using the formulae developed by Burton (1952). Heritability estimates were obtained as described by Burton and Devan (1953). Heterosis was expressed as the percentage deviation of the F_1 hybrids mean ($\overline{F_1}$) from the average of the two parents (M.P.) and better parent (B.P.) as heterobettiosis (Sinha and Khanna1975).

RESULTS AND DISCUSSION

Mean performance

The results presented in Table (1) indicate that, average root length was 35.7 cm. Parent P_3 gave the highest value of root length (41.5cm). While, Parent P_2 was record the lowest value of root length (28.8cm). The average root diameter was 13.0 cm. Parent P_4 gave the highest value of root diameter (13.9cm). However, Parent P_2 was record the lowest value of root diameter (10.8cm). The average root weight was 1801.2g. Parent P_4 gave the highest value of root weight (2017.0g). While, Parent P_2 was record the lowest value of root weight (1047.8g).

Table 1. Mean performance for some root and quality traits of seven (4 parents + 3 hybrids) sugar beet genotypes under Kafer El-Sheikh conditions, season 2023/2024.

Genotypes	Root length (cm)	Root diameter (cm)	Root weight (g)	Sucrose %	Potassium	Sodium	Alpha Amino Nitrogen	Purity %
P_1	32.3	12.5	1587.9	14.4	6.3	2.7	3.5	74.3
P_2	28.8	10.8	1047.8	14.4	6.0	3.0	5.3	73.1
P_3	41.5	13.7	1779.5	15.1	6.9	2.7	3.9	73.7
P_4	38.2	13.9	2017.0	16.1	6.2	2.8	2.7	77.4
$P_1 \times P_4$	34.1	14.0	2219.0	15.7	6.0	2.7	3.6	76.8
$P_2 \times P_4$	32.1	12.0	1617.3	15.8	6.4	3.1	3.6	76.0
$P_3 \times P_4$	42.9	14.3	2339.7	15.6	6.2	3.1	2.7	76.3
Mean	35.7	13.04	1801.2	15.3	6.3	2.9	3.6	75.4
LSD 0.05	3.68	1.26	193.97	1.18	0.36	0.31	0.43	2.72
LSD 0.01	5.16	1.77	271.94	1.66	0.50	0.43	0.59	3.82

Concerning the crosses, the highest of root length, root diameter and root weight were detected for the cross $P_3 \times P_4$ (42.9, 14.3cm and 2339.7g, respectively). However, the lowest of root length, root diameter and root weight were recorded for the cross $P_2 \times P_4$ (32.1, 12.0cm and 1617.3g respectively).The average sucrose percentage was 15.3%. Parent P_4 gave the highest value of sucrose percentage (16.1%). While, P_1 and P_2 were record the lowest value of sucrose percentage (14.4%). Concerning the crosses, the highest of sucrose percentage was detected for the cross $P_2 \times P_4$ (15.8%). While, the cross $P_3 \times P_4$ was record the lowest value of sucrose percentage (15.6%). The average potassium was (6.3). Parent P_2 gave the lowest value of potassium (6.0). While, parent P_3 was record the highest value of potassium (6.9). Concerning the crosses, the lowest of potassium was detected for the cross $P_1 \times P_4$ (6.0). While, the cross $P_2 \times P_4$ was record the highest value of potassium (6.4). The average sodium was (2.9). Parent P_1 and P_3 were recorded the lowest value of sodium (2.7). While, parent P_2 was record the highest value of sodium (3.0). Concerning the crosses, the lowest of sodium was detected for the cross $P_1 \times P_4$ (2.7). While, the cross $P_2 \times P_4$ and $P_3 \times P_4$ were record the highest value of sodium (3.1). The average alpha amino nitrogen was (3.6). Parent P_4 was record the lowest value of alpha amino nitrogen (2.7). While, parent P_2 was record the highest value of alpha amino nitrogen (5.3). Concerning the crosses, the lowest of alpha amino nitrogen was detected for the cross $P_3 \times P_4$ (2.7). While, the cross $P_1 \times P_4$ and $P_2 \times P_4$ were record the highest value of alpha amino nitrogen (3.6). The average purity percentage was 75.4%. Parent P_4 gave the highest value of purity percentage (77.4%). While, P_2 was record the lowest value of purity percentage (73.1%). Concerning the crosses, the highest of purity percentage was detected for the cross $P_1 \times P_4$ (76.8%). While, the cross $P_3 \times P_4$ was record the lowest value of purity percentage (76.3%). In general, P_3, P_4 and cross between them ($P_3 \times P_4$) were the best in most of traits. The genetic differences in most traits among sugar beet genotypes have been reported by El-Manhaly *et al* (1987), Abd Alla (1992), Younan *et al* (1997), Al-Jbawi (2000) EL-Sheikh (2003),Curcic *et al* (2010) Bayomi (2013), Bayomi (2018) and Bayomi *et al* (2022).

Heterosis

Table (2) shows heterosis and heterobettiosis for root traits i.e., root length, root diameter and root weight as well as quality traits i.e., sucrose percentage, potassium, sodium, alpha amino nitrogen and purity percentage.

Table 2. Heterosis (M.P.) and heterobettiosis (B.P.) for some root and quality traits of seven (4 parents + 3 hybrids) sugar beet genotypes under Kafer El-Sheikh conditions, season 2023/2024.

Cross	Root length (cm)		Root diameter (cm)		Root weight (g)		Sucrose%	
	H.(M.P.)%	H.(B.P.)%	H.(M.P.)%	H.(B.P.)%	H.(M.P.)%	H.(B.P.)%	H.(M.P.)%	H.(B.P.)%
$P_1 \times P_4$	-3.26*	-10.73**	5.67**	0.48	23.11	10.01	2.64**	-2.69**
$P_2 \times P_4$	-4.08**	-15.88**	-2.69**	-13.43**	5.54	-19.82	3.19**	-2.11**
$P_3 \times P_4$	7.62**	3.29	3.62**	2.88**	23.25	15.99	0.32	-2.89**
Cross	**Potassium**		**Sodium**		**Alpha Amino Nitrogen**		**Purity%**	
	H.(M.P.)%	H.(B.P.)%	H.(M.P.)%	H.(B.P.)%	H.(M.P.)%	H.(B.P.)%	H.(M.P.)%	H.(B.P.)%
$P_1 \times P_4$	-4.17**	-4.49**	0.67**	-2.26**	17.75**	3.91**	1.16	-0.84
$P_2 \times P_4$	4.13**	3.01**	8.26**	4.89**	-10.70**	-32.83**	1.04	-1.79
$P_3 \times P_4$	-5.85**	-10.58**	11.25**	8.93**	-16.69**	-29.92**	0.91	-1.49

*** and **: indicate significant at 0.05 and 0.01, respectively.**

Data presented in table 2 show $P_3 \times P_4$ cross expressed highly significant and positive heterosis effect for root length (7.62%). Also, $P_3 \times P_4$ cross exhibited positive heterobettiosis. The cross $P_3 \times P_4$ expressed highly significant and positive heterosis and heterobettiosis for root diameter (3.62 and 2.88%, respectively). All crosses expressed positive heterosis effects for root weight. The crosses $P_1 \times P_4$ and $P_2 \times P_4$

expressed highly significant and positive heterosis effects for sucrose percentage. The crosses $P_1 \times P_4$ and $P_3 \times P_4$ expressed highly significant and negative heterosis effects and heterobettiosis for potassium. The cross $P_1 \times P_4$ exhibited highly significant and negative heterobettiosis for sodium. The crosses $P_2 \times P_4$ and $P_3 \times P_4$ expressed highly significant and negative heterosis effects and heterobettiosis for alpha amino nitrogen. All crosses expressed positive heterosis effects for purity percentage. In general, the cross P3 × P4 was the best for root length, root diameter, potassium and alpha amino nitrogen. These results are in conformity with those of Ghura (1995), Stancic (1995), Kikindonov (2011) and Bayomi (2013).

Genetic parameters

Estimates of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), phenotypic variance (σ^2p), genotypic variance (σ^2g), environmental variance (σ^2e) and heritability in broad-sense (H^2) are show in Table (3).

Table 3. Genetic parameters for some root and quality traits of seven (4 parents + 3 hybrids) sugar beet genotypes under Kafer El-Sheikh conditions, season 2023/2024.

Parameters	Root length (cm)	Root diameter (cm)	Root weight (g)	Sucrose %	Potassium	Sodium	Alpha Amino Nitrogen	Purity %
σ^2 e	1.43	0.17	3961.94	0.148	0.014	0.01	0.016	0.78
σ^2 g	26.13	1.46	189123.9	0.306	0.071	0.03	0.709	1.96
σ^2 ph	27.55	1.63	193085.9	0.454	0.084	0.04	0.725	2.74
G.C.V. %	14.32	9.26	24.14	3.61	4.234	5.89	23.38	1.86
P.C.V.%	14.71	9.78	24.39	4.41	4.618	6.84	23.63	2.19
H^2 (b.s.) %	94.8	89.7	97.9	67.5	84.1	74.5	97.8	71.5

The estimates σ^2p was high for all traits. The σ^2g estimates were found greater than the σ^2e estimates for all traits. The higher proportion of σ^2p observed on all traits was due to the larger proportion of σ^2g. The

PCV and GCV were convergent for all the traits. Heritability in broad-sense (H^2) estimates was high for all traits, except sucrose percentage was moderate. This finding in agreement with this reported by Ghura *et al* (1997), Ahmadi and Assad (1998), Ogata *et al* (2003), Ghura (2006), Mohsen *et al* (2011) and Bayomi (2013).

CONCLUSION

This study is an important step for Plant Breeding and Conservation Program of Desert Research Center to identify the best genotypes for hybrids production in future and suitable for agriculture under Egyptian conditions. P_3 and P_4 were the best in most of traits. The cross P3 × P4 was the best for root length, root diameter, potassium and alpha amino nitrogen. The crosses $P_1 \times P_4$ and $P_2 \times P_4$ expressed highly significant and positive heterosis effects for sucrose percentage. Heritability in broad-sense (H^2) was high for all traits, except sucrose percentage was moderate.

REFERENCES

Abd Alla, H. A. (1992). Studies on some factors affecting the productivity of sugar beet. M.Sc. Thesis, Fac. Agri., El-Minufiya Univ., Egypt.

AI-Jbawi, M. Entessar (2000). Performance of some sugar beet genotypes under different conditions. M.Sc. Thesis. Fac. Agric., Cairo Univ., Egypt.

Ahmadi, M. and M. T. Assad (1998). Estimating genetic parameters of agronomic and quality traits in a diallel cross of sugar beet. Iran Agricultural Research.17: 1, 19-34. 13.

Bayomi, K.E.M. (2013). Studies on sugar beet breeding and seed production under Saint Catherine area condition of South Sinai. Ph. D. Thesis, Fac. of Agric. AL-Azhar Univ. Cairo, Egypt.

Bayomi, K.E.M. (2018). Response of three sugar beet genotypes for flowering and seed production in different locations in Saint Catherine. Egypt. J. Plant Breed. 22(6):1281– 1292.

Bayomi, K.E.M., E.F. El-Hashash, Nabawya S. A. Ghura and Karima M. El-Absy (2022). Genotype by environment interaction effects on the crop of sugar beet (*Beta vulgaris* L.) using multivariate analysis. Asian Journal of Research in Crop Science. 7(4): 135-149.

Brown, J. D. and O. Lilliand (1964). Rapid determination of potassium and sodium in plant material and soil extracts by Flam photometry. Proc. Amer. Soc. Hort. Sci.,48:341-346.

Burton, G.W. (1952). Quantitative inheritance in grasses.Proc. 6th Int. GrassCongr. 1:277-283.

Burton, G.W. and E.H. Devan (1953). Estimating heritability in tall fescuse (*Festuca arundinacea*) from replicated clonal material. Agron.J. 45: 478-481.

Cochran, W. C. and G. M. Cox (1957). Experimental design. 2nd ed., John Willey and Sons, New York, USA.

Curcic, Z., D. Danojevic and N. Nagl (2010). Combining abilities and mode of inheritance for some root characteristics in sugar beet. Ratarstvo i Povrtarstvo. 47: 1, 239-244. 13.

El- Manhaly, M. A., Nabila Z. Younan and M. A. Farag (1987). Sugar beet flowering and seed production in Egypt. Com.In.Sci.Dev.Res.,19:45-61.

EL-Sheikh, S. R. (2003). Studies on sugar beet breeding under Egyptian conditions, Ph. D. Thesis , Fac. Of Agric. Univ. of EL-Azhar, Cairo, Egypt.

Ghura, Nabwya S.A. (1995). Studies on sugar beet. Evaluation of sugar beet monogerm lines and estimation of general and specific combining ability. Ph.D. Thesis, Faculty of Agriculture University of Alexandria Egypt.

Ghura, Nabwya S.A. (2006). Study of gene action and genetic parameters for some quantitative characters in five crosses of sugar beet (*Beta vulgaris* L.). Alex. Sci. Exch. Jour.27, 3:282-291.

Ghura, Nabwya S.A., Nabila Z.Younan and M.A. El-Manhaly (1997). Broad and narrow sense heritability of some characters of sugar beet .Adv.Agric.Res. 2, 1: 91-101.

Kempthorne, O. (1957). An Introduction to Genetic Statistics. John Wiley and Sons Inc., New York. pp: 208-223.

Kikindonov, G. (2011). Heterosis effect in semi-sugar beet hybrids. J. of mountain Agric. on the Balkans. 14(2):284-295.

Le-Docte, A. (1927). Commercial determination of sugar beet root. Le-Docte process. Int. Sug. J. 29:488-492. (C. F. Sugar Beet Nutrition.1972. Appl. Sci. Pub. LTD., London, A. P. Draycott).

Mohsen, N., K. Mostafavi, S. H. Shojaei, E. Fayyaz and A. Shahbazi (2011). Diallel Cross Analysis in Sugar Beet (*Beta vulgaris* L.): Identification of the Best Parents and Hybrids for Resistance to Bolting and Cercospora Leaf Spot in Sugar Beet Monogerm O-type Lines. American Journal of Experimental Agriculture, 1(4): 214-225.

Ogata, N., K. Taguchi and M. Tanaka (2003). Half diallel analysis for yield components and top traits in self fertilized 0-types of sugar beet. Session Genetics and Germplasm Enhancement, 1st joint 1/RB-ASSBT Congress, 26h Feb.-1st March 2003. San Antonio (USA).

Pergl, F.(1945). Quantitative organic micro analysis. 4th. Ed. J. and Churchill LTP London.

Poehlman, J. M. (1979). Breeding sugar beet. In: Breeding field crops. West port, Connecticut. U.S.A. p.p. 383-405.

Sinha, S.K. and R. Khanna (1975). Physiological, biochemical and genetic basis of heterosis. Adv. Agron. 27: 123-174.

Stancic, I. (1995). The influence of polyploidy and monogermity of parental genotypes on productivity of F_1 generation hybrids in sugar beet. Review of Research Work at the Faculty of Agriculture, Belgrade.40: 2, 43-50. 5.

Steel, R.G.D. and J. H. Torrie (1980). Principles and procedures of statistics. 2nd edition. McGraw Hill Book Company Inc., New York.

Younan, N. Z., N. M. EL.Talkhawy, Y. H. Tawfic and M. H. El-Deeb (1997). Flowering and seed characters of five sugar beet genotypes under the Egyptian agricultural conditions .Menofiya J.Agric.Res., 22 , 1: 181-190.

قوة الهجين فى بنجر السكر لبعض صفات الجذر

خالد السيد مجاهد بيومى

وحدة تربية النبات – قسم الأصول الوراثية – مركز بحوث الصحراء

يعتبرإنتاج الهجن من بنجر السكر تحت الظروف المصرية في المرتبة الأولى لبرنامج تربية وصون النباتات بمركز بحوث الصحراء. إستخدم تحليل السلالة ×الكشاف كمعيار لتقييم قوة الهجين لصفات النمو والمحصول والجودة. تم تقييم 3 تراكيب وراثية (وحيدة الأجنة) وتركيب وراثى كشاف (عديد الأجنة) وثلاث هجن ناتجة من التزاوج بينهم تحت ظروف محافظة كفر الشيخ خلال موسم النمو 2024/2023. التصميم الاحصائي المستخدم هو القطاعات الكاملة العشوائية مع إستخدام ثلاث مكررات. أشارت النتائج إلى وجود إختلافات معنوية بين التراكيب الوراثية لمعظم الصفات، واستنادًا إلى النتائج المتحصل عليها، الأبوين الثالث والرابع كانوا الافضل لمعظم الصفات. أبدى الهجين $P_3 \times P_4$ قوة هجين موجبة ومعنوية لمتوسط الأبوين لصفتى طول الجذر وقطر الجذر(7.62 – 3.62% على التوالى).أبدى الهجين $P_2 \times P_4$ قوة هجين موجبة ومعنوية لمتوسط الأبوين لصفة نسبة السكروز (3.19%). كانت كفاءة التوريث بالمعنى العام عالية لمعظم الصفات فيما عدا نسبة السكروز فكانت متوسطة.