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Heterosis and Combining Ability for Development of Squash Hybrids (*Cucurbita pepo* L.)

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ABSTRACT

The aim of this study is to evaluate a set of inbred lines and their hybrids and to determinate the phenotypic and genotypic parameters. In addition, identify the heterosis and combining ability for the studied traits in order to determine the best combinations and the ideal improvement strategy for hybrid production in squash. The experimental study was conducted at El-Baramoon Research Station, Horticulture Research Institute during the two summer season of 2016 and 2017. Six inbred lines selected from Eskandrani cultivar and fifteen F_1 hybrids were evaluated for different traits. Significant differences were observed among the hybrids and their parents for all studied traits. Based on mid-parent heterosis, the hybrid (P_5 x P_6) gave the highest value for early yield per plant (98.51 %) followed by the hybrid (P_1 x P_4) (90.24%) for the same trait. While heterosis over better parent, the hybrid (P_1 x P_6) gave the highest value for early yield per plant (78.95 %) followed by the hybrid (P_5 x P_6) (73.91 %) for the same trait. Furthermore, the highest mid-parent hertrosis for total yield per plant was obtained by the hybrid P_4 x P_6 (75.0%) followed by P_5 x P_6 (60.38%) and P_4 x P_5 (59.65%). Otherwise, the largest heterosis over better parent for total yield per plant were expressed by P_4 x P_6 (61.77%) followed by P_4 x P_5 (46.77%) and P_5 x P_6 (37.10%), respectively. General combining ability (GCA) was significant or highly significant for all traits except for early yield per plant and shape index, specific combining ability was highly significant for all traits except for number of node female flower and early yield per plant. The estimated GCA/SCA mean squares revealed that the additive gene effects were the major effect in the inheritance of all studied traits, except for early yield per plant and vitamin C. Also, GCA estimates were larger than their corresponding estimates of SCA for most of the studied traits. The result illustrated that both additive and non-additive gene actions were positive for all studied traits. Heritability in broad sense ranged from 72.95 to 99.46 % for number of node female flower and total soluble solids, respectively. Also, heritability in narrow sense ranged from 28.49 to 81.94 % for number of leaves per plant and fruit shape index. The parent P_1, P_2 and P_3 could be recommended as good combiners for average fruit weight, vitamin C, number of fruits per plant and total yield per plant whereas the P_5 and P_6 as promising parents for plant height, leaf area, number of leaves per plant , days to anthesis of female flowers, number of node of female flower and total soluble solids.

Keywords: *Summer squash, Cucurbita pepo, herterosis , combining ability, heritability, gene action.*

INTRODUCTION

Summer squash (*Cucurbita pepo* L.), (2n= 40), is a warm season crop belongs to family Cucurbitaceae. Commercial development of squash hybrids have been increasing owing to the superior of hybrids due to the expression of heterosis for vegetative growth, yield and other important characters (Firpo *et al.* 1998; Ahmed *et al.* 2003 and López-Anido *et al. 2004*). Furthermore, squash hybrids show resistance to pests or pathogens. Therefore, squash hybrids extensively replaced local varieties.

El-Adl *et al.* (2014), Rehab *et al.* (2015) and Abdein *et al.* (2017) estimated heterosis for some economical characters and high yield in summer squash. They detected heterosis over mid-parents and over its better parents for all traits. Jahan *et al.* (2012) and Davoodi, (2016) in sweet gourd (*Cucurbita moschhata* Duch.ex Poir) found desirable mid and better parent heterosis values in the formed hybrids for number of fruits and fruit yield per plant. In the same time, Marie *et al.* (2012) observed heterosis over M.P in all yield traits, where the hybrid (L3 X L6) exhibited (16.89 and 57.57%) for the percentage of pistillate flowers and fruits number / plant, respectively.

César *et al.* (2013) obtained 56 hybrids of summer squash as a result of as a result of a complete diallel crosses mating design of eight varieties. They found heterosis for total yield, fruit diameter, fruit length and appearance of first female flower. Tamilselvi *et al.* (2015) estimated heterosis and combining ability for earliness and yield characters in pumpkin using line x tester mating design. They illustrated the parents: Kasi Harit, CO2 and Vadhalagundu Local as the best genotypes for improvement of earliness and yield characters.

Abd El- Hadi *et al.* (2014) proved that heterosis over mid – parents recorded highly significant magnitudes for all studied traits, whereas amounts of heterosis versus the better parent exhibiteded high significant magnitudes for most studied traits. Hussien, (2015) indicated that the maximum heterosis over better parents in desirable direction was recorded for early yield per plant (179.9 %), total yield (106.9 %), number of furits per plant (57.0 %), and plant height (40.9%).

Israa, (2016) found that heterosis from mid parent exhibited different values. Regrading vegetative characters, heterosis for stem length from the means of all 20 F_1: 11.7, -3.7 and 27.1%, respectively. These values were: 7.2, 5.9 and 8.4% for number of leaves per plant, respectively. As for earliness, number of nodes to first female flower was the only trait that showed significant heterosis. The heterosis values for number of fruits per plant, total yield per plot, number of fruits per plot, fruit length and shape index were: 22, 11, 24, 24 and 19%, respectively.

Abou El-Nasr *et al.* (2010) found that highly significant differences for general and specific combining abilities of leaf area, sex ratio, number of node to first female flowers, Early yield and total fruit weight per plant. On summer squash, Ahmed, *et al*. (2003) and Abd El-Hadi *et al.* (2013) illustrated that the mean squares of GCA and SCA were highly significant for stem length, leaf area, number of leaves per plant, number of male flowers per plant, number of female flower per plant and sex ratio. Moreover, they found that both GCA and SCA genetic variances were highly significant for the tested characters indicating the relative importance of both additive and non-additive gene actions. Obiadalla-Ali, (2006) and Abd, El-Hadi *et al.* (2014) noted that GCA magnitudes were larger than their corresponding magnitudes of SCA for fruit length, fruit diameter, fruit shape index, total soluble solids, average fruit weight and total yield per plant. In the same time, El-Adl *et al.*(2014) on squash, showed that GCA was larger than their corresponding estimates of SCA for most earliness traits, in the same study they found that the estimates of heritability in broad sense were greater than their corresponding estimates of narrow sense. Hassan *et al.* (2016) studied inheritance of some important traits in summer squash; they found that broad sense heritability were ranged from 80.47 to 90.36 % for plant length, 66.84 % for number of branches, 85.57 % for date of the first female flower anthesis and 71.68 % for number of nodes to the first female flower. Also, narrow sense heritability were from 39.77 to 77.39 % for plant length and 22.29 % for first female flower In summer squash, Hussien (2015) studied nature of gene action for plant length, first female flower and number of fruits per plant, average fruit weight, fruit diameter, fruit length, early and total yield per plant. Dominance degree was more than unity for all studied characters, indicating the presence of over–dominance. Broad sense heritability estimates were high for all studied characters. Narrow sense heritability was low and recorded 13 % for fruit length, 21 % for fruit diameter and 27 % for average fruit weight.

Abdein *et al.* (2017) on pumpkin showed that both additive (δ^2A) and non-additive gene action (δ^2D) were positive for all yield and its component traits excluding additive genetic variance for fruit diameter, average fruit weight , flesh thickness and seed weight. Also, they revealed that heritability magnitudes in broad sense were larger than their corresponding estimates in narrow sense.

On watermelon, El- Diasty *et al.* (2007) estimated that the heritability in broad sense were larger in magnitudes than those estimates of heritability in narrow sense for number of fruits per plant, average fruit weight, total yield per plot and total yield per plant traits.

The aim of the current investigation is to evaluate the performance of six inbred lines and their hybrids and determination the phenotypic and genotypic parameters. In addition, identify the heterosis and combining ability for the studied traits in order to determine the best combinations and the ideal improvement strategy for hybrid production in squash.

MATERIALS AND METHODS

The present investigation was carried out at El-Baramoon Research Station, Horticulture Research Institute, during summer seasons of 2016 and 2017. Six inbred lines of summer squash (*Cucurbita pepo* L.) were selected from the local Eskandarany cultivar, which have been designated as P_1, P_2, P_3, P_4, P_5 and P_6. These parental lines were obtained from Vegetable Research Department at Dokki, Giza, Egypt. Seeds of the parental inbred lines were sown in the field on March 5th in summer season of 2016. When plants start flowering stage, all possible crosses were made according to half diallel crosses mating design.

A total of 21 genotypes (6 parental lines and 15 F_1 hybrids) were planted in the summer season of 2017 in the field on March 3rd for measuring the different types of heterosis in mid- parent and better parent, gene action in the terms of general and specific combining ability (GCA and SCA), heritability in broad and narrow sense. A randomized complete block design with three replicates was adopted. Each plot contained three rows each of 5.00 m long and 1.00 m wide, the plants were spaced at 50 cm apart on one side trellis ten plants were grown in each row. All agricultural practices were applied according to the recommendations of Ministry of Agriculture. Measurements for hybrids and their parents were recorded on plant height (PH cm), number of leaves per plant, leaf area (LA cm^2), number of node female flower (NNFF), days to anthesis of female flowers (DAFF), fruit shape index (ShI) as a ratio between fruit length and diameter (L/D), average fruit weight (AFW g), total soluble solids (TSS %), Vitamin c (Vit C mg), number of fruits per plant (N.F./P), early yield per plant (EY/P kg) and total yield per plant (TY/Pkg).

Statistical procedures:

After data recording from 21 genotypes, the analysis of variance and mean squares were estimated according to Gomez and Gomez (1984).

Statistical analyses were made in order to test the significance of the differences among the 6 parents and their F_1 hybrids. LSD test was used for the comparison among genotype means. The amount of heterosis in F_1 hybrids was determined as the deviation of the mid- parents and the better parent as follows:

$$H\,\%\,(M.P) = \frac{\overline{F_1} - \overline{M.P}}{\overline{M.P}} \times 100 \quad \text{and} \quad H\,\%\,(B.P) = \frac{\overline{F_1} - \overline{B.P}}{\overline{B.P}} \times 100$$

Half diallel crosses analysis was made to provide the estimations of general (GCA) and specific combining ability (SCA), and at the same time to estimate various types of gene action (Griffing, 1956).

The estimates of GCA variance (δ^2g) and SCA variance (δ^2s) could be expressed in terms of genetic variances according to Cockerham (1963).

Heritability was calculated as narrow sense $h^2_{n.s}$% or broad sense $h^2_{b.s}$%. Narrow sense heritability was estimated as the percentage ratio of additive genetic variance to the phenotypic variance in percentage, while broad sense heritability was estimated by dividing genetic variance by the phenotypic variance in percentage.

RESULTS AND DISCUSSION

Squash varieties possess a wide range of variation for vegetative, earliness, yield and its components. Vegetable breeder usually uses this variation as a tool to improve summer squash varieties through selection programs or to produce F_1 hybrids to obtain high and quality yield.

Analysis of variance:

In this study, different vegetative, earliness and yield component traits were estimated including; plant height (PH cm), number of leaves per plant, leaf area (LA cm^2), days to anthesis female flowers (DAFF), number of node female flower (NNFF), early yield per plant (EY/P kg), fruit shape index (ShI), average fruit weight (AFWg), total soluble solids (TSS %), Vitamin C (Vit C), number of fruits per plant (NF/P) and total yield per plant (TY/P kg). The analysis of variance and mean squares for all genotypes are presented in Tables (1&2). The results indicated that the mean squares for all genotypes were highly significant for all traits.

These results were in agreement with the results obtained by Abd El- Hadi *et al.*(2013); Hussien (2015); Israa, (2016) and Abdein *et al.* (2017).

Table1. Analysis of variance and mean squares of parental inbreds and their F_1 hybrids for vegetative and earliness traits in summer squash.

S.O.V	d.f	Vegetative and earliness traits					
		PH (cm)	NL/P	LA (cm^2)	DAFF	NNFF	EY/P (kg)
Replicates	2	32.123	1.730	3764.714	6.048	0.492	0.001
Genotypes	20	569.953**	59.397**	323681.110**	47.286**	1.450**	0.026**
Error	40	7.984	1.580	3548.030	1.198	0.392	0.001

**** significant at 0.01 levels of probability**

Table 2. Analysis of variance and mean squares of parental inbreds and their F_1 hybrids for yield and its component traits in summer squash.

S.O.V	d.f	yield and yield component traits					
		ShI cm	AFW (g)	TSS %	Vit. C. (mg)	NF/P	TY/P (kg)
Replicates	2	0.100	50.486	0.002	0.001	1.159	0.007
Genotypes	20	0.769**	1202.134**	0.948**	2.133**	11.787**	0.278**
Error	40	0.018	11.573	0.005	0.034	0.609	0.010

** significant at 0.01 levels of probability

The mean performance of all genotypes:

The mean performances of varieties and their F_1 hybrids for all traits are presented in Tables (3&4). The results cleared that the obtained mean values showed that there was no single parent exceeded all the other parents for all studied traits. The results presented in Table (3) showed that the parental variety P_4 was the lowest parent for PH, NL/P and LA, while the parental variety P_6 showed the lowest values for DAFF, NNFF and EY/P. In the same time P_6 was the highest parent for PH, NL/P and LA traits, also, showed had the lowest value for DAFF, NNFF and EY/P traits. In the same time, the results indicated that the highest F_1 hybrids P_5 X P_6 for P.H (96.39 cm), NL/P (40.33) and LA (3000.30 cm^2). While F_1 hybrid P_2 X P_3, P_2 X P_5 and P_1 X P_4 showed the highest value for DAFF, NNFF and E.Y./P. The results showed that the means of the F1 hybrids ranged from 55.01 to 96.39 cm; 40.33 to 17.00; 3000.30 to 2012.30 cm^2; 48.67 to 38.00; 1.67 to 5.00 and 0.18 to 0.51 kg for PH; NL/P; LA; DAFF; NNFF and EY/P, respectively. The results indicated that the magnitudes of the means of the F_1 hybrids were close to each other most studied traits. The results presented in Table (4) showed that the parental variety P_2 was the highest parent for AFW; Vit C.; NF/P and TY/P. In the same time, the parental variety P_6 showed the lowest values for NF/P and TY/P. The results showed that the highest F_1 hybrid for AFW was P_2 X P_6 with the mean value of (133.05 g) while , P_5 X P_6 hybrid was the lowest with the mean value of (85.71g) for the same trait. On the other hand, F_1 hybrid P_2 X P_3 was the highest with the mean value (1.50 kg) for the TY/P trait. Furthermore, the results showed that the means of F_1 hybrids ranged from 4.24 to 6.21(cm); 133.05 to 85.71(g); 3.26 to 5.02(%); 12.32 to 15.07(mg); 6.33 to 12 and 0.79 to 1.50 (kg), for ShI; AFW; TSS; Vit. C; NF/P and TY/P, respectively.

Heterosis over the mid- parents

Heterosis percentage of the 15 F_1 Hybrids over the mid – parent and better parent for all traits are presented in Tables (5&6). The results show that the values of heterosis over the mid – parents for F_1 hybrids ranged from – 0.13 (P_4 X P_6) to 18.77% (P_4 X P_5); -13.62 (P_2 X P_6) to 39.52 % (P_3 X P_6) ; - 7.02 (P_2 X P_4) to 16.03 % (P_3 X P_6); -13.54 (P_4 X P_5) to 3.70 % (P_3 X P_4); -37.50 (P_1 X P_3) to 57.73 % (P_2 X P_5); -29.07 (P_4 X P_6) to 98.51% (P_5 X P_6) for P.H; NL/P; LA/P; DAFF; NNFF and EY/P. While, the values of heterosis over mid- parents for F_1 hybrids of yield and its component ranged from - 8.26 (P_1 XP_3) to 32.70 % (P_5 XP_6); 4.23 (P_1 X P_3) to 39.01 % (P_3 X P_5); - 8.79 (P_3 X P_5) to 29.58 % (P_5 X P_6); 0.60 (P_1 X P_4) to 13.37% (P_3 X P_4); -24.04 (P_2 X P_6) to 48.46 % (P_4 X P_6); -2.47 (P_2 X P_6) to 75.00 % (P_4 X P_6) for ShI; AFW; TSS%; Vit. C.; NF/P. and TY/P, respectively. Similar finding were reported by Gabr, (2003); Al-Araby(2010); Ghobary and Ibrahim(2010); César *et al.*(2013); Hussien (2015); Davoodi,(2016) and Abdein *et al.* (2017)

Table 3. The mean performance for the parental varieties and their F_1 hybrids for vegetative and earliness traits in summer squash.

Traits Geno.	PH (cm)	NL /P	LA (cm)	DAFF	NNFF	EY/P (kg)
P_1	54.69	20.67	2126.70	46.33	2.67	0.19
P_2	62.39	24.33	2569.70	41.00	3.67^H	0.28
P_3	64.82	22.00	2210.00	42.33	2.67	0.26
P_4	44.82	14.67	1797.00	38.67	2.67	0.34
P_5	85.79	27.67	2712.70	50.00	2.67	0.23
P_6	90.45	32.00	2934.00	53.00	2.00	0.17
P_1 X P_2	60.11	21.33	2365.00	40.33	4.00	0.31
P_1 X P_3	65.07	20.67	2195.00	42.33	1.67	0.38
P_1 X P_4	55.01	17.67	2057.70	39.33	2.00	0.51
P_1 X P_5	83.17	25.00	2670.70	45.67	2.67	0.25
P_1 X P_6	81.20	28.67	2676.00	45.00	2.33	0.34
P_2 X P_3	66.17	22.67	2332.70	38.00	3.33	0.48
P_2 X P_4	55.65	19.67	2030.00	40.00	4.67	0.38
P_2 X P_5	82.39	25.33	2493.70	44.33	5.00	0.28
P_2 X P_6	85.68	24.33	2876.30	45.00	2.33	0.19
P_3 X P_4	57.85	17.00	2012.00	42.00	3.00	0.31
P_3 X P_5	83.16	22.67	2597.30	43.33	2.67	0.21
P3 X P_6	94.20	37.67	2984.30	46.00	2.67	0.26
P_4 X P_5	77.56	19.00	2301.70	38.33	2.67	0.36
P_4 X P_6	67.55	23.33	2708.30	44.33	2.33	0.18
P_5 X P_6	96.39	40.33	3000.30	48.67	2.67	0.40
LSD 5%	3.66	2.07	98.29	1.80	1.03	0.02
LSD 1%	6.24	2.78	131.53	2.42	1.38	0.03

Table 4. The mean performance for the parental inbreds and their F_1 hybrids for yield and its component traits in summer squash.

Traits Geno.	ShI (L/D) cm	AFW (g)	TSS %	Vit. C. (mg)	NF /P	TY/P (kg)
P_1	4.97	108.50	3.84	13.52	8.33	0.91
P_2	4.45	119.35	4.22	14.21	11.00	1.31
P_3	4.38^L	115.13	3.19	11.11	7.33	0.84
P_4	4.46	86.70	3.06	13.40	6.00	0.52
P_5	4.59	66.19	4.08	12.46	9.33	0.62
P_6	4.77	76.10	4.43	12.72	5.67	0.43
P_1 X P_2	4.98	123.06	4.24	15.07	12.00	1.47
P_1 X P_3	4.29	116.54	3.26	12.80	8.33	0.97
P_1 X P_4	5.00	112.02	3.97	13.54	7.33	0.82
P_1 X P_5	5.13	105.66	3.83	13.32	10.00	1.05
P_1 X P_6	5.48	114.86	4.59	13.51	8.00	0.92
P_2 X P_3	4.49	125.32	4.32	14.23	12.00	1.50
P_2 X P_4	4.80	122.59	3.72	14.60	7.67	0.94
P_2 X P_5	4.30	125.40	4.37	14.18	11.00	1.38
P_2 X P_6	5.63	133.05	4.53	13.73	6.33	0.85
P_3 X P_4	4.48	127.34	3.26	13.89	8.33	1.06
P_3 X P_5	4.24	126.03	3.32	12.93	7.67	0.86
P_3 X P_6	5.08	125.17	4.08	13.17	6.33	0.79
P_4 X P_5	4.75	94.07	4.12	13.49	9.63	0.91
P_4 X P_6	5.31	97.08	4.57	13.59	8.67	0.84
P_5 X P_6	6.21	85.71	5.02	13.72	10.00	0.85
LSD 5%	0.22	5.61	0.11	0.30	1.28	0.16
LSD 1%	0.30	7.51	0.16	0.40	1.72	0.22

Heterosis over better parent

Heterosis percentage of the 15 F_1 hybrids for vegetative and earliness and yield and its components over the better parent are presented in Tables (5&6). The results show that the values of heterosis over the better parent for F_1 hybrids varied from – 25.32 (P_4 X P_6) to 6.57 % (P_5 X P_6) for P.H; - 31.33 (P_4 X P_5) to 26.03 % (P_5 X P_6) for No.L./P; - 21.00 (P_2 X P_4) to 2.26% (P_5 X P_6) for LA/P; -7.32 (P_2 X P_3) to 14.64 % (P_4X P_6) for DAFF; - 37.45 (P_1 X P_3) to 87.27 % (P_2 X P_5) for NNFF and – 47.06 (P_4 X P_6) to 78.95 % (P_1 X P_6) for EY/P. while , the values of heterosis over the better parent for yield and its components traits ranged from -13.68 (P_1 X P_3) to 30.19 % (P_5 X P_6); - 2.62 (P_1X P_5) to 12.63 % (P_5X P_6); - 18.63 (P_3 X P_5) to 24.60 % (P_5 X P_6); - 5.33 (P_1 X P_3) to 7.86 % (P_5X P_6); - 42.45 (P_2 X P_6) to 44.50 % (P_4 X P_6) and – 35.11 % (P_2 X P_6) to 61.77% (P_4 X P_6) for ShI; AFW; TSS%; Vit.C; NF/P. and TY/P, respectively. Average fruit weight possess significant positive heterosis was up to 39.01 % (P_3 X P_5) over mid – parent and 12.63 % (P_5 X P_6) over better parent. The same trend was recorded by Al-Araby (2010), Ghobary and Ibrahim (2010); Jahan *et al.* and Marie (2012); Hussien (2015) and Abdein *et al.* (2017).

Table 5. Relative heterosis as mid – parents and better parent for vegetative and earliness traits in summer squash.

Traits	PH (cm)		NL/P		LA/P (cm)		DAFF		NNFF		EY/P (kg)	
Geno.	**M.P**	**B.P**	**M.P**	**B.P**	**M.P**	**B.P**	**M.P**	**B.P**	**M.P**	**B.P**	**M.P**	**B.P**
P_1 X P_2	2.68	-3.65	-5.20	-12.33	0.72	-7.97	-7.64	-1.63	26.18	49.81	34.05	10.71
P_1 X P_3	8.89	0.39	-3.12	-6.05	1.23	-0.68	-4.51	0.00	-37.50	-37.45	71.36	46.15
P_1 X P_4	10.56	0.59	0.00	-14.51	4.89	-3.24	-7.46	1.71	-25.00	-25.09	90.24	50.00
P_1 X P_5	18.41	-3.05	3.43	-9.65	10.37	-1.55	-5.18	-1.42	37.45	37.45	17.62	8.70
P_1 X P_6	11.89	-10.23	8.87	-10.41	5.77	-8.79	-9.39	-5.03	-0.02	16.50	85.86	78.95
P_2 X P_3	4.03	2.08	-2.14	-6.82	-2.39	-9.23	-8.80	-7.32	5.24	24.72	80.90	71.43
P_2 X P_4	3.81	-10.80	0.88	-19.15	-7.02	-21.00	0.40	3.44	47.32	74.91	9.68	11.76
P_2 X P_5	11.20	-3.96	-2.58	-8.46	-5.58	-8.07	-2.57	8.12	57.73	87.27	11.64	0.00
P_2 X P_6	12.12	-5.27	-13.62	-23.97	4.52	-1.97	-4.26	9.76	-17.66	16.50	-14.22	-32.14
P_3 X P_4	5.53	-10.75	-7.28	-22.73	0.42	-8.96	3.70	8.61	12.36	12.36	2.33	-8.82
P_3 X P_5	10.43	-3.07	-8.71	-18.07	5.52	-4.25	-6.14	2.36	0.00	0.00	-14.99	-19.23
P_3 X P_6	12.32	4.15	39.52	17.72	16.03	1.71	-3.49	8.67	14.10	33.50	19.53	0.00
P_4 X P_5	18.77	-14.25	-10.25	-31.33	2.08	-15.15	-13.54	-0.88	0.00	0.00	18.67	38.46
P_4 X P_6	-0.13	-25.32	-0.02	-27.09	14.50	-7.69	-3.28	14.64	-0.02	16.50	-29.07	-47.06
P_5 X P_6	9.38	6.57	35.15	26.03	6.26	2.26	-5.50	-3.26	56.84	83.50	98.51	73.91

Table 6. Relative heterosis mid-parent and better parent for yield and its component traits in summer squash.

Traits	ShI (L/D) cm		AFW (g)		TSS %		Vit. C. (mg)		NF/P		TY/P (kg)	
Geno.	**M.P**	**B.P**	**M.P**	**B.P**	**M.P**	**B.P**	**M.P**	**B.P**	**M.P**	**B.P**	**M.P**	**B.P**
P_1 X P_2	5.77	0.20	8.02	3.11	5.25	0.47	8.66	6.05	24.14	9.09	32.70	12.21
P_1 X P_3	-8.26	-13.68	4.23	1.23	-7.21	-15.10	3.94	-5.33	6.39	0.00	11.20	6.60
P_1 X P_4	6.15	0.60	14.77	3.24	15.07	3.39	0.60	0.15	2.32	-12.00	14.93	-9.89
P_1 X P_5	7.26	3.22	20.99	-2.62	-3.21	-6.13	2.52	-1.48	13.21	7.18	37.80	15.38
P_1 X P_6	12.46	10.26	24.45	5.86	10.87	3.61	2.97	-0.07	14.29	-3.96	37.17	1.10
P_2 X P_3	1.77	0.90	6.90	5.00	16.44	2.37	12.41	0.14	30.91	9.09	39.42	14.50
P_2 X P_4	7.82	7.62	19.00	2.71	2.28	-11.85	5.77	2.75	-9.76	-30.27	2.24	-28.24
P_2 X P_5	-4.84	-6.32	35.17	5.07	5.30	3.55	6.32	-0.21	8.20	0.00	43.32	5.34
P_2 X P_6	22.23	18.03	36.15	11.48	4.70	2.26	1.96	-3.38	-24.04	-42.45	-2.47	-35.11
P_3 X P_4	21.33	0.45	26.20	10.61	4.47	2.19	13.37	3.66	24.88	13.64	55.88	26.20
P_3 X P_5	-5.42	-7.63	39.01	9.47	-8.79	-18.63	9.71	3.77	-7.96	-17.79	18.22	2.38
P_3 X P_6	11.07	6.50	30.91	8.72	7.04	-7.90	10.53	3.54	-2.62	-13.64	36.62	-5.95
P_4 X P_5	5.01	3.49	23.05	8.50	15.45	0.98	4.33	0.67	29.39	3.22	59.65	46.77
P_4 X P_6	15.16	11.32	19.26	11.97	22.00	3.16	4.06	1.42	48.46	44.50	75.00	61.77
P_5 X P_6	32.70	30.19	20.46	12.63	29.58	24.60	8.98	7.86	33.33	7.18	60.38	37.10

Analysis of combining ability variances:

Analyses of variance and mean squares of the half diallel mating design for combining ability are presented in Tables (7&8). From this analysis it was evident that both GCA and SCA variances were highly significant for all studied traits thus indicating the importance of additive (δ^2A) and non – additive gene action (δ^2D) in inheritance of these traits. The GCA effects and SCA effects were estimated for six parents and 6 x 5 half diallel crosses without reciprocals, an estimate of GCA effects of parents to which this particular parent was crosses in the crossing system. If the parent has exactly the same average in its combination as the general average performance of the parent in their combinations, would indicate that the parent is such better or much poorer than the overall average of parents involved in the test.

Table 7. Analysis of combining abilities and the mean square of F_1 hybrids for vegetative and earliness traits in summer squash.

S.O.V	d.f	PH (cm)	NL/P	LA (cm)	DAFF	NNFF	EY/P (kg)
Replicates	2	32.12	1.73	3764.71	6.05	0.49	0.0001
Genotypes	20	569.95**	59.40**	323681.11**	47.29**	1.45**	0.026**
GCA	5	2042.59**	218.30**	1164993.17**	150.40**	3.74**	0.02^{ns}
SCA	15	79.09**	6.40**	43219.10**	12.93**	0.68^{ns}	0.03^{ns}
Error	40	7.98	1.58	3548.03	1.20	0.39	0.0001
GCA / SCA		25.826	34.109	26.956	11.632	5.500	0.667

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

The results indicated that the mean squares due to crosses were highly significant for all studied traits. The values of GCA mean squares were higher than those of SCA means foe all studied traits. The mean squares due to general combining ability (GCA) exhibited significant differences for all studied traits. The mean squares due to specific combining ability (SCA) were highly significant for all studied traits. It means that additive genetic variance was more important in the inheritance of those characters. These results are in agreement with those of Al-Araby (2010), Ghobary and Ibrahim (2010), Abd El- Hadi *et al.*(2013), Israa, (2016) and Abdein *et al.*(2017).

Table 8. Analysis of combining abilities and the mean square of F_1 hybrids for yield and its component traits in summer squash.

S.O.V	d.f	ShI cm	AFW (g)	TSS %	Vit. C. (mg)	NF/P	TY/P (kg)
Replicates	2	0.100	50.486	0.001	0.001	1.159	0.007
hybrids	20	0.769**	1202.134**	0.948**	2.133**	11.787**	0.278**
GCA	5	1.47^{ns}	3056.43**	2.98**	2.13*	30.27**	0.87**
SCA	15	0.53**	584.01**	0.27**	5.70**	5.64**	0.08**
Error	40	0.018	11.573	0.005	0.034	0.609	0.010
GCA / SCA		2.774	5.234	11.037	0.374	5.367	10.875

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

General combining ability effects (gi) for the parents:

The general combining ability effects *(gi)* of the six parents for vegetative and earliness and yield and its components are presented in Tables (9&10), respectively. In Table 9, reflected that the best general combiner parent that appeared to have the significant highest positive value of GCA. The results illustrated that (P_5 and P_6) had the greatest GCA effects (10.65 ± 0.527) and (11.24± 0.527) for plant height, respectively. While, the other parents were poor combiner at the same traits. Also, the results revealed that (P_6) was a good combiner at P.H, NL/P and DAFF traits, respectively.

Table 9. Estimates of GCA and SCA effects for vegetative and earliness traits for parental varieties and their F_1 hybrids in summer squash.

Traits Geno.	PH (cm)	NL /P	LA (cm)	DAFF	NNFF	EY/P (kg)
			GCA			
P_1	-5.64	- 0.86	-109.20	0.09	-0.22	0.01
P_2	-3.03	0.50	18.55	-1.88	0.74	0.01
P_3	-1.24	-1.24	-93.76	-1.04	- 0.18	0.01
P_4	-11.97	-4.44	-298.46	-2.92	-0.01	0.03
P_5	10.65	2.14	152.60	1.96	0.07	-0.02
P_6	11.24	4.35	330.60	3.80	-0.39	-0.05
S.E. (gi)	0.527	0.234	11.099	0.203	0.116	0.002
			SCA			
P_1 X P_2	-2.51	-0.94	14.36	-1.40	-0.05	-0.01
P_1 X P_3	0.66	-0.32	-43.67	-0.23	-0.47	0.07
P_1 X P_4	1.33	-0.11	23.73	-1.36	-0.30	0.16
P_1 X P_5	6.86	0.64	185.68	0.11	-0.72	-0.04
P_1 X P_6	4.31	2.10	12.97	-2.40	0.41	0.07
P_2 X P_3	-0.85	0.77	-33.38	-2.61	0.24	0.17
P_2 X P_4	-0.64	0.98	-131.38	1.27	0.41	-0.01
P_2 X P_5	3.48	0.06	-118.73	0.72	0.66	-0.01
P_2 X P_6	6.19	-3.15	85.86	-0.44	0.55	-0.07
P_3 X P_4	0.23	-0.40	-37.41	2.44	0.67	-0.03
P_3 X P_5	2.46	-1.31	96.84	-1.11	0.24	-0.08
P_3 X P_6	5.92	-1.52	105.83	-0.27	-0.30	-0.01
P_4 X P_5	7.60	-1.78	5.94	-4.24	0.07	0.03
P_4 X P_6	-3.00	0.35	234.53	-0.07	0.20	-0.10
P_5 X P_6	-6.79	1.77	-101.52	-0.60	-0.22	0.17
S.E.(ij)	1.994	0.531	25.17	0.462	0.265	0.005

Data in table 10 shows the general combining ability effects *(gi)* for yield and its component. Where the (P_2) which was the good combiner for AFW (14.10 ± 0.633), (Vit. C (0.78 ±0.034), NF/P (1.64 ± 0.145) and TY/P (0.31 ± 0.019), respectively. At the same time, the results showed that the (P_1) which appeared to be good combiner parental cultivar for ShI (0.42 ± 0.025), followed by (P_5) which was seemed to be the best combiner for TSS % (0.19 ± 0.013). From such results, it could be generally concluded that combining ability estimates can be used to select the parents to be involved in hybrid combinations to predict the good hybrids.

Also, it showed be mentioned that the parents with best GCA. don't necessary produce superior cross with best SCA in all combinations. These results were in agreement with the results obtained by Ahmed, *et al.*(2003), Abou El-Nasr *et al.*(2010); Abd El-Hadi *et al.* (2014); Tamilselvi *et al.* (2015); Israa, (2016) and Abdein *et al.*(2017).

Table 10. Estimates of GCA and SCA effects for yield and its component traits for parental varieties and their F_1 hybrids in summer squash.

Traits Geno.	ShI (L/D) cm	AFW (g)	TSS %	Vit. C. (mg)	NF /P	TY/P (kg)
		GCA				
P_1	0.11	4.23	- 0.11	0.17	0.56	0.10
P_2	- 0.10	14.10	0.17	0.78	1.64	0.31
P_3	- 0.32	10.67	- 0.46	- 0.59	-0.44	0.02
P_4	- 0.08	- 6.10	- 0.29	0.20	-1.19	-0.18
P_5	- 0.02	- 13.26	0.19	- 0.31	0.60	0.06
P_6	0.42	- 9.65	0.50	- 0.25	-1.15	-0.19
S.E. (gi)	0.025	0.633	0.013	0.034	0.145	0.019
		SCA				
P_1 X P_2	0.13	-3.17	0.31	0.70	1.54	0.17
P_1 X P_3	-0.35	-6.26	-0.05	-0.20	-0.05	-0.04
P_1 X P_4	0.13	5.99	-0.31	-0.25	-0.30	0.05
P_1 X P_5	0.18	6.79	-0.12	0.04	0.58	0.12
P_1 X P_6	0.10	12.38	-0.18	0.17	0.33	0.12
P_2 X P_3	0.07	-7.35	-0.26	0.61	2.54	0.27
P_2 X P_4	0.14	6.69	-0.02	0.19	-1.04	-0.09
P_2 X P_5	-0.43	16.65	-0.06	0.29	0.49	0.24
P_2 X P_6	0.47	20.70	-0.01	-0.23	-2.43	-0.16
P_3 X P_4	0.04	14.89	-0.02	0.85	-1.30	-0.06
P_3 X P_5	-0.27	20.72	-0.29	0.41	-0.75	0.01
P_3 X P_6	0.14	6.25	0.16	0.59	-0.34	0.01
P_4 X P5	0.01	-4.47	0.35	0.07	-0.34	-0.04
P_4 X P_6	0.13	-5.07	0.48	0.01	2.75	0.22
P_5 X P_6	0.96	-9.28	0.46	-0.14	0.29	-0.04
S.E.(ij)	0.057	1.438	0.030	0.077	0.330	0.042

Specific combining ability effects (Sij)

Estimates of specific combining ability effects (*Sij*) of the 15 F_1 hybrids for vegetative and earliness and yield and its component traits are presented in Tables (9&10), respectively. These effects are an effective way to test and select the good combinations obtained from the different crosses. The high values of Sij cross which involving two parents would be a promising way for genetic improvement (Cruz and Regazzi, 2001). For vegetative and earliness and yield and its component which appear in table 10. The results illustrated that GCA and SCA effects were shown to be major contributing factors in squash, indicating the importance of additive (δ^2A) and non additive (δ^2D) types of gene action in the inheritance of the studied traits.

The results illustrated that comparisons among the estimated values of SCA illustrated that the good hybrid combination which showed the highest value for P.H traits was found to be the cross (P_4 X P_5)(7.60 ± 1.994). The results illustrated that the hybrids (P_4 X P_6) (234.53 ± 25.17) showed the best combinations for LA trait, while, the cross (P_3 X P_4) (-4.24 ± 0.462) showed desirable negative value of *Sij* for DAFF trait. Similarly, the specific combinations *Sij* for yield and its component were estimated and are presented in Table 10. The results illustrated that the hybrid (P_4 X P_6) (0.48 ± 0.30) (2.75 ± 0.030) showed that the best combinations for TSS % and No F/P, respectively. This result illustrated that this F_1 hybrid could be considered as the best hybrid combination for TSS %, while, hybrid (P_3 X P_5) (20.72 ± 1.438) showed the best combination for AFW trait.

Genetic parameters and heritability:

The relative magnitudes of genetic parameters were estimated for vegetative and earliness and yield and its component traits the present results in Tables (11&12), respectively. The results illustrated that both additive (δ^2A) and non additive genetic variances including dominance (δ^2D) were positive for all studied traits. The results reported that the magnitudes of additive genetic variances were larger than dominance genetic variances for all studied traits expect for ShI. Thus, it could be suggested that additive genetic variance predominant in the inheritance of the studied traits. The results illustrated generally that the estimations of heritability percentages in the broad sense ($h^2_{b.s}$%) for the various studied traits, were found to be high and ranged from 72.95% for NNFF trait up to 99.43 % for EY/P trait and 94.84 % for NF/P up to 99.46 % for TSS % trait. Also, the results showed that the heritability in broad sense were 98.60 %, 97.34 %, 98.90 % and 97.47% for PH, NL/P, LA, DAFF, respectively and 97.60 %, 99.04 %, 98.42 % and 96.44 % for ShI, AFW, Vit C. and TY/P, respectively.

Table 11. The estimates of genetic variance components and heritability for vegetative and earliness traits in summer squash.

Genetic parameters	PH (cm)	NL/P	LA (cm)	DAFF	NNFF	EY/P (kg)
δ^2ph	189.98	19.80	107893.70	15.76	0.48	0.09
δ^2A	163.62	17.66	93481.17	11.46	0.26	0.001
δ^2D	23.70	1.61	13223.69	3.91	0.10	0.009
δ^2e	3.187	0.12	629426.18	0.07	0.01	0.00
$h^2_{b.s}$%	98.60	97.34	98.90	97.47	72.95	99.43
$h^2_{n.s}$%	35.32	28.49	35.02	49.82	44.88	40.55
D. d	0.179	0.020	0.029	0.158	0.961	0.00

Table 12. The estimates of genetic variance components and heritability for yield and its component traits in summer squash.

Genetic parameters	ShI (L/D cm	AFW (g)	TSS %	Vit. C. (mg)	NF/P	TY/P (kg)
δ^2ph	0.26	400.71	0.32	0.71	3.93	0.09
δ^2A	0.08	206.03	0.23	0.40	2.05	0.07
δ^2D	0.17	190.81	0.09	0.30	1.68	0.02
δ^2e	0.0001	6.70	0.0001	0.0001	0.02	0.0001
$h^2_{b.s}$%	97.60	99.04	99.46	98.42	94.84	96.44
$h^2_{n.s}$%	81.94	69.01	53.07	65.28	65.29	49.89
D. d	2.702	0.769	0.415	0.579	0.740	0.186

Generally the heritability in broad sense ($h^2_{b.s}$%) were larger than their corresponding values of heritability in narrow sense ($h^2_{n.s}$%) for all studied traits. In the same study, the highest values of ($h^2_{n.s}$ %) was (49.82 %) for DAFF followed by 44.88 % for NNFF trait, 40.55 % for 35.32 % for P.H trait, 35.02 % for LA trait and 28.49 % for No.L./P trait. In the same time, the highest values of ($h^2_{n.s}$%) for yield and its component were 81.94 % for Sh.I cm^2 trait followed by 69.01 % for AFW, 65.29 % for No.F./P trait, 65.28 % for Vit C, 53.07 % for TSS % and 49.89 % for TY/P.

The degree of dominance (D.d) was less than one for all studied traits while, it was larger than one for Sh.I trait indicating the presence of non – additive variances for this trait. The results seemed to agree with those obtained by Abd El-Rahman *et al*. (2001); El- Diasty *et al.* (2007); Abd El-Hadi *et al.* (2014); Israa (2016) and Abdein *et al.* (2017).

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قوة الهجين والقدرة على التآلف لإنتاج هجن الكوسة

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أجريت هذة الدراسة خلال الموسمين الصيفين 2016 و2017 بمزرعة محطة بحوث البساتين بالبرامون التابعة لمعهد بحوث البساتين وقد أستخدم فى هذة الدراسة ستة سلالات نقية من الكوسة الاسكندرانى حيث أجرى التهجين بين الستة سلالات بنظام التزاوج النصف دائرى وقد قيمت الأباء والهجن الناتجة منها فى تجربة قطاعات كاملة العشوائية فى ثلاث مكررات وتم تسجيل البيانات على صفات (طول النبات بالسم و عدد الأوراق للنبات و المساحة الورقية بالسم^2 وعدد الأيام حتى تفتح أول زهرة مؤنثة و رقم أول عقدة تحمل زهرة مؤنثة والمحصول المبكر للنبات بالكجم ومعامل شكل الثمرة بالسم ومتوسط وزن الثمرة بالجم ونسبة السكريات الذائبة الكلية وفيتامين سى وعدد الثمار للنبات والمحصول الكلى للنبات بالكجم. وقد أوضحت النتائج الأتى : - وجود أختلافات بين الأباء والهجن لكل الصفات محل الدراسة ولكن معظم التراكيب الوراثية للجيل الأول تميزت عن الآباء الداخلة فى تركيبها. - أظهرت النتائج وجود قيما موجبة لقوة الهجين قياسا بمتوسط الاباء .وقد أظهر الهجين $P_5X\ P_6$ معنوية عالية وأعطى أعلى قيمة لقوة الهجين 98.51 % لصفة المحصول المبكر للنبات تلاها الهجين $P_1X\ P_4$ وقد أعطى قوة هجين 90.24 %. بينما عند حساب قوة الهجين عن طريق أحسن الأباء فقد وجد أن الهجين $P_1X\ P_6$ قد أعطى أعلى قيمة لقوة الهجين 78.95 % لصفة المحصول المبكر تلاه الهجين $P_5X\ P_6$ وقد أعطى قوة هجين 73.91% لنفس الصفة. بينما اعطي الهجين $P_4X\ P_6$ اكبر القيم لقوة الهجين قياسا بمتوسط الاباء لصفة المحصول الكلي للنبات (75.0 %) ثم الهجينين $P_5X\ P_6$ (60.38%) و $P_4\ X\ P_5$ (59.65%) علي التوالي. و بالنسبة لقوة الهجين علي اساس الاب الاعلي فقد اظهر الهجين $P_4\ XP_6$ اعلي قوة هجين لصفة المحصول الكلي للنبات (61.77%) ثم كل من الهجين $P_4X\ P_5$ (46.77%) والهجين $P_5X\ P_6$ (37.10%).- وجد أيضاً أن القيم المقدرة للقدرة العامة والخاصة على التآلف كانت عالية المعنوية لمعظم الصفات المدروسة وهذا يوضح أهمية كلاً من التاثير الاضافى والسيادى فى وراثة الصفات محل الدراسة وكانت القيم المقدرة للتباين الاضافى أكبر من القيم المقدرة للتباين السيادى لجميع الصفات تحت الدراسة ماعدا صفة معامل شكل الثمرة والتى كان الفعل السيادى له الفعل الأكبر او الرئيسى فى وراثتها. - أوضحت النتائج أيضاً أن الأب الأول والثانى والثالث قد أظهروا قدرة عالية على التآلف لصفات متوسط وزن الثمرة وفيتامين سى وعدد الثمار للنبات والمحصول الكلى للنبات وكذلك وجد أن الاب الخامس والسادس قد أظهروا قدرة عالية على التآلف لصفات أرتفاع النبات وعدد الأوراق للنبات والمساحة الورقية ورقم العقدة لأول زهرة مؤنثة. - أظهرت النتائج أن القيم المقدرة لمعامل التوريث فى المدى الواسع كانت أكبر من القيم المقدرة لمعامل التوريث فى مداه الضيق وأظهرت النتائج أن القيمة المقدرة لمعامل التوريث فى مداه الواسع تراوحت بين 72.95 الى 99.46 % لكل من صفتى رقم العقدة لأول زهرة مؤنثة والمواد الذائبة الكلية بينما تراوحت القيمة المقدرة لمعامل التوريث فى مداه الضيق تراوحت بين 28.49 الى 81.94 % لصفتى عدد الأوراق للنبات ومعامل شكل الثمرة. وبناءً على ماسبق فان على مربى الخضرعند تصميم برامجهم لانتاج هجن متفوقة من الكوسة الأنتخاب فى الأجيال الأنعزالية المتقدمة وذلك لتحسين الصفات الاقتصادية الهامة.