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INTRA AND INTER-SPECIFIC HYBRIDS IN SUMMER SQUASH.

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ABSTRACT

The development of local squash hybrids or varieties that have the capacity for higher yielding and earliness over foreign cultivars or hybrids is a pressing need. The objectives of this study were to select the combinations which produce the best F_1 by combining different germplasm in crosses. Furthermore, to study heterosis and the nature of gene action associated with this phenomenon. Four varieties belong to *Cucurbita pepo* L.; Militte (P_1), Caserta Italian (P_2), Zucchini Grey (P_3), Eskandrani (P_5) and one variety belongs to *C. maxima* Duch Abobrinha redonda (P_4) were used in this study. In the summer season of 2014, these five varieties were selfed and also crossed to produce 20 F_1 hybrids according to the complete diallel crosses mating design. In the spring season, 2015, all the F_1 hybrids including their reciprocals and parental varieties were evaluated and grown in a randomized complete blocks design with three replicates. Data were recorded on the following traits: steam length (S.L in cm), the percentage of female flower (FF%), number of days to the first female flower (NDFF), early yield kg/plot (EY/P), number of fruits/plant (NF/P), average fruit weight (FW), total yield/plot (TY/P) and fruit length (FL). The performance of the five parents, the 10 F_1 hybrids and their 10 F_{1r} reciprocal hybrids were variable. The P_5 appeared to be the best parent for vegetative traits. For yield and fruit traits, once more P_5 was not only the best parent but also better than most the F_1 hybrids for almost all traits. Heterosis from the better parent was not present for all vegetative traits where, many values were negative. The analysis of complete diallel crosses showed that both GCA, SCA and reciprocal were highly significant indicating their importance. The magnitude of GCA was always larger than SCA. The σ_A^2 variances were larger than σ_D^2, although, σ_D^2 variances were also present. These results were supported by absence of heterosis from the better parent. The hybrids including P_4 as a male or a female parent would be consider as interspecific hybrids. The results indicated that the means of interspecific hybrids i.e. 1x4, 2x4, 3x4 and 4x5 and their reciprocals showed better performance from the other hybrids for many studied traits.

Keywords: additive and non-additive variance, heterosis, *Cucurbita spp*., reciprocal effects.

INTRODUCTION

Summer squash is an important vegetable crop grown in Egypt. The cultivated area estimated by 84571 feddan with an average yield of 7.491 tons per feddan (Ministry of Agriculture and Land Reclamation A. R. Egypt, 2013). There are three economically important Cucurbita species i.e. *C. pepo* L., *C. maxima* Duch. and *C. moschata* Duch. These species have different climatic adaptations and are widely distributed in agricultural regions worldwide (Robinson and Decker-Walters, 1997). *C. pepo* L. displays a great diversity representing the most polymorphic species for fruit characteristics.

Most of the cultivated area in Egypt is planting using imported hybrids or varieties which contributing to the production of high yield. Therefore, development of local squash hybrids or varieties that have the capacity for higher yielding and earliness over foreign cultivars or hybrids is a pressing need and requires special breeding programs.

Breeders have attempted to explore the amounts and types of variability in the cucurbita genus for crop improvement through intraspecific and interspecific hybridizations. Breeders utilized the two species i.e. *C*. *pepo* and *C. maxima* which are the most economically important cultivated species (Blanca *et al*., 2011; Robinson, 1995). These two species are remarkably diverse in morphology, and fruit characteristics (Whitaker and Bemis, 1964; Saade and Hernandez, 1994 and Loy, 2004). Onur and Ahmet (2013) performed a total of 234 pollinations of different combinations among twelve *C. maxima* lines and eleven *C. moschata* lines obtained 79 interspecific hybrids.

The estimate of heterosis among different varieties of summer squash were obtained by many investigators among them Ghobary and Ibrahim, (2010) who obtained values of heterosis from the mid-parent of 35 % and 38.2 % for the traits average fruit weight and total marketable fruits per plant. Heterosis from better parent was also investigated by many authors among them Hussien (2015) who studied the heterotic performance for yield and yield components in summer squash. The results showed that the maximum significant heterosis from the better parent (BP%) was in the desirable direction for early yield/plant which recorded 179.9% followed by total yield 106.9%, fruits number/plant 57.0%, steam lenght 40.9%, average fruit weight 32.5% and number of days to female flowering -17.2%.

The presence of large amount of heterosis from the better parent would be associated with the presence of significant amount of non-additive genetic variance including dominance. Therefore, specific combining ability would be present of large magnitude. The presence of significant general combining ability would indicate the importance of additive variance which enable intern plant breeder to select and improve squash traits. El-Adl *et al*., (2014) evaluated 42 hybrids through applying a complete diallel cross of seven lines of summer squash during 2008 to 2010. Their results indicated that the viability of some parental varieties as good combiners were noticed for earliness traits such as number of first female flowering node, data of first female flower and first picking date. Furthermore, they obtained significant amount of GCA and SCA but the GCA was larger than their corresponding estimates of SCA for most earliness traits. Reciprocal effects (r) were significant for most earliness traits. In the same time, the estimates of heritability in broad sense were larger in magnitudes than their corresponding estimates of narrow sense.

The objectives of this study were to determine the combinations which produce the best F_1 by combining different germplasm in crosses. Furthermore, to study heterosis and the nature of gene action associated with this phenomenon.

MATERIALS AND METHODS

Genetic material:

Four varieties belong to *Cucurbita pepo* L. and one variety belongs to *C. maxima* Duch were used in this investigation. These varieties were originated and characterizes as following: Militte (P_1) obtained from National Genebank, Agricultural Research Center, Giza, Egypt; Caserta italiana; (P_2) obtained from Brazil; Zucchini Grey (P_3) obtained from USA; Abobrinha redonda (P_4) was a foreign variety having variables traits and finally Eskandrani (P_5) obtained from Agricultural Research Center Giza, Egypt. These five varieties were used to generate 20 possible $F_{1,1r}$ crosses according to a complete diallel mating design using Method I Model II of Griffing (1956). In the summer season of 2014 these five varieties were selfed and also crossed to produce the 20 $F_{1,1r}$ hybrids which included 10 F_1 and 10 F_{1r} reciprocal hybrids.

Experimental design

On the 15 th of March 2015, all 20 $F_{1,1r}$ hybrids and their five parents were evaluated in a randomized complete blocks design with three replicates. Each replication contained 25 genotypes. Each plot contained eight plants at a distance of 80 cms. apart and 30 cms between plots. Weed control and other cultural practices were performed according to the requirements of squash plants.

Data were recorded using three randomly selected plants from each plot and from each replicate on the following traits: steam length (S.L. in cm), the percentage of female flower (FF%), number of days to the first female flower (NDFF), early yield kg/plot (EY/P), number of fruits/plant (NF/P), Average fruit weight (FW g), total yield/plot (TY/P) and fruit length (FL).

Statistical analysis

The statistical analyses were made according to the analyses of variance as indicated by Steel and Torrie (1960) using random model. The analysis of variance of the complete diallel crosses was carried out according to the procedure of Griffing (1956) using method I model II. Heterosis from the mid-parent value (MP %) and the better parent (BP %) were estimated as follows: $H\%\,(MP) = \frac{F_1 - M.P}{M.P} \, x\, 100$ and $H\%\,(BP) = \frac{F_1 - BP}{BP} \, x\, 100.$

Heritability is estimated either from broad sense ($\boldsymbol{h}^2{}_b$) or narrow sense ($h^2{}_n$) as follows:

$$\boldsymbol{h}_b^2\% = \frac{2\sigma^2 g + \sigma^2 s + \sigma_{rc}^2}{\sigma^2 P\boldsymbol{h}} \, x\, 100 \quad \text{and} \quad \boldsymbol{h}_n^2\% = \frac{2\sigma^2 g}{\sigma^2 P\boldsymbol{h}} \, x\, 100,$$

where:

$$\sigma^2 P\boldsymbol{h} = 2\sigma^2 g + \sigma^2 s + \sigma_{rc}^2 + \sigma^2 e$$

The average degree of dominance ($\bar{d}$) would be obtained according to the following formula**.**

$$\bar{d} = \sqrt{\frac{\sigma^2 D}{\sigma^2 A}}.$$

RESULTS AND DISCUSSION

Genotypic variation

The analyses of variance and mean squares of vegetative traits which included steam length and the percentage of female flower (FF%) are presented in Table 1. It appeared from the Table that the mean squares of the genotypes were highly significant for the two traits. These results indicated there were significant differences not only among the five parents, but also among the F_1 hybrids and their F_{1r}. The presence of significant differences would indicate that the comparison among the means of genotypes would be a valid test.

The analysis of variance and mean squares of earliness traits which included number of days to the first female flower (NDFF) and early yield per plot kg (EY/P) are also presented in Table 1. Tests of significance of the mean squares revealed the presence of highly significant differences among the five parents, F_1 hybrids and their F_{1r} hybrids.

The analyses of variances and mean squares regarding yield components which included a number of fruits/plant (NFP)**;** average fruit weight (FW); total yield/Plot (TY/P) and fruit length (FL) are shown in Table 1. The analyses of variance indicated the presence of highly significant differences not only for the five parents, but also among their F_1 and F_{1r} hybrids for all studied traits.

Table 1. Analysis of variance and mean squares for vegetative, earliness, yield and fruit traits in summer squash.

S. of V.	d.f	S.L (cm)	FF%	NDFF	EYP	NF/P	FW	TY/P	FL
Replications	2	30.61	0.84	1.21	0.02	0.09	19.58	0.00	0.65
Genotypes	24	2613.9**	23.27**	1.70**	0.06**	9.93**	1787.31**	1.20**	17.29**
Error	48	95.88	2.62	0.59	0.02	0.56	54.41	0.01	0.75

The performance of parental varieties and their 20 $F_{1,1r}$ hybrids

The mean performance of the parental varieties and their 20 F_1 hybrids for vegetative, earliness, yield and fruit traits of squash were obtained and the means are presented in Table 2. The means of the five parents showed variation for S.L cm, and FF%. For steam length (S.L cm), the parent P_5 appeared to be the best one for these traits. It showed plant high of 120.44 cm followed by P_4, P_3, P_1 and P_2. The percentage of female flower (FF%) showed that parent P_4 gave 62.83% and P_5 gave 61.69%. While the other three parents had the minimum values for this trait. In general, the parental variety Eskandrani (P_5) appeared to be the best parent.

The 10 F_1 and their 10 F_{1r} hybrids showed variable means where the means ranged from 52.89 to 121.78 cm for steam length, respectively. For the percentage of female flower (FF%), the hybrids 1x2, 2x4 and 2x5 showed the highest values of 62.74, 60.30 and 60.53%, respectively. The lowest hybrids for FF% were 1x3 and 1x4 which gave 54.95 and 54.72 %, respectively. The F_{1r} reciprocal hybrid 5x4 had the highest for S.L cm followed by 4x3 which gave 150cm and 139.20cm, respectively. Regarding the percentage of female flower (FF%), the highest means were observed for hybrids 5x4 and 5x2 which recorded 69.30 and 65.33%, respectively. The other F_{1r} hybrids gave variable means and some of them were less than their parents.

In general, it appeared that vegetative traits did not show hybrid vigor for all hybrids, but some of them showed a significant increase over both the mid-parent and better parent. It was noticed that the hybrids which included the P_5 were the better hybrids. These results were in common agreement with these results obtained by Hussien (2015), Jahan *et al*., (2012), and other authors.

Regarding the earliness traits, both the parents, P_4 and P_5 were the earliest varieties for NDFF giving 40.67 and 40.33 days, respectively as seen in Table 2. Therefore, both P_1 and P_5 appeared to have the high early yield per plot where both of them gave about 0.99 kg/plot. The majority of hybrids showed high values of NDFF than most parents except the hybrid obtained from 3x2 which gave 40.67 days to first female flower. The two hybrids 5x1 and 5x2 showed the highest amount of early yield of 1.04 and 1.07 kg/plot, respectively. Similar results were also obtained by César *et al*., (2013); El-Adl *et al*., (2014) and Tamilselvi *et al*., (2015).

Regarding the yield traits, P_5 appeared to be the best parent for NF/P followed by P_4. The two parental varieties P_5 and P_4 recorded 10.70 and 10.07 for number of fruits/plant (NF/P), 149.33 and 83.33 gr for average fruit weight (FW), with a total yield (TY/P) of 6.14 and 5.28 kg/plot, respectively.

In the case of F_1 hybrids, the hybrid 2x5 showed the highest value for NF/P of 9.82, while for FW and TY/P, the hybrid 4x5 had the largest values of 153.37gm and 6.48kg/plot, respectively. For F_{1r} reciprocal hybrids, they generally showed higher values with respect to NFP comparing with their F_1 hybrids as seen in Table 2. The F_{1r} hybrid 5x3 gave the highest NF/P followed by the hybrids 5x4 and 5x1 giving 12.21, 11.29 and 11.08 fruits, respectively. For FW, the F_{1r} hybrid 5x3 recorded the highest value of average fruit weight followed by 4x3 and 4x2 giving 166.33, 158.10 and 157.10gr, respectively. In addition, the F_{1r} hybrids 5x2, 5x4 and 4x3 showed the highest values for TY/P with mean values of 6.90, 6.47 and 5.86 kg/plot, respectively. For fruit length (FL), it ranged from 7.87 cm (P_4) to 14.97 cm (P_5). In the case of the F_1 and their F_{1r} reciprocals hybrids, the hybrid 5x2 had highest fruit length of 20.63 cm while the recommends values for commercial use range from 13 to 15 cm. Generally, the majority of hybrids showed FL ranged from 12.00 to 15.77 cm. In this respect, many authors obtained close results for yield components and fruit traits among them Ghobary and Ibrahim, (2010) and César *et al*., (2013).

The performance of interspecific hybrids

In this study five parental varieties were used. Among the parent, Militte, Caserta Italian, Zucchini Grey and Eskandrani which belong to *Cucarbita pepo* L. where Abobrinha redonda belong to *Cucarbita maxima*

Duch. Therefore, all the hybrids including P_4 as a male or a female parent would be consider as interspecific hybrids. The results indicated that the means of interspecific hybrids: 1x4, 2x4, 3x4 and 4x5 and their reciprocals showed better performances than the other hybrids. They showed large values for plant height where the hybrid 4x5 and its reciprocal 5x4 which showed 122 and 150 cm, respectively which exceeded all other hybrids. The interspecific hybrids 4x5 and its reciprocal 5x4 also gave largest values for FW and TY/P than the other intraspecific hybrids as presented in Table 2.

The reciprocal effects

The performances of the F_1 hybrids were different than F_{1r} reciprocal hybrids for almost all traits. The difference in the performance of F_1 versus F_{1r} would be due to maternal effect. In general, the reciprocal effect varied from hybrid to hybrid and from trait to another according to the nature of each trait. The differences in performances of the F_1 vs F_{1r} hybrids for vegetative traits were obtained and the results are presented in the Table 3. For steam length (S.L cm) and the percentage of female flower (FF%), significant differences between each hybrid and its reciprocal for steam length (S.L cm) and FF% were highly significant.

It appears from the data were recorded in Table 2 that the differences between each F_1 and its F_{1r} hybrid depend on which parent is the male parent. When P_2, P_3 and P_4 were used as female parent all the significant differences were in favor the parents which were used as the female parent. It would be concluded for the steam length the female parent was more effective in the performance of this trait.

The percentage of female flower (FF%) showed variable results for the F_1 and its reciprocal hybrid. When the P_1 was used as a male parent, it yielded F_1 hybrid which produced more female flowers than when it was used as female parent with the other parents. This was also true for P_3 when it was used as the female parent. On the other hand, when P_4 was used as a male parent, it gave the fewest female flowers than when it was used as the female parent. In general, it appeared that the male parent in six hybrids gave more female flower than their reciprocals. Only, P_4 gave more female flower when it was used as a female parent. Therefore, the results for vegetative traits indicated that these traits were affected by the hybrid combinations according to the first parent is male or female.

For NDFF, it appeared that when the P_1 was the male parent with the other parent, the hybrids were earlier than their reciprocals. P_2, P_4 and P_5 as male parents produced late hybrids than if they were used as the female parents. The two parents P_3 and P_4 when used as a male parent produce late F_1 hybrids, than if they were used as female parents. In general, the differences for NDFF of the hybrids and their reciprocals ranged from two days to a maximum of five days. The early yield per plant (EY/P) showed the advantage of all five parents when used as male parents.

Table 2. The mean performances of the parental varieties and their 20 $F_{1,1r}$ crosses for vegetative, earliness, yield and fruit traits in summer squash.

Genotypes		S.L cm.	FF%	NDFF	EY/P	NF/P	FW	TY/P	FL
P_1 (Militte)		53.03	56.33	46.33	0.99	6.85	109.33	4.81	12.53
P_2 (C. Italian)		42.67	57.74	47.33	0.78	6.66	134.97	4.12	11.83
P_3 (Z. Grey)		61.87	54.13	51.33	0.79	6.04	119.83	4.90	12.20
P_4 (A. redonda)		95.94	62.83	40.67	0.73	10.07	83.33	5.28	7.87
P_5 (Eskandrani)		120.4	61.69	40.33	0.99	10.70	149.33	6.14	14.97
1x2		63.28	62.74	45.00	1.41	8.37	99.00	4.98	14.53
1x3		72.25	54.95	47.00	0.92	7.84	148.17	5.24	16.63
1x4		68.50	54.72	47.67	0.79	9.33	98.73	5.46	14.00
1x5		63.67	58.36	46.67	0.80	8.62	135.17	5.97	14.67
2x3		65.53	58.33	44.00	0.88	8.87	119.97	5.16	14.53
2x4		52.89	60.30	46.33	0.94	9.54	150.97	5.49	15.43
2x5		57.94	60.53	45.67	0.86	9.82	134.67	6.11	13.33
3x4		72.00	57.43	46.33	0.69	6.95	120.00	5.42	16.67
3x5		82.67	57.58	49.33	0.89	6.16	139.00	6.27	15.77
4x5		121.7	56.92	50.67	0.99	8.74	153.37	6.48	15.00
2x1		77.33	55.02	47.67	0.90	6.17	115.07	5.19	12.00
3x1		58.09	50.33	44.00	0.90	7.68	103.67	5.30	12.63
4x1		57.67	52.47	48.00	0.79	7.79	90.47	4.98	13.00
5x1		66.05	54.61	48.00	1.04	11.08	83.67	5.15	13.00
3x2		86.05	55.59	40.67	0.81	10.96	110.90	5.05	15.87
4x2		88.89	64.17	46.67	0.92	10.66	157.10	5.45	15.53
5x2		94.67	65.33	43.67	1.07	10.69	138.73	6.90	20.63
4x3		139.2	50.98	48.00	0.89	9.91	158.10	5.86	17.33
5x3		132.4	60.68	45.67	0.97	12.21	166.67	5.74	13.87
5x4		150.0	69.30	46.00	0.95	11.29	116.33	6.47	13.00
LSD	5%	13.46	2.226	1.056	0.194	1.029	10.14	0.137	1.191
	1%	19.37	3.202	1.520	0.280	1.480	14.59	0.198	1.713

For NF/P, it appeared that the differences between the hybrids and their reciprocals were either significant or highly significant where the majority of the reciprocals had larger values than their F_1 hybrids. The hybrids which had P_1 and P_3 as parents did not show significant differences due to maternal effect when used as male or female parents. For fruit weight, the hybrids and their reciprocals showed significant differences except for the hybrids 2x4 and 2x5 where there were no significant differences or maternal effect when P2, P_4 and P_5 were used as male or female parents. Regarding total yield/plot, the results were similar to FW since most hybrids and their reciprocals gave significant differences except for the hybrids 1x3, 2x4 and 5x4 where there were had no significant differences due to male or female parent. For fruit traits which included fruit length (FL), there were significant or highly significant differences due to the maternal effect between the majority of the hybrids and their F_{1r} hybrids as it is shown in Table 3.

Table 3. Reciprocal effects of F_1 vs F_{1r} for vegetative, earliness yield and fruit traits in summer squash.

Crosses		S.L cm.	FF%	NDFF	EY/P	NF/P	FW	TY/P	FL
1x2 V 2x1		-14.05	7.720	-2.670	0.900	2.200**	-16.070**	-0.210**	2.530**
1x3 V 3x1		14.16	4.620	3.000	0.900	0.160	44.500**	-0.060	4.000**
1x4 V 4x1		10.83	2.250	-0.330	0.790	1.540**	8.260*	0.480**	1.000*
1x5 V 5x1		-2.380	3.750	-1.330	1.040	-2.460**	51.500**	0.820**	1.670**
2x3 V 3x2		-20.52	2.740	3.330	0.810	-2.090**	9.070*	0.110*	-1.340**
2x4 V 4x2		-36.00	-3.870	-0.340	0.920	-1.120*	-6.130	0.040	-0.100
2x5 V 5x2		-36.73	-4.800	2.000	1.070	-0.870*	-4.060	-0.790**	-7.300**
3x4 V 4x3		-67.20	6.450	-1.670	0.890	-2.960**	-38.10**	-0.440**	-0.660
3x5 V 5x3		-49.77	-3.100	3.660	0.970	-6.050**	-27.67**	0.530**	1.900**
4x5 V 5x4		-28.22	-12.38	4.670	0.950	-2.550**	37.04**	0.010	2.000**
LSD	5%	9.520	1.574	0.747	0.137	0.728	7.172	0.097	0.842
	1%	13.70	2.264	1.075	0.198	1.047	10.319	0.140	1.212

Heterosis as general phenomena in summer squash

The estimates of heterosis from the mid-parent for all the F_1 and their F_{1r} hybrids were obtained and the results were presented for vegetative, earliness, yield and fruit traits in Table 4. For S.L cm trait, the mid-parent of the five parents was 74.4 cm while the average of 20 F_1 hybrids was 83.5 cm showing significant heterosis for this trait. For FF%, the lowest parent, the highest parent and the overall average of 20 F_1 hybrids are presented in the same Table. The lowest parent was P_3 while the highest parent was P_5. The estimated heterosis from mid-parent for this trait was -0.89%, which was in significant. In general, mid-parent heterosis for all the 20 F_1 hybrids were only significant for S.L cm but it was insignificant for FF%.

For S.L cm, the average of 10 F_1 and their ranges in addition to the average of the 10 F_{1r} hybrids and their ranges were also presented in Table 4. It appeared that the averages of 10 F_1 hybrids were smaller than F_{1r} hybrids showing 72 and 95 cm, respectively. Thus, heterosis from the mid-parent for the F_1 hybrid was insignificant of -3.7%, while for F_{1r} it was significant of 27.1%. These results for steam length (S.L cm) showed the importance of reciprocal effect. In this respect, it should be indicated that the best hybrid from the F_1 hybrids was the hybrid 4x5 which showed 128 cm while it's reciprocal 5x4 showed 150 cm indicating the presence of maternal effect. Also, FF% did not show significant heterosis since it showed negative heterosis. All F_1 hybrids which including P_5 was the highest for this trait.

For earliness traits, NDFF and EY/P, it appeared from the data in the same Table that the mid-parent of the five parents for NDFF was 45.20 while the average of 20 F_1 hybrids was 46.35 which shows modest amount of heterosis for days to the first female flower. The earliest parent was P_5 while the latest parent was P_2. The estimated heterosis for this trait was 2.55% from the mid parent. The heterosis from the mid-parent for the F_1 hybrid was 3.688%, while for F_{1r} was 1.40%. These results for days to the first female flower showed differences due to reciprocal effect for this trait. In this respect, it should be indicated that the best hybrid for NDFF was the hybrid 3x2 which only showed 40.67 days and was as early as the earliest parent P_5. Also, EY/P showed significant heterosis from the averages of 20 $F_{1,1r}$ hybrid, 10 F_1 and 10 F_{1r} hybrids. The two hybrids, 5x1 and 5x2 were the highest for this trait and both of them have P_5 as a male parent.

The mid-parent for NFP was 8.07 % while the average of 20 F_1 hybrids was 9.13 % showing significant heterosis for number of fruit per plant. The best parent was P_5 while the lowest parent was P_3. The estimated of heterosis of this trait was 13.18%, from all 20 F_1 hybrids which were highly significant. For FW, the estimated values of heterosis from the mid-parent for this trait were significant of 6.36% when estimated from the 20 $F_{1,1r}$ hybrids. For NFP, the heterosis from the mid parent for the F_1 hybrid was 4.387%, while it was 21.98% for F_{1r}. This result revealed the importance of reciprocal effect for this trait. In this respect, it should be indicated that the best hybrid for NF/P was the hybrid 5x3 which showed 12.21 fruits per plant and exceeded the best parent.

Table 4. The parent means of all varieties, F_1 and F_{1r} hybrids, and the estimated values of heterosis relative to mid-parent for vegetative, earliness, yield and fruit traits in summer squash

Generation		S.L cm	FF%	NDFF	EY/P	NF/P	FW	TY/P	FL
M.P.		74.79	58.54	45.20	0.86	8.07	119.36	5.05	11.88
Range		42.67	54.13	40.33	0.73	6.04	83.33	4.12	7.87
		120.4	62.83	47.33	0.99	10.70	149.33	6.14	14.97
$F_{1\ (20)}$		83.54	58.02	46.35	0.92	9.13	126.99	5.63	14.87
Range		52.89	50.33	40.67	0.69	6.16	83.67	4.98	13.00
		150.0	69.30	50.67	1.41	12.21	166.7	6.90	16.67
$H_{(20)}$ (MP) %		11.71**	-0.89	2.55**	7.03**	13.18**	6.36**	11.55**	25.18**
LSD	5%	4.760	1.667	0.787	7.03**	0.069	3.586	0.364	0.049
	1%	6.849	2.399	1.132	0.275	0.099	5.159	0.523	0.070
$F_{1\ (10)}$		72.05	58.19	46.87	0.92	8.42	129.91	5.66	15.06
Range		52.89	54.72	44.00	0.69	6.16	98.73	4.98	13.33
		121.78	62.74	50.67	1.41	9.82	153.37	6.48	16.67
$F_{1r\ (10)}$		95.04	57.85	45.84	0.92	9.84	124.07	5.61	14.69
Range		57.67	50.33	40.67	0.79	6.17	83.67	4.98	12.00
		150.00	69.30	48.00	1.07	12.21	166.67	6.90	20.63
$H_{(10)}$ F_1 %		-3.662	-0.605	3.688**	6.628**	4.387**	8.798**	12.04**	26.73**
$H_{(10)}$ F_{1r} %		27.07**	-1.18	1.40*	7.44**	21.98**	3.91*	11.07**	23.62**
LSD	5%	5.214	1.826	0.862	0.301	0.075	3.928	0.399	0.053
	1%	7.503	2.628	1.240	0.433	0.108	5.652	0.573	0.077

For TY/P, the estimated heterosis for this trait was 11.55%. Similarly, the estimates of heterosis of 10 F_1 and 10 F_{1r} hybrids were 12.04 and 11.07%, respectively, which were highly significant. FL showed significant heterosis from the overall mean of the 20 F_1 hybrids by 29.18%. The heterosis estimates values from mid-parent for the same trait for the 10 F_1 hybrids was 26.7%. While for the 10 F_{1r} hybrids, it was 23.6%. Thus, heterosis from mid parent was presence of hybrids having high values for some traits.

Heterosis from the better parent

Some F_1 hybrids presented in Table 5 exceeded the best parent for steam length (S.L cm). The F_1 hybrid 5x4 had mean value of 150 cm for S.L cm and its reciprocal gave 120 cm which exceeded or it was as good as P_5 giving 120 cm. For FF%, the better parent exceeded the three means of 20 F_1, 10 F_1, and 10 F_{1r} hybrids. The better parent was P_4 which showed 62.3%, while the three means of 20 $F_{1,1r}$, 10 F_1, and 10 F_{1r} hybrids were: 58.02%, 58.19% and 57.85%, respectively. For this trait, it should be indicated that the hybrid 5x4 gave 69.3 %, which exceeded the better parent. The P_5 was as good as P_4 for this trait with insignificant difference which indicated once more that P_5 was the best parent for this trait and steam length.

The means of NDFF and EY/P are also presented in Table 5. For NDFF, the better parent was 40.33 days to first female flower while the average of 20 $F_{1,1r}$, 10 F_1 and their 10 F_{1r} hybrids were: 46.35, 46.87 and 45.84 days, respectively. Therefore, the heterosis from the better parent would be highly significant but unfavorable. The obtained values of heterosis were: 10.13, 11.35 and 8.91%, respectively. For EY/P, the values of heterosis of this trait in hybrids were close to the better parent. The better parent was also P_5 which showed 0.93 kg/plot while the three means of hybrids showed the same 0.920 kg/per plot. For this trait, it would be indicated that the hybrid 1x2 gave 1.41 kg/plot, which exceeded the better parent.

For number of fruits per plant, the better parent was P_5 with a mean of 10.70 fruits. While, the averages of the 20 $F_{1,1r}$, 10 F_1 and their 10 F_{1r} hybrids were: 9.13, 8.42 and 9.84 fruits, respectively. For average fruit weight, negative values of heterosis were obtained for three means of -4.62, -2.57 and -6.66%, respectively. However, there are some F_1 hybrids such as 5x3 and 4x3 gave 166.33 and 158.1 grams, respectively which exceeded the better parent (144.3 gr). For FW, Similar trend was observed for TY/P, where the P_5 was the better parent, which gave 6.14 kg per plot which exceeded the three means of 20 $F_{1,1r}$, 10 F_1, and 10 F_{1r} hybrids which gave 5.63, 5.66 and 5.61 kg/plot, respectively. However, there were some F_1 hybrids such as 5x2 and 5x4 gave 6.90 and 6.47 kg/plot exceeding the better parent. For fruit length, in general, its behavior did not differ much than the other traits since there were significant and highly significant heterosis relative to the better parent. Furthermore, the P_5 still stand as the better parent for the majority of studied traits including yield and fruit characters.

In general, heterosis is always present for most traits when estimated from the mid-parent but few hybrids exceeded their better parent. Therefore, the choice of the cross combination is of great importance to obtain high yielding F_1 hybrids which show hybrid vigor. In this respect, many investigators reported similar results among them Jahan *et al*., (2012); César *et al*., (2013) and Hussien (2015).

Table 5. The better parent and the means of all 20 $F_{1,1r}$ hybrids, 10 F_1 and 10 F_{1r} hybrids and the estimated values of heterosis relative to the better parent for vegetative, earliness, yield and fruit traits in summer squash.

Generation		S.L cm	FF%	NDFF	EY/P	NF/P	FW	TY/P	FL
B.P.		120.44 (P_5)	62.33 (P_4),(P_5)	40.33 (P_5)	0.93 (P_5)	10.70 (P_5)	149.3 (P_5)	6.14 (P_5)	14.97 (P_5)
M $_{20}$ F_1		83.54	58.02	46.35	0.920	9.130	126.9	5.630	14.87
H% $_{20}$ F_1		-7.054	-4.543**	10.13**	-0.348**	0.462	-4.620	2.645**	12.64**
M $_{10}$ F_1		72.05	58.19	46.87	0.920	8.420	129.9	5.660	15.06
H% $_{10}$ F_1		-18.57**	-4.165**	11.35**	-0.703**	-6.203**	-2.574	3.000**	14.23**
M $_{10}$ F_{1r}		95.04	57.85	45.84	0.920	9.840	124.07	5.610	14.69
H% $_{10}$ F_1r		4.461	-4.921**	8.914**	0.008	7.127**	-6.665	2.289**	11.05**
LSD	5%	9.520	1.574	0.747	0.137	0.728	7.172	0.097	0.842
	1%	13.70	2.264	1.075	0.198	1.047	10.319	0.140	1.212

Diallel crosses analysis and nature of gene action

The genetic materials used in this investigation were setup in a complete diallel crosses mating design and yielded 10 F_1 hybrids and 10 F_{1r} reciprocal hybrids. The analysis of variance of complete diallel crosses for vegetative traits which including S.L cm and FF% were obtained and the results are presented in Table 6. It appeared from the Table that the mean squares of GCA were highly significant for the two vegetative traits. The same was true for SCA which was highly significant for S.L cm but it was not significant for FF%. The magnitudes of the mean squares of both GCA and SCA indicated their importance. However, the mean squares of GCA for the two traits were larger in their magnitudes than those of SCA and the ratio of GCA/SCA was larger than unity. The magnitudes of reciprocal variances were also highly significant indicating the importance of maternal effect. Therefore, the choice of the male or female parent is very important to produce the best hybrids. In this respect, many authors among them Abd El-Hadi *et al*., (2013) and Hussien (2015) obtained similar results indicating the importance of GCA variances.

The mean squares of GCA and SCA were significant and highly significant for both NDFF and EY/P. These results indicated the importance of GCA and SCA for these two traits. The ratio of GCA/SCA was larger than unity indicating the importance of GCA relative to SCA. Therefore, it would be concluded that the additive genetic variance would be more present and effective than non-additive variance including dominance. Similarly, the mean squares of reciprocal effects were also highly significant for NDFF and EY/P indicating the importance of maternal effects.

The magnitudes of mean squares of GCA were larger than SCA and significant for yield and fruit traits.

The large magnitudes of GCA and SCA were supported by the results which showed the absence of heterosis from the better parent for most F_1

hybrids, although heterosis was present from the mid-parent. The presence of significant SCA suggested the possibility of developing breeding programs to improve yield components and fruit characters from the segregating generations of the promising F_1 hybrids especially those hybrids which exceeded P_5. In this respect, similar results were reported by Abd El-Salam *et al*., (2010); Kumar and Wehner (2011) and Abed Al-Muhsin *et al*., (2012).

Table 6. The analysis of variance of the complete diallel crosses of vegetative, earliness, yield and fruit traits in summer squash

S. O. V.	DF	MS							
		S.L cm.	FF%	NDFF	EY/P	NF/P	FW	TY/P	FL
Reps	2	53.14	12.87	1.550	0.005	0.254	56.04	0.004	1.209
Hybrids	19	2589.6**	70.69**	14.718**	0.063**	8.889**	1819.7*	0.957**	12.05**
GCA	4	5661.8*	182.9**	33.766**	0.073**	10.07**	3293.5**	3.225**	12.57**
SCA	5	1897.9**	$17.22^{N.S}$	7.5490*	0.058**	4.278**	1675.4**	0.434**	8.940**
Reciprocal	10	1706.5**	52.51**	10.683**	0.061**	10.72**	1302.6**	0.311**	13.40**
Error	38	99.51	13.19	3.0237	0.013	0.5912	51.66	0.005	0.7990
GCA/SCA		2.983	10.62	4.472	1.258	2.353	1.965	7.430	1.406

The magnitude of genetic variance components

The additive variances predominated over the non-additive including dominance variances as estimated and presented in Table 7. Also, the reciprocal variances were also large for all studied traits which emphases the significant role of maternal and paternal effects in controlling there traits.

Similarly, for earliness traits, the additive variance predominanted the dominance variance except for EY/P trait as presented in Table 7 with modest values of reciprocal variances. Regarding the heritability in broad and narrow senses, the NDFF showed the highest percentage of heritability. In general, the magnitude of heritability in narrow sense was smaller than those of broad sense indicating the presence of non-additive variances. The degree of dominance was less than unity for NDFF while it was larger than unity for EY/P indicating the presence of non-additive variances for this trait. Generally, earliness traits followed the same trend of vegetative traits where they indicated the importance of additive variance. NF/P and TY/P showed σ^2 A larger than σ^2 D, while for FW, the σ^2 D was dominant over σ^2 A. The σ^2 recp. was larger for FW emphasizing the importance of maternal effect on the expression of this trait which depends on the male or the female parent. The heritability values were larger in broad than narrow sense for all traits. The magnitude of narrow sense heritability for TY/P revealed that reciprocal recurrent selection would be effective in the improvement this trait. The degree of dominance was less than unity for NF/P and TY/P while it was larger than unity for the other traits indicating that both additive and non-additive variances would have a significant role in the inheritance of yield traits. The absence of heterosis from the better parent was also found by other investigators among them Jahan *et al*., (2012) and Cruz and Regazzi (2001).

Table 7. The estimates of genetic variance components and heritability of vegetative, earliness, yield and fruit traits in summer squash.

Genetic parameters	S.L cm.	FF%	NDFF	EY/P	NF/P	FW	TY/P	FL
σ^2 ph	3056.9	90.13	17.85	0.0540	9.421	2028.3	1.305	12.37
σ^2 A	1254.6	55.26	8.740	0.004	1.920	539.20	0.940	1.200
σ^2 D	899.2	2.020	2.260	0.0200	1.840	811.9	0.2100	4.070
σ^2 recp.	803.5	19.66	3.830	0.0200	5.070	625.5	0.1500	6.300
σ^2 e	99.52	13.19	3.024	0.0100	0.5910	51.66	0.005	0.8000
$H_{b.s}$ %	70.46	63.55	61.61	44.44	39.91	66.62	88.12	42.60
$H_{n.s}$ %	41.04	61.31	48.95	7.41	20.38	26.59	72.03	9.70
$\bar{d}$	0.847	0.191	0.509	2.236	0.979	1.227	0.473	1.842

General and specific combining effects of parents and hybrids GCA effects (gi)

According to the results in Table 8, Eskandrani (P_5) was the best combiner for vegetative traits which include S.L cm. and FF% followed by Caserta italiana (P_2) which was the best for the percentage of female flower (FF%). While, for earliness traits, Caserta Italiana (P_2) was the best combiner for earliness traits which include days to the first female flower (NDFF). For early yield per plot (EY/P), the GCA effects were modest and close to the general mean of the hybrids obtained from the half diallel population. Regarding yield and fruit traits, no specific parental variety was the best or inferior for both traits. However, the Eskandrani (P_5) was the best combiner for most yield components traits.

Table 8. Estimates of general combining ability effects for parental varieties for vegetative, earliness, yield and fruit traits in summer squash.

Parents	S.L cm	FF%	NDFF	EY/P	NF/P	FW	TY/P	FL
P1	-3.91	-3.49	0.53	0.031	-1.032	-23.66	-0.47	-1.418
P2	-1.17	2.98	-1.86	0.070	0.334	1.751	-0.122	0.482
P3	0.69	-3.05	-0.97	-0.068	-0.415	8.429	-0.172	0.721
P4	0.38	0.36	1.48	-0.067	0.189	4.862	0.091	0.166
P5	4.01	3.20	0.81	0.035	0.923	8.618	0.669	0.049
SE	0.11	0.76	0.36	0.02	0.16	1.51	0.01	1.18

SCA effects (Sij)

The diallel crosses mating design yield F1 hybrids which are the result of combining two parents showing specific combining ability effects (Sij) as presented in Table 9. These effects are an effective way to test and select the best combinations obtained from the different crosses. Therefore, to identify the best hybrid combinations, the specific combining ability effects (Sij) for the 20 crosses were estimated. The high value of Sij cross which involving two parents with would be a promising way for genetic improvement (Cruz and

Regazzi, 2001). Furthermore, The Sij values reflect the importance of non-additive genetic effects including dominance and epistasis.

For vegetative traits, the hybrids1x2 and 4x5 showed the best combinations for steam length. Whereas, the reciprocal cross 2x1 had the best value for the percentage of female flowers. Regarding earliness traits, the hybrid 2x3 showed desirable negative value of Sij for days to the first female flower. While, for the early yield per plot, modest values for Sij were recorded for the majority of hybrids except the hybrid 1x2 for early yield. In the same trend, the specific combining ability effects (Sij) for yield and fruit traits revealed that the hybrids 1x2 and 4x5 showed the best positive values for NFP. While, the hybrids 5x1 followed by 2x4 were the best combinations. For FW, For total yield per plot, the hybrids 5x1 and 2x5 exhibited the best positive values of Sij. The hybrids 2x5, 3x1 and 2x1 were the promising hybrids for FL. The results obtained for GCA and SCA effects were in agreement with the magnitudes of heterosis and with the performances of F_1 hybrids. In this respect, many authors among them Shamil and Wiam (2011) and Abd El-Hadi *et al*., (2013) obtained similar results.

In collusion, the performance of the five parents, the 10 F_1 hybrids and the 10 F_{1r} reciprocal hybrids were variable. The P_5 appeared to be the best parent for vegetative traits where no parents or hybrids were earlier than it. For yield and fruit traits, once more P_5 was not only the best parent but also better than most the hybrids for almost all traits. The reciprocal effects were variable from one hybrid to another for all traits. Heterosis from the better parent was not present for all traits where, many values were negative. The analysis of complete diallel crosses showed that GCA, SCA and reciprocal were highly significant indicating the presence of important differences among the parents and hybrids. The magnitude of GCA was always larger than SCA. The σ_A^2 variances were larger thanσ_D^2, although, σ_D^2 variances were also present. These results were supported by absence of heterosis from the better parent. Therefore, the estimates of heritability in narrow sense were smaller than their corresponding estimates of heritability in broad sense for all traits. In general, the results revealed that the choice of the parents is of great importance to produce superior hybrids which would exceed the better parents. In this study, the parents were commercial varieties obtained from breeding program and have good performances.

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الهجن النوعية و بين النوعية في قرع الكوسة

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يعد الإنتاج المحلى لهجن او أصناف جديدة لمحصول قرع الكوسة متميزة بمحصولها الوفير و تبكيرها عن الهجن المستورده ضروره ملحة. لذا كان الهدف من هذه الدراسة هو محاولة الحصول على افضل التراكيب الوراثية المبشرة بإعطاء افضل هجن F_1 عن طريق دمج جيرمبلازم متباين الخلفية الوراثية. علاوة على ذلك, دراسة قوة الهجين و طبيعة فعل الجين المتعلقة بالشكل المظهرى. في هذه الدراسة تم استخدام اربعة أصناف تنتمى الى *Cucurbita pepo* L. و هي Militte (P_1) , Caserta italiana (P_2) , Zucchini Grey (P_3) , Eskandrani (P_5) بالإضافة الى صنف ينتمى الى النوع *C. maxima* "Abobrinha redonda" Duch . تم زراعة هذه الإباء في الموسم الصيفى 2014 و عمل لها تلقيح ذاتى بالإضافة الى إدخالها في برنامج تهجين كامل لاعطاء 20 هجين. في الموسم التالى 2015 , تم تقييم كافة التراكيب الوراثية فى تجربة حقلية باستخدام تصميم القطاعات الكاملة العشوائية في ثلاث مكررات. تم تسجيل البيانات على الصفات التالية: طول الساق, نسبة الأزهار المؤنثة, عدد الأيام حتى ظهور أول زهرة مؤنثة, المحصول المبكرلكل وحدة تجريبية, عدد الثمار على النبات, متوسط وزن الثمرة , المحصول الكلى لكل وحدة تجريبية و طول الثمرة. كان أداء الإباء بالإضافة الى الهجن و الهجن العكسية الناتجه متبايناً. حيث كان الاب إسكندرانى افضل الاباء اقلمة من حيث الصفات الخضرية. وبالنسبة اللمحصول وصفات الثمار, تفوق الصنف اسكندرانى على بقية الأباء وايضاً على معظم الهجن الناتجة بالنسبة لغالبية الصفات المدروسة. لم تظهر قوة الهجين بالنسبة لأفضل الأباء للصفات الخضرية حيث كان هناك العديد من القيم السالبة. اظهر تحليل التباين لنظام التزاوج الكامل فروقا معنوية كل من القدرة العامة , الخاصة على التالف وكذلك تأثير الام. التباين التجميعى كان اكثر أهمية مقارنة بالتباين السيادى على الرغم من حضور الأخير. هذه النتائج تتوافق مع غياب قوه الهجين بالنسبة لافضل الإباء. اشارت النتائج ان متوسط الهجن النوعية على سبيل المثال 1x4 , 2x4 , 3x4 و 4x5 و الهجن العكسية كانت افضل في أدائها مقارنة ببقية الهجن. الهجن المشتملة على الاب P_4 كاب او ام يمكن اعتبارها كهجن نوعية يمكن استغلالها في الحصول على اتحادات وراثية جديدة قد تكون مفيدة لبرامج تحسين قرع الكوسة.

Table 9. Estimates of specific combining ability effects (Sij) for the hybrids and their reciprocals for vegetative, earliness, yield and fruit traits in summer squash.

Hybrids	S.L cm		FF%		NDFF		EY/P		NF/P		FW		TY/P		FL	
	Sij	Rij	Sij	Rij	Sij	Rij	Sij	Rij	Sij	Rij	Sij	Rij	Sij	Rij	Sij	Rij
1x2	23.98	-7.03	1.375	3.86	1.306	-1.334	0.130	0.254	23.98	-7.03	1.956	-8.033	0.042	-0.106	-0.67	1.27
1x3	-1.43	7.08	1.157	2.307	-0.417	1.500	0.027	0.014	-1.43	7.08	14.161	22.25	0.273	-0.031	0.46	2.00
1x4	-10.63	5.42	-1.293	1.1265	-0.528	-0.167	-0.092	0.003	-10.63	5.42	-13.589	4.133	-0.038	0.24	-0.12	0.50
1x5	-11.91	-1.19	-1.239	1.878	-0.361	-0.667	-0.065	-0.119	-11.91	-1.19	-2.528	25.75	-0.278	0.4105	0.33	0.83
2x3	-0.77	-10.26	-0.992	1.3685	-1.194	1.667	-0.078	0.035	-0.77	-10.26	-21.733	4.533	-0.233	0.057	-0.87	-0.67
2x4	-12.79	-18.00	0.879	-1.9335	0.528	-0.167	0.008	0.012	-12.79	-18.00	20.434	-3.0665	-0.132	0.017	-0.04	-0.05
2x5	-10.42	-18.36	-1.262	-2.403	-0.639	1.000	-0.060	-0.102	-10.42	-18.36	-0.656	-2.033	0.323	-0.397	1.58	-3.65
3x4	1.65	-33.60	-1.126	3.2265	0.306	-0.834	0.006	-0.097	1.65	-33.60	-1.228	-19.05	0.088	-0.2215	1.24	-0.33
3x5	0.55	-24.89	0.961	-1.5515	1.306	1.833	0.046	-0.040	0.55	-24.89	8.800	-13.833	-0.127	0.264	-0.82	0.95
4x5	21.77	-14.11	1.540	-6.1885	-0.306	2.334	0.079	0.019	21.77	-14.11	-5.617	18.517	0.082	0.002	-1.09	1.00
SE (Sij, Rji)	2.78	4.07	1.04	1.48	-0.306	2.334	0.033	0.046	2.78	4.07	2.07	2.93	0.020	0.028	0.25	0.36