

## 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.; Milite ( $P_1$ ), 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: stem 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  $F_1$  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  $\sigma_A^2$  variances were larger than  $\sigma_B^2$ , although,  $\sigma_D^2$  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%, stem length 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<sub>1</sub>) obtained from National Genebank, Agricultural Research Center, Giza, Egypt; Caserta italiana; (P<sub>2</sub>) obtained from Brazil; Zucchini Grey (P<sub>3</sub>) obtained from USA; Abobrinha redonda (P<sub>4</sub>) was a foreign variety having variables traits and finally Eskandrani (P<sub>5</sub>) obtained from Agricultural Research Center Giza, Egypt. These five varieties were used to generate 20 possible F<sub>1,1r</sub> 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<sub>1,1r</sub> hybrids which included 10 F<sub>1</sub> and 10 F<sub>1r</sub> reciprocal hybrids.

### Experimental design

On the 15<sup>th</sup> of March 2015, all 20 F<sub>1,1r</sub> 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: stem 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:  $H\% (MP) = \frac{F_1 - M.P}{M.P} \times 100$  and  $H\% (BP) = \frac{F_1 - BP}{BP} \times 100$ .

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

$$h^2_b\% = \frac{2\sigma^2g + \sigma^2s + \sigma_{rc}^2}{\sigma^2Ph} \times 100 \quad \text{and} \quad h^2_n\% = \frac{2\sigma^2g}{\sigma^2Ph} \times 100$$

where:

$$\sigma^2Ph = 2\sigma^2g + \sigma^2s + \sigma_{rc}^2 + \sigma^2e$$

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

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

## RESULTS AND DISCUSSION

### Genotypic variation

The analyses of variance and mean squares of vegetative traits which included stem 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<sub>1</sub> hybrids and their F<sub>1r</sub>. 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 (NDF) 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<sub>1</sub> hybrids and their F<sub>1r</sub> 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<sub>1</sub> and F<sub>1r</sub> 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%	NDF	EYP	NFP	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<sub>1,1r</sub> hybrids

The mean performance of the parental varieties and their 20 F<sub>1</sub> 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 stem length (S.L cm), the parent P<sub>5</sub> appeared to be the best one for these traits. It showed plant high of 120.44 cm followed by P<sub>4</sub>, P<sub>3</sub>, P<sub>1</sub> and P<sub>2</sub>. The percentage of female flower (FF%) showed that parent P<sub>4</sub> gave 62.83% and P<sub>5</sub> gave 61.69%. While the other three parents had the minimum values for this trait. In general, the parental variety Eskandrani (P<sub>5</sub>) appeared to be the best parent.

The 10 F<sub>1</sub> and their 10 F<sub>1r</sub> hybrids showed variable means where the means ranged from 52.89 to 121.78 cm for stem 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<sub>1r</sub> 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<sub>1r</sub> 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<sub>5</sub> 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<sub>4</sub> and P<sub>5</sub> were the earliest varieties for NDFP giving 40.67 and 40.33 days, respectively as seen in Table 2. Therefore, both P<sub>1</sub> and P<sub>5</sub> 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 NDFP 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<sub>5</sub> appeared to be the best parent for NF/P followed by P<sub>4</sub>. The two parental varieties P<sub>5</sub> and P<sub>4</sub> 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<sub>1</sub> 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<sub>1r</sub> reciprocal hybrids, they generally showed higher values with respect to NFP comparing with their F<sub>1</sub> hybrids as seen in Table 2. The F<sub>1r</sub> 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<sub>1r</sub> 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<sub>1r</sub> 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<sub>4</sub>) to 14.97 cm (P<sub>5</sub>). In the case of the F<sub>1</sub> and their F<sub>1r</sub> 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, Milite, Caserta Italian, Zucchini Grey and Eskandrani which belong to *Cucurbita pepo* L. where Abobrinha redonda belong to *Cucurbita maxima*

*Duch.* Therefore, all the hybrids including  $P_4$  as a male or a female parent would be considered as interspecific hybrids. The results indicated that the means of interspecific hybrids:  $1 \times 4$ ,  $2 \times 4$ ,  $3 \times 4$  and  $4 \times 5$  and their reciprocals showed better performances than the other hybrids. They showed large values for plant height where the hybrid  $4 \times 5$  and its reciprocal  $5 \times 4$  which showed 122 and 150 cm, respectively which exceeded all other hybrids. The interspecific hybrids  $4 \times 5$  and its reciprocal  $5 \times 4$  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 stem length (S.L cm) and the percentage of female flower (FF%), significant differences between each hybrid and its reciprocal for stem 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 stem 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<sub>1,1r</sub> crosses for vegetative, earliness, yield and fruit traits in summer squash.**

Genotypes	S.L cm.	FF%	NDF	EY/P	NF/P	FW	TY/P	FL	
P <sub>1</sub> (Militte)	53.03	56.33	46.33	0.99	6.85	109.33	4.81	12.53	
P <sub>2</sub> (C. Italian)	42.67	57.74	47.33	0.78	6.66	134.97	4.12	11.83	
P <sub>3</sub> (Z. Grey)	61.87	54.13	51.33	0.79	6.04	119.83	4.90	12.20	
P <sub>4</sub> (A. redonda)	95.94	62.83	40.67	0.73	10.07	83.33	5.28	7.87	
P <sub>5</sub> (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<sub>1</sub> hybrids. The hybrids which had P<sub>1</sub> and P<sub>3</sub> 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 P<sub>2</sub>, P<sub>4</sub> and P<sub>5</sub> 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<sub>1r</sub> 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 stem 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 its 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<sub>5</sub>. Also, EY/P showed significant heterosis from the averages of 20 F<sub>1,1r</sub> hybrid, 10 F<sub>1</sub> and 10 F<sub>1r</sub> hybrids. The two hybrids, 5x1 and 5x2 were the highest for this trait and both of them have P<sub>5</sub> as a male parent.

The mid-parent for NFP was 8.07 % while the average of 20 F<sub>1</sub> hybrids was 9.13 % showing significant heterosis for number of fruit per plant. The best parent was P<sub>5</sub> while the lowest parent was P<sub>3</sub>. The estimated of heterosis of this trait was 13.18%, from all 20 F<sub>1</sub> 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<sub>1,1r</sub> hybrids. For NFP, the heterosis from the mid parent for the F<sub>1</sub> hybrid was 4.387%, while it was 21.98% for F<sub>1r</sub>. 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<sub>1</sub> and F<sub>1r</sub> 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	FP%	NDF	EY/P	NFP	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 <sub>1 (20)</sub>	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 <sub>(20)</sub> (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 <sub>1 (10)</sub>	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 <sub>1r (10)</sub>	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 <sub>(10)</sub> F <sub>1</sub> %	-3.662	-0.605	3.688**	6.628**	4.387**	8.798**	12.04**	26.73**	
H <sub>(10)</sub> F <sub>1r</sub> %	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<sub>1</sub> and 10 F<sub>1r</sub> 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<sub>1,1r</sub> hybrids, 10 F<sub>1</sub> and 10 F<sub>1r</sub> 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	N/P	FW	TY/P	FL	
B.P.	120.44 (P <sub>5</sub> )	62.33 (P <sub>4</sub> ),(P <sub>5</sub> )	40.33 (P <sub>5</sub> )	0.93 (P <sub>5</sub> )	10.70 (P <sub>5</sub> )	149.3 (P <sub>5</sub> )	6.14 (P <sub>5</sub> )	14.97 (P <sub>5</sub> )	
M <sub>20</sub> F <sub>1</sub>	83.54	58.02	46.35	0.920	9.130	126.9	5.630	14.87	
H% <sub>20</sub> F <sub>1</sub>	-7.054	-4.543**	10.13	-0.348	0.462	-4.620	2.645	12.64	
M <sub>10</sub> F <sub>1</sub>	72.05	58.19	46.87	0.920	8.420	129.9	5.660	15.06	
H% <sub>10</sub> F <sub>1</sub>	-18.57**	-4.165**	11.35	-0.703	-6.203	-2.574	3.000	14.23	
M <sub>10</sub> F <sub>1r</sub>	95.04	57.85	45.84	0.920	9.840	124.07	5.610	14.69	
H% <sub>10</sub> F <sub>1r</sub>	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<sub>1</sub> hybrids and 10 F<sub>1r</sub> 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<sub>1</sub>

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<sub>1</sub> hybrids especially those hybrids which exceeded P<sub>5</sub>. 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%	NDF	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 <sup>ns</sup>	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 emphasizes the significant role of maternal and paternal effects in controlling there traits.

Similarly, for earliness traits, the additive variance predominated 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 NDF 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 NDF 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  $\sigma^2_A$  larger than  $\sigma^2_D$ , while for FW, the  $\sigma^2_D$  was dominant over  $\sigma^2_A$ . The  $\sigma^2_{recp.}$  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%	NDF	EY/P	NF/P	FW	TY/P	FL
$\sigma^2_{ph}$	3056.9	90.13	17.85	0.0540	9.421	2028.3	1.305	12.37
$\sigma^2_A$	1254.6	55.26	8.740	0.004	1.920	539.20	0.940	1.200
$\sigma^2_D$	899.2	2.020	2.260	0.0200	1.840	811.9	0.2100	4.070
$\sigma^2_{recp.}$	803.5	19.66	3.830	0.0200	5.070	625.5	0.1500	6.300
$\sigma^2_e$	99.52	13.19	3.024	0.0100	0.5910	51.66	0.005	0.8000
H <sub>b.s</sub> %	70.46	63.55	61.61	44.44	39.91	66.62	88.12	42.60
H <sub>n.s</sub> %	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<sub>5</sub>) was the best combiner for vegetative traits which include S.L cm. and FF% followed by Caserta italiana (P<sub>2</sub>) which was the best for the percentage of female flower (FF%). While, for earliness traits, Caserta Italiana (P<sub>2</sub>) was the best combiner for earliness traits which include days to the first female flower (NDF). 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<sub>5</sub>) 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%	NDF	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 hybrids 1x2 and 4x5 showed the best combinations for stem 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<sub>1</sub> hybrids. In this respect, many authors among them Shamil and Wiam (2011) and Abd El-Hadi *et al.*, (2013) obtained similar results.

In conclusion, the performance of the five parents, the 10 F<sub>1</sub> hybrids and the 10 F<sub>1r</sub> reciprocal hybrids were variable. The P<sub>5</sub> 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<sub>5</sub> 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  $\sigma_A^2$  variances were larger than  $\sigma_D^2$ , although,  $\sigma_D^2$  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 رحاب محمد محمد حبيبة ، علي ماهر محمد العدل و إسراء عبدالخالق حامد عثمان قسم الوراثة كلية الزراعة – جامعة المنصورة- مصر.

يعد الإنتاج المحلي لهجن او أصناف جديدة لمحصول قرع الكوسة متميزة بمحصولها الوفير و تكبيرها عن الهجن المستورده ضروره ملحة. لذا كان الهدف من هذه الدراسة هو محاولة الحصول على افضل التراكيب الوراثية المباشرة بإعطاء افضل هجن  $F_1$  عن طريق دمج جيرمبلازم متباين الخلفية الوراثية. علاوة على ذلك، دراسة قوة الهجين و طبيعة فعل الحين المتعلقة بالشكل المظهري. في هذه الدراسة تم استخدام اربعة أصناف تنتمي الى *Cucurbita pepo* L. وهي ( $P_1$ ) Militte ، ( $P_2$ ) Caserta italiana ، ( $P_3$ ) Zucchini Grey ، ( $P_5$ ) Eskandrani بالإضافة الى صنف ينتمي الى النوع *C. maxima* Duch "Abobrinha redonda". تم زراعة هذه الإباء في الموسم الصيفي ٢٠١٤ و عمل لها تلقيح ذاتي بالإضافة الى إدخالها في برنامج تهجين كامل لاعطاء ٢٠ هجين. في الموسم التالي ٢٠١٥ ، تم تقييم كافة التراكيب الوراثية في 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 المبكر لكل وحدة تجريبية، عدد الثمار على النبات، متوسط وزن الثمرة ، المحصول الكلي لكل وحدة تجريبية و طول الثمرة. كان أداء الإباء بالإضافة الى الهجن و الهجن العكسية الناتجة متبايناً. حيث كان الاب إسكندرانى افضل الإباء اقلمة من حيث الصفات الخضرية. وبالنسبة للمحصول و صفات الثمار، تفوق الصنف إسكندرانى 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 التجميعي كان اكثر أهمية مقارنة بالتباين السيادة على الرغم من حضور الأخير. هذه النتائج تتوافق مع غياب قوة الهجين بالنسبة لأفضل الإباء. اشارت النتائج ان متوسط الهجن النوعية على سبيل المثال  $1 \times 4$  ،  $2 \times 4$  ،  $3 \times 4$  و  $4 \times 5$  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%		NDF%		EY/P		NFP		FW		TYP		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



