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STUDIES ON PRODUCTION OF HYBRIDS PEPPER (*Capsicum annuum* L.):
2- ESTIMATION OF HETEROSIS AND TYPES OF GENETIC VARIANCES IN SWEET PEPPER (*Capsicum annuum* L.) FOR SOME ECONOMIC TRAITS

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ABSTRACT

Four pepper cultivars and their hybrids included reciprocals were evaluated in two experimental seasons (2003 and 2004) to the estimates of heterosis , combining ability , types of genetic variations and heritability for some economic characters . The results showed that , heterosis was detected for all the studied traits in both seasons , and the highest values of heterosis were recorded for early yield , total yield and quality traits , while flowering date and fruit shape traits gave a negative and significant estimates of heterosis, however flowering date as an exception showed heterosis, since it had negative value from both mid and better parent . General combining ability (G.C.A) was significant for all the studied traits and was the more important for all traits except for flowering date , early yield and total soluble solids (T.S.S.) ,since, specific combining ability was the large component in inheritance these traits . Both additive and non-additive gene effects were involved in the inheritance of all the studied traits , the additive gene effects were more important than the non-additive ones in the genetic mechanism for the all traits except for flowering date , early yield and total soluble solids (T.S.S.) , the dominance genetic variance play the main role in inheritance of these traits . The presence of large amounts of additive gene variance indicated that selection for improving quantitative traits would be possible in the segregating generations . Moderate to high heritability estimates were observed for all traits in both seasons and fruit characteristics and vitamin C gave the highest estimates of heritability .

INTRODUCTION

Sweet pepper (*Capsicum annuum* L.) is one of the important vegetables cultivated in Egypt and in many other countries for its green , immature fruits and used in various preparations and salads . It is cultivated in open field and in greenhouses . Therefore , it is available in the market all year around. An important goal of the present investigation was the determination of the amounts of heterosis , so the means of the F_1 hybrids (F_1) and F_1 reciprocal hybrids (F1r) were compared with the mid- parents (M.P.) and the better parent (B.P.) , many investigators reported presence of heterosis in pepper (Khalf – Allah *et al*., 1975 ; Taychasinpitak and Taywiya 2003 and Khalil *et. al*., 2004). Also , to improve any quantitative trait of economic usefulness , information about the nature of gene action of this trait should be investigated with respect to the relative magnitudes of additive and non additive genetic variances. When the additive genetic variance is the main component of the total genetic variation, a maximum progress would be expected through selection programs (Khalf – Allah *et al*., 1975; Khem *et. al*., 1980 and Patel *et al.*, 2004) . On the other hand , the presence of a relatively high non- additive genetic variance would indicate that the

production of F_1 hybrids should be the ultimate improvement as a result of the direct relationship between non- additive gene action and heterosis (Miranda *et al*., 1988 ; Ahmed *et. al*., 1994 and Mini and Khader 2004). Additive and non – additive genetic variances could be determined from the estimates of general combining ability and specific combining ability, respectively. Therefore, these estimates were of a greet value in establishing the most promising breeding programs. Thus, the main objectives of present study were : the determination of heterosis over the mid parents and the better parent for the traits and obtain the estimates for different types of gene actions in terms of general and specific combining ability , these estimates could be obtained by evaluating the diallel crosses mating design .

MATERIAL AND METHODS

This work was carried out during two seasons (2003 and 2004) in the Experimental Station at El Baramoon and the genetic material use in this study include four cultivars; i.e., Marconi Rosso , California Wonder , Fushimi Long Green and Vikima . All these cultivars belonging to the species of *Capsicum annuum* L. . Plants from each cultivar were selfed for three generations throughout 1999 and 2000 seasons and in the summer season of 2001, all single crosses including the reciprocals were made among the four parental cultivars according to a complete diallel crosses mating system and these crosses yielded 6 F_1 hybrids (F_1) and 6 F_1 reciprocals hybrids (F_{1r}) . All the genotypes (4 parents , 6 F_1 hybrids and 6 F_1 reciprocals hybrids) were evaluated in two field trials in the Experimental Station at El Baramoon in 2003 and 2004 summer seasons .

The experimental design was a randomized complete blocks design with three replications. The all field practices were carried out in accordance with the regular procedures used in Horticulture Experimental Station at El –Baramoon for pepper cultivation . The plot consisted of one ridge 3 m. long and 50 cm. wide . In each replicate , 10 plants for each parents , crosses and check cultivar (F_1 Gedion) were planted in a single row at a spacing of 50 cm . between rows and 30 cm. between plants within the row . Seeds of different genotypes were sown in mid February and forty five day old seedling were transplanted in the first week of April with one seedling per pit on the northern side. Observation were recorded growth characteristics; i.e., plant height (from the crown to the top of the plants in the end of the season) and days to 50 % flowering , yield and yield components; i.e., early yield (as the average weight of fruits per plant in the first three harvests) , total yield (as the average total weight of picked fruits per plant throughout the entire harvesting season), number of fruits / plant and average fruit weight (g.) , fruit characteristics(using 10 randomly picked fruits per plot) ;i.e., fruit length (cm.) , fruit diameter (cm.), fruit shape and fruit flesh thickness(mm.) and quality traits i.e., total soluble solids % (Rick , 1974) and vitamin C (A.O.A.C.,1990).

The values of heterosis, genetic parameters and correlation coefficient were estimated form the following equations :

1- Heterosis from the mid –parents :

$H\ (M.P.)\ \% = \{(MF_1 - M.P.) / M.P.\} \times 100.$

$= \{(MF_{1r} - M.P.) / M.P.\} \times 100.$

2- Heterosis from the better –parent :

$H\ (B.P.)\ \% = \{(MF_1 - B.P.) / B.P.\} \times 100.$

$= \{(MF_{1r} - B.P.) / B.P.\} \times 100.$

General combining ability (G.C.A) and specific combining (S.C.A) were estimated according to the analysis of the complete diallel cross mating system (Griffing 1956, Model II method I) .

Additive (σ^2A) and non additive (σ^2D) genetic variance were obtained as follows : .

$\sigma^2A = 2\sigma^2g$

$\sigma^2D = \sigma^2s$

The estimates of heritability in both narrow and broad sense were determined according to the following equations:

$$h^r_n\ \% = \frac{2\sigma^2g}{2\sigma^2g+\sigma^2s+\sigma^2r+\sigma^2e} \times 100.$$

$$h^2_b\ \% = \frac{2\sigma^2g + \sigma^2s}{2\sigma^2g+\sigma^2s+\sigma^2r+\sigma^2e} \times 100.$$

RESULTS AND DISCUSSION

Heterosis:

The important goal of the present investigation was to determine the amounts of heterosis for all traits studied in different seasons (2003 and 2004) . The mean of the four parents (M.P.) and the value of better parent (B.P.) for each trait were compared against the mean of the six F_1 hybrids (F_1) and their reciprocals (F_{1r}) and the results presented in Table (1). The results showed presence of significant estimates of heterosis for most traits in both seasons since the values of heterosis were positive and significant for all the studied traits except for flowering date and fruit shape in both seasons which gave a negative and significant estimates of heterosis , however flowering date showed heterosis , since it had negative and significant values when estimated on the base of both mid and better parent . Fruit length and average fruit weight in both seasons and plant height in the second season all these when F_{1r} compared against mid parents (M.P.) gave a not significant estimates of heterosis. The positive and significant estimates of heterosis when the F_1 hybrids compared with the mid parents (M.P.) were 12.24 and 8.66% for plant height , 22.98 and 30.43% for early

yield , 22.82 and 32.87% for total yield , 8.97 and 7.64% for number of fruits / plant , 7.48 and 6.01% for fruit length , 10.26 and 12.27% for fruit diameter , 18.73 and 13.89% for fruit flesh thickness , 20.90 and 16.57% for total soluble solids (T.S.S.) and 13.75 and 7.47% for vitamin C in the first and second season, respectively. Moreover , when the F_1 reciprocal hybrids compared with the mid parents (M.P.) , the positive and significant estimates were 32.03 and 25.89% for early yield , 32.89 and 33.57% for total yield , 10.59 and 12.04% for number of fruits / plant , 9.49 and 15.40 % for fruit diameter , 12.75 and 15.08% for fruit flesh thickness , 21.93 and 16.37% for total soluble solids (T.S.S.) and 11.24 and 7.65% for vitamin C in the first and second season , respectively and 6.38% for plant height only in the first season . On the other hand , the average means of the hybrids(F_1 and F_{1r}) did not significantly exceed the better parent (B.P.) for all traits in both seasons. These results indicated that the estimates of heterosis were high for early yield, total yield and quality traits when the means of F_1 hybrids and F_1 reciprocal hybrids compared with the means of the mid parents (M.P.) , and the estimates of heterosis for these traits did not significantly decrease when the means of F_1 hybrids and F_1 reciprocal hybrids compared with the means of the better parent(B.P.) . So, the choice of parental varieties for hybridization should be taken carefully . Plant breeders should be select high yielding parents in order to obtained superior F_1 hybrids . In this genetic material certain parental cultivars such as Marconi Rosso cv. gave high performing F_1 hybrids , since all F_1 hybrids which had this parent (Marconi Rosso cv.) as a female or male parent were higher than all other hybrids for yield traits. Therefore , these F_1 hybrids increased the average of all F_1 hybrids (F_1) and all F_1 reciprocal hybrids (F_{1r}). Concerning heterosis in pepper , many investigators obtained similar results in which they reported the presence of heterosis over thye mid parents .Among those authors , Khalf –Allah *et. al*., (1975) and Khalil *et al.,* (2004) .

Combining Ability:

Plant breeders are concerned with determination of general combining ability (G.C.A) and specific combining ability (S.C.A)of their genetic materials. According to the expectation of the mean squares, the design variance components for general and specific combining ability could be calculated and translated in terms of genetic variance components (additive and non- additive effects), since they dictate the proper breeding method that should be chosen. General combining ability (G.C.A) and specific combining ability (S.C.A) variances were studied for all characters and the analysis of variance of complete diallel crosses were done for all traits and the results are presented in Table (2). The tests of significance indicated that the mean squares of general combining ability (G.C.A) was significant for all the studied traits in both seasons and was more important and larger than the specific combining ability (S.C.A) for all traits ,except for flowering date which almost equal , early yield and total soluble solids (T.S.S.), while for specific combining ability (S.C.A) , tests of significance indicated that the mean squares of specific combining ability were significant for all traits except for fruit characters which was not

significant in both seasons. The results also showed that specific combining ability (S.C.A) played the main role in inheritance of flowering date(relatively) , early yield and total soluble solids (T.S.S.). These results were in agreement with the obtained results by ,Khem *et al*., (1980) and Miranda *et. al.,* (1988).

Concerning the types of genetic variations , the results in Table (2) indicated that , generally , the variances of additive (σ^2A) and dominance genetic variance(σ^2D) indicated the importance of the first over the later one for all the traits except for flowering date , early yield and total soluble solids (T.S.S.) . Khem *et. al*., (1980) and Patel *et al*., (2004) showed that the additive effects were the most important component of genetic variance for most pepper traits , while , Miranda *et. al*., (1988) and Mini and Khader (2004) mentioned that non additive effects were more important and played the main role in the inheritance of some pepper traits . According to present results mentioned earlier, it could be indicate that additive genetic variance (σ^2A) was more important than dominance genetic variance(σ^2D), the importance of additive genetic variance (σ^2A) and with relatively low of dominance genetic variance(σ^2D) in this genetic materials in most traits , may explain the absence of heterosis from the better parent, except flowering date , which showed better parent heterosis, high S.C.A. and σ^2D. It is known that high values of heterosis and the production of superior F_1 hybrids depend mainly on the presence of large and significant dominance genetic variance. Therefore , the absence of heterosis from the better parent would be understood in view of these results . On the other hand , the presence of large amount of additive genetic variance (σ^2A) indicated that selection for improving quantitative traits in pepper would be possible in the segregating generations of the superior F_1 hybrids .

Moderate to high heritability estimates were observed for all traits from Table (2). Generally , heritability in broad sense was high for fruit characteristics and the values of heritability in broad sense (h^2_b%) were close to their corresponding estimates of heritability in narrow sense (h^2_n %) for these traits. These results were obtained because these traits showed not significant estimates of specific combining ability (S.C.A) and therefore , dominance genetic variance (σ^2D) and the large proportion of additive genes for the inheritance of theses traits with less environmental influences . This was in according with the reports of Khem *et. al.,* (1980) and Patel *et. al*., (2004). For flowering date, early yield , total yield and total soluble solids (T.S.S.), these traits gave a moderate heritability values , these indicated the environmental conditions played a role in inheritance of these traits and also ,the estimates of heritability in broad sense were generally larger than the corresponding of heritability in narrow sense for these traits , these results indicated that the dominance genetic variance was more important in the genetic variation for these traits . It could be indicated that when the traits gave high estimates of heritability indicating that selection would be effective for these traits.

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تقدير قوة الهجين و طرز التباينات الو راثية في الفلفل الحلو لبعض الصفات الاقتصادية.

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تم تقييم اربعة أصناف من الفلفل الحلو والهجن الناتجة منهم شامله الهجن العكسية خلال موسمي ٢٠٠٣ و ٢٠٠٤ وتم تقدير قوة الهجين ، قدرة التآلف ، طرز التباينات الو راثية , درجات التوريث بالإضافة إلى تقدير معامل الارتباط لبعض الصفات الاقتصادية في الفلفل . أظهرت النتائج وجود قوة الهجين لكل الصفات المدروسة وسجلت أعلى القيم لقوة الهجين لصفات المحصول المبكر , المحصول الكلى و صفات الجودة , بينما صفتي موعد التزهير و شكل الثمرة أعطت قيم سلبية ومعنوية لقوة الهجين حيث تدل القيمة السالبة لموعد الزهير على قوة الهجين فى هذه الصفة. بحساب التباين في القدرة العامة على التآلف و القدرة الخاصة على التآلف وجد أن القدرة العامة على التآلف كانت معنوية لكل الصفات المدروسة وكانت الأكبر والأكثر أهمية من القدرة الخاصة على التآلف لكل الصفات عدا صفات موعد التزهير ,المحصول المبكر , المواد الصلبة الكلية الذائبة كانت القدرة الخاصة على التآلف المكون الأكبر في وراثة تلك الصفات. النتائج أيضا أظهرت أن التباين الاضافى والسيادي للجين يدخلوا في وراثة كل الصفات المدروسة وان التباين الاضافى للجين هو الأكثر أهمية في وراثة كل الصفات عدا صفات موعد الأزهار ، المحصول المبكر ، المواد الصلبة الكلية الذائبة كان التباين السيادي هو الذي يلعب الدور الاساسى في وراثة تلك الصفات , وجود نسب أعلى للتباين الاضافى دليل على إمكانية الانتخاب للصفات الكمية في الأجيال الانعزالية. قيم متوسطة إلى مرتفعة من درجات التوريث تم الحصول عليها لكل الصفات و لوحظ ان صفات الثمرة سجلت أعلى القيم لدرجات التوريث.

Table 1 : Estimates of heterosis for all the studied traits in 2003 and 2004 seasons .

Heterosis / Characters	Season 2003				Season 2004			
	Heterosis from the mid parents		Heterosis from the better parent		Heterosis from the mid parents		Heterosis from the better parent	
	F_1 – M.P. / M.P. %	F_{1r} – M.P. / M .P. %	F_1 – B.P. / B.P. %	F_{1r} – B.P. / B.P. %	F_1 – M.P. / M .P. %	F_{1r} – M.P. / M .P. %	F_1 – B.P. / B.P. %	F_{1r} – B.P. / B.P. %
Plant height	12.24 %**	6.38 %*	-7.00%*	-11.85%**	8.66 %**	5.43 %	-11.51 %**	-14.14%**
Flowering date	-8.95 %**	-9.41 %**	-5.25 %**	-5.72 %**	-10.65 %**	-11.18 %**	-6.65 %**	-7.19 %**
Early yield	22.98 %**	32.03 %**	-2.78 %	4.38 %	30.43 %**	25.89 %**	8.81 %	5.02 %
Total yield	22.82 %**	32.89 %**	-7.11 %	0.51 %	32.87 %**	33.57 %**	2.70 %	3.24 %
Number of fruits//plant	8.97 %**	10.59 %**	-50.22 %**	-49.48 %**	7.64 %**	12.04 %**	-53.25%**	-51.34%**
Average fruit weight	-8.44%	-4.39 %	-32.80%**	-29.83%**	-3.44%	-4.16%	-29.15%**	-29.68%**
Fruit length	7.48 %*	-3.16 %	--8.30 %*	-17.38 %**	6.01 %*	-0.67 %	-14.19 %**	-15.59 %**
Fruit diameter	10.26 %**	9.49 %**	-18.87 %**	-19.43 %**	12.27 %**	15.40 %**	-21.82 %**	-19.64 %**
Fruit shape	-13.87 %**	-20.80% **	-55.14**	-58.75 %**	-14.05 %**	-18.73%**	-48.85%**	-51.64%**
Fruit flesh thickness	18.73%**	12.75%**	-12.35 %**	-16.76 %**	13.89%**	15.08%**	-15.09%**	-14.20%**
Total soluble solids	20.90%**	21.93%**	0.00 %	0.85 %	16.57%**	16.37%**	-1.97%	-2.13%
Vitamin C	13.75%**	11.24 %**	-2.04 %	-4.20 %	7.47%**	7.65%**	-4.69%	-4.53%

Table 2 : Estimates of the genetic parameters in pepper genotypes in 2003 and 2004 seasons .

Genetic parameters / Characters	Season 2003						Season 2004					
	G.C.A	S.CA	σ^2A	σ^2D	h^2_n%	h^2_b%	G.C.A	S.CA	σ^2A	σ^2D	h^2_n%	h^2_b%
Plant height	423.745**	18.301**	101.690	10.545	62.46%	68.94%	327.013**	50.028**	70.170	29.549	53.90%	76.61%
Flowering date	15.508**	19.850**	3.540	12.093	22.08%	81.00%	15.067**	16.989**	3.830	9.157	28.72%	77.90%
Early yield	5260.830**	8975.040**	1735.200	5240.154	23.29%	65.26%	3892.180**	4777.170*	7978.316	8241.933	33.45%	68.01%
Total yield	0.169 **	0.175**	0.102	0.108	33.69%	69.37%	0.400**	0.427**	0.160	1.121	41.38%	72.67%
Number of fruits //plant	1322.703**	32.795**	323.090	19.606	64.50%	68.41%	1168.984**	18.851**	287.878	11.046	71.10%	76.56%
Average fruit weight	2391.753**	68.939**	582.016	42.022	69.16%	74.18%	2127.320**	68.888**	515.920	41.967	72.90%	79.01%
Fruit length	10.937**	0.409	2.636	0.126	78.77%	82.29%	11.366**	0.128**	2.810	0.002	80.16%	82.22%
Fruit diameter	5.281**	0.315	1.248	0.190	74.77%	82.29%	6.111**	6.196**	1.482	0.118	81.58%	88.07%
Fruit shape	9.226**	0.201	1.075	0.106	83.91%	89.72%	6.762**	0.224	1.724	0.042	80.32%	86.32%
Fruit flesh thickness	2.559**	0.095*	0.622	0.044	77.65%	83.15%	2.428**	0.103	0.582	0.061	77.87%	86.00%
Total soluble solids	0.426 **	0.643**	0.052	0.259	26.46%	75.51%	0.548**	0.777**	0.042	0.476	28.06%	83.30%
Vitamin C	486.072**	558.603**	96.694	113.962	44.57%	87.10%	791.860**	166.381**	159.554	101.889	58.45%	90.78%

G.C.A : General combining ability . S.C.A : Specific combining ability . σ^2A : Additive genetic variance
σ^2D : Dominance genetic variance. h^2_n % : Heritability in narrow sense. h^2_b % : Habitability in broad sense.

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