Study on Combining Ability and Heterosis of Yield and Its Components in Pepper (*Capsicum annum*, L.).

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ABSTRACT

Six parental genotypes and their fifteen F_1 hybrids in a diallel cross system, without reciprocals, were used in the present study to estimate heterosis percentage relative to both mid and better parents, potence ratios and combining ability (general and specific) for some characters in pepper (*Capsicum annum,* L.). The experiment was conducted at the Experimental Station Farm of Fac. Agric. Minufiya Univ., Shebin El Kom, Egypt, during two successive summer seasons of 2012 and 2013.

The obtained results reflected generally that the mean squares for general (GCA) and specific (SCA) combining abilities were highly significant for all the studied traits, suggesting the presence of both additive and non-additive gene effects in the inheritance of the various studied characters. However, the high ratio of GCA: SCA mean squares showed that GCA effect was more important than SCA effect. The preponderance of GCA effects implied that these characters would respond favorably to direct selection.

Estimates of GCA effects showed that the best combiner parents werer found to be those of P_3 and P_1 for early fruits number, P_6 and P_1 for early fruits weight, P_3 and P_2 for total yield as fruits number and weight, P_1 for fruit diameter, P_4 and P_6 for fruit length, P_6 and P_1 for average fruit weight. For pericarp thickness and vitamin C content, the parental genotype P_1 was the best combiner, while P_2 for TSS content. Estimates of SCA effects showed that the F_1 cross 1×6 reflected the highest value in all the studied traits. For heterotic effect, hybrid vigour was detected in many characters; i.e., early fruits yield, total yield, fruit length, vitamin C and total soluble solids contents. These results suggested that hybrid vigour is available for commercial production of sweet pepper hybrid, and that isolation of pure lines from the progenies of heterotic F_1's is a possible way to enhance the fruits yield and fruit quality.

Key words: heterosis, dominance, combining ability, additive, non-additive, genotypes, potence ratio.

INTRODUCTION

Pepper (*Capsicum annum*, L., 2n=24) is an important vegetable crop that is widely grown in Egypt as well as in many other countries of the world. The cultivated area of pepper, in Egypt, reached 91404 feddans (fed. 4200 m^2), which produced 655841 tons with an average of 7.175 tons/feddan*. This average is relatively low, therefore, much attention must be given to increase it by developing new cultivars or hybrids through sound breeding programs. The popularity of F_1 hybrid cultivars are due to their vigour, uniformity, disease resistance, stress tolerance and good horticultural traits including earliness and long shelf life and therefore giving constant stable high yield (Sood and Kumar 2010). Heterosis, or hybrid vigor, is defined as the ability of hybrids to outperform their best inbred parent with respect to growth, yield and other quantitative traits. Heterosis is defined as the excess of F_1 mean over the better parent (BP), so called better parent heterosis, or the superiority of the F_1 over the mean of the two parents (MP), so called mid-parents heterosis. When the F_1 mean lies within the parental range, this may be appropriately ascribed to dominance (Hill *et al*., 1998). However, the term heterosis describes increased size and yield in crossbred as compared to the corresponding inbred lines (Shull, 1948). It has also been applied to the expression of adaptive traits such as increased fertility and resistance to biotic and abiotic stress (Dobzhansky, 1950). Maximum heterosis is observed in the F_1, but the superiority of the progeny over their parents is progressively lost in subsequent generations obtained through successive selfing (Meyer *et al*., 2004).

Several studies have been conducted on heterosis in F_1 hybrids of pepper for most studied quantitative traits by many researchers such as Geleta *et al*., (2004), Sood and Kaul (2006) and Sood and Kumar (2010) for total fruits yield. Significant heterotic effects were also shown by some crosses for fruit number per plant, number of marketable fruits/plant, fruit length, pericarp thickness and fruit firmness (Sood and Kumar, 2010). They added that none of the cross combinations exhibited significant heterosis for fruit width, average fruit weight and lobes number per fruit. On the other hand, positive heterotic effects

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were observed on the characters fruit weight and fruit number per plant, average fruit weight, fruit width, fruit length, and pericarp thickness in some studied crosses (Thunya and Pratchya, 2003). Dominance for earlier parent, number of fruit per plant and fruit length was observed by Hatem and Salem (2009), and Sood and Kumar (2010). High heterosis in the yield of sweet pepper was primarily due to the increased fruits number per plant, interacting with average fruit weight as reported by Betlach (1967). He also added that fruit length and width characters have direct influence on fruit shape. To develop a good looking hybrid, it is important to have a good balance between length and width of the fruit. Pericarp thickness is a desirable trait as it imparts fruit firmness and also prolongs harvest shelf life. In general, he mentioned that medium sized fruit was preferred over large size fruits.

With regard to combining ability effects, Griffing (1956) reported that, analysis of combining ability is an one of the potential tools for identifying productive parents to develop commercial F_1 hybrids. Information on the relative importance of general combining ability (GCA) and specific combining ability (SCA) are of great values in the breeding programs for the species which are amenable to the development of F_1 hybrid cultivars, as sweet pepper. In general, when a particular line reflects a high estimate of GCA it means that it is a good combiner parent and possesses good genes; whereas , a high SCA of a particular combination means that the parents of this cross can combine well to produce a hybrid with a superior general performance, which reflects a clear heterotic effect. Moreover, when the additive gene action represents the major component of the total genetic variation; GCA parameter would be high and a maximum progress would be expected in a selection program; while, a hybrid breeding program may be the appropriate choice, as reflected with SCA estimate. According to Geleta and Labuschagne (2006), the mean squares for both general (GCA) and specific (SCA) combining abilities were highly significant for vitamin C and total soluble solids (TSS) contents, suggesting the importance of both additive and non-additive gene effects in the inheritance of both traits. Meanwhile, the non-additive gene effects played more important role than additive gene effects for vitamin C according to Farag (2003). He mentioned also that the additive gene effect was involved in the inheritance of fruit length, while the non-additive effect was involved in the inheritance of fruit diameter.

Kamble *et al*., (2009), reported that variances due to GCA and SCA in pepper showed that the non-additive gene action was predominant, though the additive component was also significant. The same conclusion was reported by Fekadu *et al*., (2009) for the studied characters i.e., plant and fruit traits with few exceptions. He mentioned also that the additive gene effect was more important than non-additive effects in the inheritance of pericarp thickness, locule number and fruit length of sweet pepper.

Sarujpisit *et al*., (2012) on their studies in chillies reported that no parental varieties showed a good performance in all characters, but some parent varieties show a high GCA in some characters. They added that the performance of parent and F_1 hybrids indicated the relationship with additive and non-additive expression of the hybrid (Legesse, 2000), (Zewdie *et al*., 2001), (Huang *et al*., 2009) and (Rêgo *et al*., 2009).

Accordingaly, the present investigation was conducted to estimate some important genetic parameters i.e., general and specific combining abilities (GCA and SCA), heterosis relative to both mid and better parents, and potence ratios for some important characters of sweet pepper.

MATERIALS AND METHODS

The experimental work was carried out at the Experimental Farm Station of the Faculty of Agriculture, Minufiya University, Shibin El-Kom, Egypt, during two summer seasons of 2012 and 2013. The genetic materials used in this study were six parental genotypes, vis, the cultivar Big Dipper (from USA) and five lines, i.e., LS 2-2, W 5-15, LS.5-6, B.23-5 and B.16-10 (obtained from Dr. Kansouh, Hort. Res. Inst., Agric. Res. Center, Egypt). These genotypes were at high degree of homozygosity. The five breeding lines were produced by pedigree selection programme by Dr. Kansouh. The Big Dipper was selfed for two generations to keep its homozygosity and homogeneity. The parental used were widely differed on most characters.

In the first season of 2012, crossing was made among the six parents, without reciprocals, to produce the required F_1 populations. In the second season of 2013, all genotypes (the six parents and 15 F_1's) were evaluated in a field experiment. A randomized complete blocks design with three replicates was used. Each replicate consisted of 10 plants for each population. The seeds were sown in speedling trays on the first week of January and the plants were transplanted in the field on the first week of March in the two experimental seasons. The plants of each population (parents and F_1 crosses) were destributed in ridges 4.0 meters long and 70 cm in width, the space within plants was about 40 cm. The other normal agricultural practices for pepper production, i.e., irrigation, fertilization, plant protected against weeds, and pests control were practiced as recommended. The studied characters were, early and total yield as fruit number and weight (g) per plant, average fruit weight (g), fruit length and width (cm), pericarp thickness (mm), vitamin C content according to A.O.A.C. (1975) and total soluble solids (TSS) which was determined by a hand refractometers.

Analysis of variance was made in order to test the significant of the differences among the various means of tested populations, according to Cochran and Cox (1957). Differences among means for all characters were tested for significant, according to the least significance differences (reviesed L.S.D.). (Snedecor and Cochran, 1990).

Average degree of heterosis was estimated as a percent increase or decrease of F_1 performance from the mid-parental (MP) and better parental (BP) values (Sinha and Khanna, 1975). Potence ratio (P) was estimated to determine the nature of dominance and its direction (Smith, 1952). The general combining ability (GCA) and specific combining ability (SCA) effects were estimated accordining to Griffing (1956) model (1) of method (2), which depends on the parental cultivars and their F_1 crosses in one direction.

RESULTS AND DISCUSSION

Heterosis degree:

Early fruits number and weight:

Data presented in Table 1 showed that seven out of the studied 15 F_1 combinations, significantly exceeded the mid-parents in early number of fruits, suggesting desirable heterotic effects. From these crosses, five ones showed significant positive heterosis over better parent (BP), suggesting over dominance for high value of number of fruits. This suggestion was verified by the high estimated potence ratio, which was more than one (2.50 – 11.00). These crosses were (1x2, 1x3, 1x4, 1x6 and 4x5). Dominance for the better parent and incomplete dominance were also found in the remaining crosses.

Regarding early fruits weight, hybrid vigour was reflected by three crosses (1x6, 2x3 and 4x5). The estimates of potence ratio reflected also the presence of over-dominance in the inheritance of this trait. Meanwhile, dominance was observed for the three crosses (1x3, 1x5 and 3x5). No dominance was found in the crosses (1x2, 1x4, 2x6, 3x6, 4x6 and 5x6). The potence ratio was agreement with these dominance degrees.

Total fruits number and weight:

Hybrid vigour was found regarding fruits number per plant in six crosses, since they gave highly significant positive ADH values (ranging from 1.37 – 10.15%) in relation to the better parent (Table 1). Partial dominance to large number of fruits was also found in three crosses, since they showed significant positive and significant negative heterosis values, based on MP and BP, respectively.

Hybrid vigour was also noticed in six crosses for total fruits weight (Table 2), since they showed highly significant positive heterosis values over BP with high potence values, these crosses were 1x3, 1x5, 2x3, 2x6, 3x4 and 3x5. On the other hand, the trait was controlled by no-dominance genes in some crosses, since both parent and F_1 means did not significantly different. Also dominance and partial dominance of high fruits yield were observed in the other crosses.

Table 1: Estimates of heterosis based on mid-and better parents and potence ratio for early fruits number, early fruits weight and total fruits number per plant of pepper.

Hybrids #	Early fruits No. / plant.			Early fruits weight / plant.			Total fruits No. / plant.		
	Heterosis (%)		Potence ratio P	Heterosis (%)		Potence ratio P	Heterosis (%)		Potence ratio P
	MP	BP		MP	BP		MP	BP	
1 x 2	33.33**	27.27**	7.00	12.82	-15.03*	0.39	-22.89**	-46.22**	-0.53
1 x 3	38.46**	20.00**	2.50	18.79*	-3.96	0.79	21.14**	-17.19**	0.46
1 x 4	30.00**	18.18*	3.00	-4.78	-35.44**	-0.10	1.85	-9.83	0.14
1 x 5	33.33**	9.09	1.50	41.06**	-2.69	0.91	-1.69	-18.31	-0.08
1 x 6	47.83**	41.67**	11.00	46.14**	38.94**	8.91	1.67	-16.44	0.08
2 x 3	-12.00	-26.67**	-0.6.0	52.96**	39.23**	5.37	9.31**	5.47**	2.56
2 x 4	5.26	11.11	0.00	0.18	-14.69	0.01	15.56**	-12.61**	0.48
2 x 5	5.88	-10.00	0.33	6.79	-6.56	0.48	12.63**	-10.08**	0.50
2 x 6	-9.09	-16.67*	-1.00	0.49	-26.81**	0.01	1.04**	-18.49	0.04
3 x 4	8.33	-13.33*	0.33	7.32	-15.38	0.27	44.97**	7.03**	1.27
3 x 5	27.27**	-6.67	0.75	45.40**	17.44	1.91	41.71**	10.15**	1.46
3 x 6	3.70	-6.67	0.33	-9.26	-29.39**	-0.32	28.36**	0.78**	1.04
4 x 5	62.50**	44.44**	5.00	58.71**	53.75**	18.20	9.09**	1.41**	1.20
4 x 6	4.76	-8.33	0.33	17.28	-22.54**	0.34	10.45**	1.37**	1.18
5 x 6	5.26	-16.67*	0.2	11.37	-25.25**	0.23	1.39	0.00	1.00

* - Significant at 5 % level, and ** - Significant at 1% level.

1= Big Dipper, 2=LS 2-2, 3=W 5-15, 4=LS 5-6, 5=B 23-5 and 6=B 16-10.

Table 2: Estimates of heterosis based on mid-and better parents and potence ratio for total fruits weight /plant, fruit Diameter and fruit length of pepper.

Hybrids	Total fruits weight			Fruit Diameter			Fruit length		
	Heterosis (%)		Potence ratio	Heterosis (%)		Potence ratio	Heterosis (%)		Potence ratio
	MP	BP	P	MP	BP	P	MP	BP	P
1 x 2	-24.24**	-35.32**	-1.41	22.30**	-17.19**	0.47	0.79	-16.59**	0.04
1 x 3	18.63**	7.33**	1.77	-45.83**	-59.38**	-1.38	7.14	0.00	1.00
1 x 4	-17.36**	-35.60**	-0.61	25.67**	-14.58	0.54	1.05	-16.52**	0.05
1 x 5	16.21**	10.69**	3.25	18.47**	-3.13	0.83	32.50**	24.71**	5.20
1 x 6	0.81	-17.71**	0.04	9.22*	-16.67**	0.30	-34.59**	-49.45**	-1.18
2 x 3	86.38**	74.63**	12.84	-8.54	-21.88*	-0.50	24.79**	-2.18	0.90
2 x 4	6.531*	-25.68**	0.15	6.57	5.8001	9.00	-0.44	-0.65	-2.00
2 x 5	14.31**	-6.25**	0.65	-13.68*	-32.79**	-0.48	10.28**	-3.93	0.69
2 x 6	23.48**	16.95**	4.21	0.59	-15.84**	0.03	-26.59**	-32.73**	-2.91
3 x 4	43.60**	4.27*	1.16	6.67	-8.33	0.41	14.44**	-10.43**	0.52
3 x 5	59.66**	38.31**	3.87	-6.42	-16.39**	-0.54	6.33	-6.18	0.48
3 x 6	20.09**	6.98	1.64	-0.5	-2.97	-0.20	-28.40**	-47.27**	-0.79
4 x 5	3.58	-16.24**	0.15	1.57	-20.49**	0.06	7.75*	-6.30	0.57
4 x 6	27.29**	-13.86**	0.57	1.18	-14.85	0.06	4.16	-4.36	0.47
5 x 6	14.10**	-10.29**	0.52	1.35	-7.38	0.14	11.91**	-9.45**	0.50

* - Significant at 5 % level, and ** - Significant at 1% level.

Fruit diameter and length:

With regard to fruit diameter, none of the evaluated crosses showed hybrid vigour for the high or low diameter (Table, 2). Two crosses 1x4 and 1x5 showed dominance for the high width, it gave insignificant average degree of heterosis (ADH) value in relation to BP. On the other hand, insignificant heterosis values from MP were reflected by some crosses, i.e., 2x3, 2x6, 3x5 and 4x5, suggesting no-dominance for the trait.

Regarding fruit length, the cross 1x5 showed hybrid vigour for long fruit with highly significant ADH value (24.71%). Insignificant ADH values based on MP were estimated for six crosses, suggesting incomplete dominance. Partial dominance for long fruit was observed in two crosses.

Average fruit weight and pericarp thickness:

Most crosses exhibited no dominance for average fruit weight, since the estimated MP heterosis values were insignificant (Table 3). The cross 2x3 reflected highly positive heterosis (54.17%) based on BP, suggesting hybrid vigour for the heavy fruit weight with a potence ratio of 6.8. Regarding pericarp thickness, all the studied F_1 crosses did not reflect heterotic effects. Meanwhile, incomplete dominance was observed in six crosses (1x2, 1x4, 2x3, 2x4, 2x6 and 4x6). Two crosses; i.e, 1x3 and 1x6 showed dominance to thin pericarp, the estimated ADH% values in relation to the MP were highly negative significant (-40.74 and -26.67%, respectively).

Vitamin C and Total soluble solids contents

Estimated ADH over MP for vitamin C content exhibited that eight crosses significantly exceeded the MP, suggesting dominance towards the better parent (Table 4). When these crosses were compared with BP cleared that two crosses (1x2 and 1x6) showed hybrid vigour for the high content with high potence values. Meanwhile, four combinations were statistically similar to their respective better parent, suggesting dominance for the high content; the potence ratio was about 1.00. Partial dominance for the high content was reflected by the crosses 1x5 and 2x5. The estimated ADH% was significantly positive from MP and significantly negative from BP.

With regard to total soluble solids content, insignificant ADH% values based on MP were found in the crosses 1x4, 1x5 and 2x3, indicating no-dominance. On the other hand, two crosses i.e., 1x3 and 3x6 exhibited hybrid vigour and the crosses 2x5 and 2x6 exhibited complete dominance to the high content. The estimated potence ratios were in accordance with the postulated hypothesis.

In general, the variation of magnitude of heterosis for different characters in different studied crosses is due to varying extent of genetic diversity of parents involving in the crossing as reported by Tsaftaris (1995); Rajesh and Gulshan (2001) and Fekadu *et al*., (2009), who found maximum heterosis over mid, better parent, and standard check for total yield per plant and number of fruits per plant. They added that the possibility of maximizing heterosis by considering genetically diverse parental genotypes.

Several studies have reported a positive correlation between genetic distance of the parental lines and superior hybrid performance (Liu *et al*., 2002; Barbosa *et al*., 2003).Also, genetic divergence of parents is positively related to the heterosis of the F_1 (Kallo, 1988). According to Shifriss and Sacks (1980), when the parents are widly different in certain character, the results of F_1 show high heterosis value.

Generally, some crosses gave insignificant heterosis values based on both MP and BP, therefore, the assess of heterosis degree in these crosses is difficult, because of the difference between the two parents is small. Therefore, large difference between the parents may be necessary to determine dominance degree in resulted F_1 crosses.

Table 3: Estimates of heterosis based on mid-and better parents and potence ratio for average fruit weight and pericarp thickness of pepper.

Hybrids	Average fruit weight			Pericarp thickness		
	Heterosis (%)		Potence ratio	Heterosis (%)		Potence ratio
	MP	BP	P	MP	BP	P
1 x 2	-14.18	-33.14**	-0.50	-3.45	-26.31**	-0.11
1 x 3	-19.20	-41.28**	-0.51	-40.74**	-57.89**	-1.00
1 x 4	-23.58	-45.35**	-0.59	-15.38	-42.10**	-0.33
1 x 5	12.00	-10.47	0.48	14.29*	-15.79**	0.40
1 x 6	-0.86	-1.71	-1.00	-26.67**	-42.11**	-1.00
2 x 3	70.11**	54.17*	6.78	-11.11	-20.00*	-1.00
2 x 4	-3.53	-14.58	-0.27	-5.88	-20.00*	-0.33
2 x 5	0.50	-2.91	0.14	5.26	0.00	1.00
2 x 6	13.65	-12.00	0.47	-14.29	-18.18*	-3.00
3 x 4	0.00	-2.56	0.00	6.67	0.00	1.00
3 x 5	8.29	-4.85	0.6.0	5.88	0.00	1.00
3 x 6	-16.21	-39.43**	-0.42	5.26	-9.09	0.33
4 x 5	-3.95	-17.48	-0.24	0.00	-11.11	0.00
4 x 6	18.88	-15.43	0.47	0.00	-18.18*	0.00
5 x 6	12.95	-10.29	0.50	10.00	0.00	1.00

* - Significant at 5 % level, and ** - Significant at 1% level.

Table 4: Estimates of heterosis based on mid-and better parents and potence ratio for vitamin C and total soluble solids contents of pepper.

Hybrids	Vitamin C content			Total soluble solids content (TSS)		
	Heterosis (%)		Potence ratio P	Heterosis (%)		Potence ratio P
	MP	BP		MP	BP	
1 x 2	18.20**	3.81**	1.31	4.41	4.41	0.55
1 x 3	14.63**	-1.17	0.91	33.33**	19.44**	2.87
1 x 4	11.55**	-0.88	0.92	0.787	-8.57*	0.08
1 x 5	2.53**	-4.99**	0.32	-1.61	-8.96*	-0.20
1 x 6	20.20**	6.45**	1.56	7.2.0	-1.47	0.82
2 x 3	0.59	-1.55	0.27	-5.96	-10.13*	-1.29
2 x 4	0.19	-1.13	0.14	6.04	0.00	1.00
2 x 5	2.73*	-3.09**	0.45	8.22*	0.00	1.00
2 x 6	0.96	0.00	1.00	8.84*	1.27	1.18
3 x 4	3.91**	0.38	1.11	4.23	2.78	3.00
3 x 5	3.72**	-4.12	0.45	-0.72	-4.17	-0.20
3 x 6	0.39	-2.66*	0.13	12.86**	9.72*	4.50
4 x 5	2.16	-2.41*	0.46	3.65	1.43	1.67
4 x 6	0.00	-0.38	0.00	2.90	1.43	2.00
5 x 6	1.08	-3.78**	0.21	0.74	0.00	0.01

* - Significant at 5 % level, and ** - Significant at 1% level.

Combining ability

Analysis of variance revealed highly significant mean squares for general and specific combining abilities for all studied traits (Table, 5), suggesting that both additive and non-additive gene effects are involved in their genetic mechanism. The similar results were obtained by Geleta and Labuschagne (2006) for vitamin C and TSS contents.

However, the high estimated values which ranged from 2.71 to 18.15 of the GCA: SCA mean squares ratio indicated that the additive gene effects played the main role in the inheritance of these traits. Geleta and Labuschagne (2006) found the same trend, since GCA effects were more important than SCA one. The preponderance of GCA effects implied that these characters would respond favorably to direct selection.

Estimated general combining ability values for the parental lines showed that the best lines (as general combiner) for each character was as follows: P_3 and P_1 for early fruits number, P_6 and P_1 for early fruits weight, P_3 and P_2 for total fruits number and weight, P_1 and P_5 for fruit diameter, P_6 and P_4 for fruit length, P_6 and P_1 for average fruit weight, P_1 for pericarp thickness and vitamin C content, and P_2 for total soluble solids content. These parents showed the highest GCA effect values. It is noticed that, certain parental lines had good GCA effects for certain traits, but not for all of them (Table, 6). This result is agree with that reported by Sarujpisit, *et al*., (2012), who found that no parental varieties showed a good performance in all characters, but some parents show a high GCA for some characters.

Estimated SCA values showed that the following combinations have highly significant values: 1x2, 1x3, 1x6, 3x5 and 4x5 for early fruits number; 1x5, 2x3, 1x6 and 3x5 for early fruits weight; 1x3, 1x6, 2x4, 2x5, 3x4, 3x5 and 3x6 for total fruits number; 2x3, 3x4, 3x5 and 4x6 for total fruits weight; 1x2, 1x4, 1x5, 3x4 and 3x6 for fruit diameter; 1x3, 1x6, 1x5, 2x3, 3x4, 4x6 and 5x6 for fruit length; 1x5, 1x6, 2x3 and 4x6 for average fruit weight; 1x5, 1x6, 3x4 and 3x6 for pericarp thickness; 1x2, 1x3, 1x4, 1x6, 4x5, 3x4 and 3x5 for vitamin C content; 1x3, 1x6, 2x4, 2x5, 2x6 and 3x6 for total soluble solids content (Table, 7).

Table 5: Mean squares for combining abilities (GCA and SCA) for some characters in pepper.

Characters	Early fruits No.		Early fruits weight		Total fruits No.		Total fruits weight		Fruit Diameter	
Source of variation	MS	F	MS	F	MS	F	MS	F	MS	F
GCA	5.69	23.52**	32996.92	65.02**	1108.9	1287.75**	1.24	1068.66**	16.12	236.81**
SCA	1.37	5.64**	3153.47	6.21**	61.10	70.96**	0.21	181.99**	1.43	21.08**
GCA/SCA	4.16		10.46		18.15		5.87		11.24	

*Significant at 0.05 level of probability.
**Significant at 0.01 level of probability.

Table 5: (cont.)

Characters	Fruit length		Average fruit weight		Pericarp thickness		Vitamin C content		Total soluble solids content	
Source of variation	MS	F	MS	F	MS	F	MS	F	MS	F
GCA	55.59	104.93**	1256.68	13.99**	0.087	33.4**	1493.34	603.27**	1.22	16.39**
SCA	12.96	24.47**	139.44	1.55	0.009	3.60**	112.08	45.27**	0.45	6.06**
GCA/SCA	4.28		9.01		9.28		13.32		2.71	

*Significant at 0.05 level of probability.
**Significant at 0.01 level of probability.

Table 6: Estimated general combining ability (GCA) effects for the parental lines regarding some characters in pepper.

Parents \ Characters	Early fruits No.	Early fruits weight	Total fruits No.	Total fruits weight	Fruit Diameter
1	1.45**	134.13**	-24.92**	-0.56**	4.58**
2	-1.29**	-65.88**	13.45**	0.49**	-1.93**
3	1.96**	-14.88	33.33**	0.67**	-1.65**
4	-0.79**	-119.88**	-9.17**	-0.93**	-1.48**
5	-1.54**	-73.38**	-5.54**	-0.28**	0.74**
6	0.21	139.87**	-7.17**	0.61**	-0.26**

* Significant at the 0.05 level of probability according to "T" test.
** Significant at the 0.01 level of probability according to "T" test.

Table 6: (cont.)

Parents # \ Characters	Fruit length	Average fruit weight	Pericarp thickness	Vitamin C content	Total soluble solids content
1	-5.10**	18.83**	0.334**	46.79**	-0.95**
2	2.97**	-4.79	-0.029	-11.58**	0.93**
3	-6.08**	-18.04**	-0.154**	-17.21**	0.55**
4	4.43**	-24.54**	-0.167**	-9.96**	-0.05
5	0.20	-3.67	0.008	0.92	-0.48**
6	3.58**	32.21**	0.008	-8.96**	0.00

* Significant at the 0.05 level of probability according to "T" test.
** Significant at the 0.01 level of probability according to "T" test.
# * 1= Big Dipper, 2=LS 2-2, 3=W 5-15, 4=LS 5-6, 5=B 23-5 and 6=B 16-10.

Table 7: Estimates of specific combining ability (SCA) effects for the studied F_1 regarding some characters in pepper.

Parents	Characters	SCA effect				
		2	3	4	5	6
1	Early fruits No.	1.78**	2.54**	0.29	0.04	71.29**
	Early fruits weight.	-7.25	11.75	-82.25**	78.25**	3023**
	Total fruits No.	-15.59**	6.54**	-1.96*	-2.59**	332.04**
	Total fruits weight.	-0.92**	0.02	-0.23**	0.38**	13.45**
	Fruit Diameter.	2.33**	-6.06**	2.38**	2.36**	78.66**
	Fruit length.	0.68	1.53*	-0.59	7.64**	168.66**
	Average fruit weight.	-17.52*	-18.27*	-18.77*	20.36*	638.48**
	Pericarp thickness.	0.08	-0.40**	-0.09	0.24**	6.54**
	Vitamin C content	29.70**	18.32**	12.07**	-12.80**	1730.07**
	Total soluble solids content	-0.09	3.29**	-0.51*	-0.69**	67.84**
2	Early fruits No.		-1.71*	0.04	-0.21	-0.96*
	Early fruits weight.		147.75**	-17.25	-37.75	-37.00
	Total fruits No.		-2.84**	8.66**	8.04**	-0.34
	Total fruits weight.		2.04**	-0.19**	-0.19**	0.42**
	Fruit Diameter.		0.16	-0.21	-1.53**	-0.23
	Fruit length.		8.26**	-1.35*	1.18	-9.20**
	Average fruit weight.		52.36**	-7.14	-10.02	8.11
	Pericarp thickness.		-0.04	-0.02	0.01	-0.10*
	Vitamin C content		-6.30**	-5.55**	3.57*	-5.55**
	Total soluble solids content		-1.59**	0.61*	1.04**	0.76**
3	Early fruits No.			-0.21	1.54**	-0.21
	Early fruits weight.			-11.25	70.25**	-106.00**
	Total fruits No.			21.79**	22.16**	11.79**
	Total fruits weight.			0.28**	0.77**	-0.18**
	Fruit Diameter.			1.01**	0.18	0.78**
	Fruit length.			3.20**	-1.87**	-8.15**
	Average fruit weight.			0.11	1.23	-26.64**
	Pericarp thickness.			0.10*	0.03	0.13**
	Vitamin C content			4.07**	6.20**	-6.93**
	Total soluble solids content			-0.01	-0.59*	0.94**

* Significant at 0.05 level of probability according to the (T) test.
** Significant at 0.01 level of probability according to the (T) test

Table 7: (Cont.)

Parents	Characters	SCA effect 2	3	4	5	6
4	Early fruits No.				3.29**	-0.46
	Early fruits weight.				86.25	47
	Total fruits No.				-4.34**	-0.71
	Total fruits weight.				-0.20**	0.53**
	Fruit Diameter.				-0.48*	-0.58*
	Fruit length.				-1.19	4.94**
	Average fruit weight.				-5.27	21.86*
	Pericarp thickness.				-0.06	0.04
	Vitamin C content				3.95**	-6.18**
	Total soluble solids content				0.41	-0.06
5	Early fruits No.					-0.71
	Early fruits weight.					-18.50
	Total fruits No.					-5.34**
	Total fruits weight.					0.04
	Fruit Diameter.					-0.11
	Fruit length.					6.36**
	Average fruit weight.					9.98
	Pericarp thickness.					0.06
	Vitamin C content					-1.05
	Total soluble solids content					-0.24

* Significant at 0.05 level of probability according to the (T) test.
** Significant at 0.01 level of probability according to the (T) test

However, the cross 1x6 was the best for all studied traits, since it showed the highest SCA value. Generally, no relationships were observed between GCA effects for parental lines and the SCA of the F_1 combinations. Since all types of combinations; i.e., poor × poor, poor × medium, poor × high, medium ×medium, medium ×high, and high × high GCA parents, showed significant SCA effects. These findings were similar to those obtained by Kansouh (1989), Huang *et al*., (2009) and Rêgo *et al*., (2010).

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الملخص العربى

دراسة القدرة على التآلف وقوة الهجين للمحصول ومكوناته فى الفلفل

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أُجريت هذه الدراسة بمزرعة كلية الزراعة –جامعة المنوفية بشبين الكوم خِلال المُوسم الصَيفي لِعَامَي ٢٠١٢، ٢٠١٣، وذلك بهدف تقدير قُدرتى التآلف العامة والخاصة وكذلك تقدير درجة قوة الهجين ودرجة السيادة للحُصول على مزيد من المَعلومات التى تعكس طبيعة وأهمية أنواع التفاعل الجينى المتحكم فى السلوك الوراثى لبعض الصفات لمُساعدة المُربى عند وضع وتنفيذ برامج التربية لتحسين محصول الفلفل والذي يُعتبر من محاصيل الخُضر الهامة في مصر.

وأستخدم في هَذه الدراسة صنف واحد مفتوح التلقيح تم تلقيحه ذاتياً لعدة أجيال للتأكد من أنه على درجة عالية من النقاوة الوراثية- وخمسة سُلالات ناتجة من التربية الذاتية والانتخاب وهي:-

Big Dipper (1), LS 2-2 (2), W 5-15 (3), LS 5-6 (4), B 23-5 (5) and B 16-10 (6)

وأُجرى التَهجين فيما بينها في مُوسِم ٢٠١٢ للحُصول على بُذور الجيل الأول اللازمة للدراسة مع اتباع نظام الداى أليل فى اتجاه واحد، كما تم التلقيح الذاتى للآباء الستة للحصول على البذور اللازمة للدراسة، وفي موسم ٢٠١٣ زُرعت الآباء والهُجُن الخمسَة عشر في تجربة مُصَممَه بطريقة القِطاعات الكاملةُ العَشوائية في ثلاث مُكررات- وكانت الصِفات التي تناولتها الدراسة هى. المحصول المبكر(عدد ووزن الثمار)– المحصول الكلى(عدد ووزن الثمار- قُطر وطول الثمرة- متوسط وزن الثمرة- سمك لحم الثمرة – محتوى الثمرة من فيتامين ج – والمواد الصلبة الذائبة الكلية.

وكانت أهم النتائج المُتحصل عليها هي:

كان التباين لكلٍ من القُدرة العامة والخاصة على الائتلافِ مَعنوياً لكُل الصِفات التي تم دراستها- وهذا يوضح أهمية كلا من الفعل الإضافى والغير الإضافى للجينات في وراثةِ هذه الصِفات. أظهرت النسبة المحسوبة بين مُتوسط مُربع الانحرافات للقُدرة العامة والخاصة على الائتلاف أن التفاعل الإضافى للجين يَلعب دوراً أكثر أهمية من التفاعل الغير إضافى في وراثة الصِفات تحت الدراسة. وهذا يُشير إلى فاعلية الإنتخاب كطريقة تربية فى تَحسين مُعظم الصِفات. عكست النتائج أيضاً أن الآباء تختلف في تأثيرات القُدرة العامة على الائتلاف فكل سُلالة أبوية أظهرت قُدرة عالية ومَعْنَوِيَة لعَدَد من الصِفات وليس لكل الصفات. وأفضل الآباء هى Big Dipper وW 5-15 لعدد الثمار المبكرة، Big Dipper وB 16-10 لوزن المحصول المبكر ومتوسط وزن الثمرة، LS 2-2, و W 5-15 للمحصول الكلى، Big Dipper قطر الثمرة، LS 5-6 و B 16-10 لطول الثمرة، Big Dipper سمك لحم الثمرة ومحتوى الثمرة من فيتامين ج، LS 2-2 لمحتوى الثمرة من المواد الصلبة الذائبة الكلية. أوضَحت دِراسة تأثيرات القُدرة الخاصة على الائتلاف أن الهُجن التي يَدخل في تكوينُها أحد هذه الآباء أعْطت قِيم عالية ومَعنوية للقُدرة الخاصة على الائتلاف في مُعظم الصِفات المَدروسَة وعلى هذا يُمكن استخدام هذه السُلالات لِلاستفادة مِنها في بَرامِج تربية وتَحسين الفلفل.

ظهرت كل نُظُم السيادة(غياب السِيادة، السِيادة الجُزئية، السيادة التامة، السيادة الفائقة)بدرجات متفاوتة وباختلاف الصفات التى درست فى الهُجن التى تم إنتاجها وتقييمها- وظهور قوة الهَجين فى صِفة كمية المحـصول كعدد ووزن الثمار للنبات مما يُشجع على إنتاج الهُجن محلياً من الفلفل وزراعتها على النطاق التُجارى لزيادة الإنتاج.