J. Plant Production, Mansoura Univ., Vol. 5 (8): 1471 - 1490, 2014

ASSOCIATION OF HYBRID PERFORMANCE, HETEROSIS AND DOMINANCE TYPES IN PEPPER(*Capsicum annuum*, L.)

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ABSTRACT

During successive summer seasons of 2008 to 2011, this study was conducted at Middle Delta region. Eight sweet pepper breed lines were used in half-diallel cross mating design to produce 28 F_1 pepper hybrids. The extent of heterosis was estimated based on (MP), (BP), (TP) and commercial hybrid (CH) for some palnt and fruit traits. Analysis of variance showed a great diversity and significant differences among the studied genotypes (parents and hybrids). 13 hybrids gave better parent heterosis (heterobeltiosis) for plant height and total yield, while five F_1's for number of branches and early yield. Relative to the top parent, seven hybrids (for plant height) and two ones (for number of branches and total yield) reflected top heterosis (TH%). None of the studied hybrids showed heterosis over MP, BP and TP for average fruit weight, fruit length and diameter, while standard heterosis (SH%) was obtained for all the studied traits. Additive and non-additive gene effects were found for number of branches and early yield. Non-additive effects were predominance for plant height and total yield, white fruit characters (weight, length and diameter) of the whole were controlled by additive effects. Based on the standard heterosis expressed by the hybrids, "B.23-5 x MAR-6" (Balady fruited type) and "L.S.5-14 x L.S.2-2" (Long fruited type) were found to be superior over the commercial hybrid and could be used for commercial production, which must be depended on its actual high productivity and not on its average degree of heterosis.

INTRODUCTION

Pepper (*Capsicum annuum* L.) is one of the important vegetable crops in Egypt. Therefore, attention must be given to increase its yield. The high productivity can be obtained by selection for developing new cultivars or by hybrid breeding method through heterosis phenomenon. Heterosis is a genetic phenomenon resulting from heterozygosity, which usually described as superior F_1 hybrid performance over their parents. Average degree of heterosis not considered a fixed measure but is a variable percentage according to the extent of heterosis expertation. The difference between the hybrid and the mean of their two parents which termed relative heterosis or mid-parent heterosis determined only the percentage of the mid-parents performance (Falconer and Mackay, 1996). Also, the better parent heterosis which reflected the difference between the hybrid and the high (better) parent is preferred in some circumstances, particularly in self-pollinated crops, for which the goal is to find a better hybrid than either of their parents only (Lamkey and Edwards, 1999). Meanwhile, the difference between the hybrid and the standard variety (check hybrid) can be termed standard or commercial heterosis, and from the plant breeding viewpoint, standard hetersosis is of practical significance (Geleta and Labuschagne, 2004).

Heterosis over the mid-parents (MPH), i.e., relative heterosis; better parent (BPH), i.e., heterobeltiosis and standard cultivar (SH), i.e., standard heterosis was reported for plant height and number of primary branches in pepper by Rajesh Kumar *et al*. (2001), Patil *et al* . (2001) , Kumar *et al*. (2005) and Karthik *et al*. (2009). Also, heterosis for early and total yield in respect of mid-parents, better parent and standard cultivar have been reported in pepper by Kansouh (1997), Patel *et al*. (2001), Geleta and Labuschagne (2004), Farag and Khalil (2007), Reddy *et al*. (2008), Patel *et al*. (2010). Likewise, all types of heterosis, i.e., mid-parent, better parent, top and standard heterosis also previously detected by Singh *et al*. (2012) in pepper for plant height, number of branches, early and total yield. Meanwhile, no better parent heterosis was found in pepper for average fruit weight (Kansouh, 1997 and Khalil *et al*., 2004) and for fruit length and diameter (Nayaki and Natarajan, 2000 and Burli *et al*., 2001), since the crosses showed lower values than their better parent for these fruit traits.

The main objectives of this research were to determine all types of heterosis, i.e., mid-parents (MPH), better parent (BPH), top heterosis (TH) and standard heterosis (SH); identify the relations between the average degree of heterosis and dominance type and also between the hybrid performance and their heterosis manifestation in some local pepper hybrids.

MATERIALS AND METHODS

This study is a part of a breeding programme started in 1997 (Kansouh, 2007). The present part was conducted from 2008 to 2011 at Kafr-Farses, Zifta district, Gharbia governorate, Middle-Delta region. Eight sweet pepper breed lines, i.e., B.10-22, B.23-5, Z.M.3-6, T.S.6-3, MAR-6, L.S.5-14, L.S.2-2 and W-5-1 were chosen from the mentioned original programme and used in 8 x 8 half-diallel cross mating design to obtain 28 F_1 hybrids in the summer season of 2008. The obtained F_1 hybrids and their parents with the two commercial hybrids Top star (baldy type fruit) and S.107 (long fruited type) as a control (standard cultivar) were evaluated in the two successive summer seasons of 2009 and 2010. Based on data obtained from the evaluated F_1 hybrids and their parents with the two controls, the two superior F_1 hybrids "B.23-5 x MAR-6" as balady fruited type and "L.S.5-14 x L.S.2-2" as long fruited type were chosen and grown again with the same two commercial hybrids in large scale experiment in the summer season of 2011. The seedlings were transplanted on first March in a randomized complete blocks design with three replicates. In the two seasons of 2009 and 2010 each plot consisted of four rows, 0.75 m width and 6.0 m length (18 m^2), while in the season of 2011, it consisted of 100 rows 0.75 m width and 6.0 m length (450 m^2) and the plants were spaced at 35 cm part. Routine cultural practices, similar to those used in pepper commercial production were done as needed.

Data were recorded on the following characters: plant height (cm) and number of primary branches per plant were measured for ten plants per plot at the end of the growing seasons. Early yield as the yield of the first three harvest, total yield as the total weight of all harvested fruits (early and total yield were recorded as kg/plant in the season of 2009 and 2010, while in the season of 2011 was recorded as kg/plot and ton/fed. was calculated). A random sample of 20 fruits per plot were used for measuring average fruit weight, fruit length and diameter and the measurements were recorded three times (first, middle and end) during the growing season and the means were calculated. The average degree of heterosis (ADH%) was calculated as follows: relative (mid-parents) heterosis (MPH%) and heterobeltiosis (better parent heterosis, BPH%) were calculated as the percentage of the deviation of the F_1 mean over the mid parents (MP) and the better parent (BP) means, respectively (Mather and Jinks, 1971); heterosis from the top parent (top heterosis, TH%) and heterosis from the commercial hybrid (standard heterosis, SH%) were calculated by the formula:

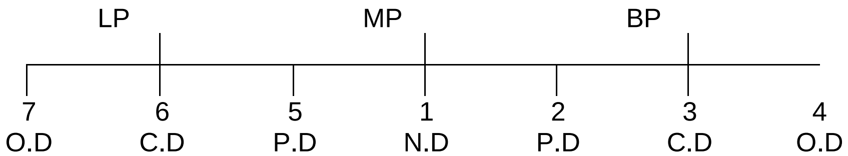
$$TH\% = \frac{\overline{F_1} - \overline{TP}}{\overline{TP}} \times 100$$

$$SH\% = \frac{\overline{F_1} - \overline{CH}}{\overline{CH}} \times 100$$

Where:

$\overline{F_1}, \overline{TP}$ and $\overline{CH}$ are the means of F_1 generation, top parent (the highest parent for each character) and commercial hybrid (control), respectively. Heterosis over the better parent (heterobeltiosis) was only calculated for the crosses whose showed significant positive MPH% values. Top heterosis (TH%) was only estimated for the crosses whose showed significant positive BPH% values.

Degree type of dominance (no, partial, complete and over) was obtained according to the dominance line which depended on the results of ADH% based on MP and BP as follows:



Where:

1- No dominance (N.D) where MPH% was insignificant (significantly $\overline{F_1} = \overline{MP}$).
2- Partial dominance (P.D) toward the better parent where MPH% and BPH% were significantly positive and negative, respectively (significantly $\overline{MP} < \overline{F_1} < \overline{BP}$).
3- Complete dominance (C.D) to the better parent where BPH% was insignificant (significantly $\overline{F_1} = \overline{BP}$).
4- Over dominance (O.D) toward the better parent where BPH% significantly was positive (significantly $\overline{F_1} > \overline{BP}$).

5- Partial dominance (P.D) toward the low parent (LP) where MPH% and LPH% (low parent heterosis) were significantly negative and positive, respectively (significantly $\overline{MP} > \overline{F_1} > \overline{LP}$).

6- Complete dominance (C.D) to the low parent (LP) where LPH% was insignificant (significantly $\overline{F_1} = \overline{LP}$).

7- Over dominance (O.D) toward the low parent (LP) where LPH% significantly was negative (significantly $\overline{F_1} < \overline{LP}$).

RESULTS AND DISCUSSION

A.Mean performance of the F_1 hybrids and their parents:

Data in Table (1) showed high significant differences among the parental lines and the crosses for all studied traits. For plant height, the crosses gave taller plants than those of the parental lines, since their means ranged from 72.33 to 105.00 with a mean value of 83.99 cm, while those of parental lines ranged from 45.00 to 81.66 with a mean of 67.75 cm. The overall mean value of the F_1 crosses exceeded that of the parental lines by 23.97%. Among the parental lines, B.23-5 was considered the top parent, since showed the highest plant height (81.66 cm), while the shortest plants (45.00 cm) was recorded in the line Z.M.4-6. For the crosses, the tallest plants (more than 100 cm) were given by the F_1 hybrids, "B.23-5 x L.S.2-2" and "MAR-6 x L.S.5-14", while the hybrids "B.10-22 x L.S. 2-2" and "Z.M.3-6 x L.S. 5-14"showed the shortest plants (72.33cm.). Compared with the top parent and the two controls, seven F_1 hybrids gave plants significantly taller (more than 90.00 cm) than those of both of B.23-5 (the top parent) and the commercial hybrid Top star (CH1). While, 21 F_1 hybrids significantly exceeded the second control S.107 (CH2), since showed plants with height values more than 77 cm.

For number of primary branches per plant, plants of parental lines recorded a range from 5.43 (in the line Z.M.3-6) to 10.47 branch/plant (in the line L.S.2-2). Meanwhile, a range from 6.43 (in the cross "B-10-22 x Z.M.3-6" to 12.53 branch/plant (in the cross L.S.5-14 x L.S.2-2) was recorded by the crosses, indicating high significant differences among the evaluated entries (lines and crosses). However, the overall mean value of the hybrids (9.26 branch/plant) exceeded that of the parental lines (7.92 branch/plant) by 16.79%, indicating that, the resulted F_1 hybrids gave higher number than those of their parental lines. Compared with the top parent and the control, two crosses, i.e., "B.23-5 x MAR-6" and "L.S. 5 -14 x L.S. 2-2 " showed higher than that of the line L.S.2-2 (the top parent). While, 14 F_1 hybrids significantly exceeded that of the commercial F_1 hybrid S.107 (CH2) in this trait, since their plants recorded more than 9.30 branches.

Table (1):Mean performance of the evaluated F_1 hybrids and their parents for some plant and fruit traits.

Entries	Plant height	No. of branches	Early yield (kg/pl)	Total yield (kg/pl)	Av. fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)
Lines							
B.10-22	55.16	6.23	0.610	1.547	36.38	7.53	4.20
B.23-5	81.66	8.43	0.917	2.823	81.64	12.13	7.17
Z.M.3-6	45.00	5.43	0.571	1.915	76.05	13.57	6.13
T.S.6-3	76.33	7.50	0.850	2.653	94.32	12.83	6.80
MAR-6	70.83	9.10	1.033	2.347	45.29	8.43	5.07
L.S.5-14	75.17	8.67	0.713	2.027	50.82	19.50	3.77
L.S.2-2	72.67	10.47	0.812	1.650	23.47	17.37	2.33
W.5-1	65.17	7.57	0.462	1.233	40.67	13.53	5.17
Mean	67.75	7.92	0.746	2.024	56.08	13.11	5.07
Crosses							
B.10-22 x B.23-5	85.16	9.10	0.897	2.353	62.32	10.30	6.50
B.10-22 x Z.M.3-6	75.00	6.43	0.888	2.497	53.81	10.03	5.67
B.10-22 x T.S.6-3	80.66	7.17	0.872	2.760	67.57	9.83	5.43
B.10-22 x MAR-6	76.66	9.53	0.940	2.653	42.77	8.30	5.03
B.10-22 x L.S.5-14	80.00	8.00	0.652	1.923	43.88	13.57	4.30
B.10-22 x L.S.2-2	72.33	9.07	0.755	2.457	30.06	13.10	3.83
B.10-22 x W.5-1	82.66	7.61	0.608	2.253	43.47	10.57	5.10
B.23-5 x Z.M.3-6	83.67	7.60	0.828	2.763	87.83	11.63	6.43
B.23-5 x T.S.6-3	80.00	7.97	0.870	2.940	92.88	11.56	6.97
B.23-5 x MAR-6	96.67	12.50	1.151	3.223	63.35	10.46	6.63
B.23-5 x L.S.5-14	93.16	10.17	1.043	2.477	69.88	14.83	6.27
B.23-5 x L.S.2-2	101.33	10.11	1.010	2.426	45.67	14.03	5.13
B.23-5 x W.5-1	85.00	10.50	0.717	2.353	60.69	12.03	6.50
Z.M.3-6 x T.S.6-3	79.67	7.10	0.783	2.412	88.54	11.73	6.63
Z.M.3-6 x MAR-6	83.00	10.33	0.810	2.752	59.21	10.67	5.67
Z.M.3-6 x L.S.5-14	72.33	7.90	0.943	2.330	65.81	15.87	5.33
Z.M.3.6 x L.S.2-2	74.00	9.20	0.842	2.307	40.99	15.03	4.43
Z.M.3-6 x W.5-1	75.00	7.50	0.856	1.960	55.93	12.83	5.77
T.S.6-3 x MAR-6	79.50	8.50	1.043	3.057	68.53	10.10	6.13
T.S.6-3 x L.S.5-14	86.17	9.33	0.820	2.773	73.52	15.77	5.33
T.S.6-3 x L.S. 2-2	78.67	9.70	0.903	2.407	50.74	14.67	5.43
T.S.6-3 x W.5-1	75.17	7.67	0.653	2.282	58.54	13.13	6.23
MAR-6 x L.S.5-14	105.00	11.10	1.003	2..813	50.73	13.73	4.83
MAR-6 x L.S.2-2	85.00	11.60	0.918	2.747	30.91	12.93	3.97
MAR-6 x W.5-1	91.00	11.30	0.891	2.067	47.40	10.47	5.27
L.S.g-14 x L.S.2-2	98.33	12.53	1.037	2.523	38.70	19.13	3.23
L.S.5-14 x W.5-1	81.33	9.53	1.913	1.937	46.02	15.67	4.33
L.S.2-2 x W.5-1	95.00	10.13	0.725	2.020	30.95	15.13	4.45
Mean	83.99	9.26	0.867	2.480	56.09	12.75	5.38
Top star F_1 (CH1)	80.17	11.06	1.100	3.042	54.88	9.10	5.53
S.107 F_1 (CH2)	70.00	7.70	0.808	1.722	25.33	15.36	3.23
LSD 5%	7.01	1.52	0.120	0.227	11.10	1.18	0.65
LSD 1%	9.33	2.17	0.172	0.325	15.87	1.68	0.93

Regarding early yield, the parental lines and their crosses varied widely in this respect. The parents produced early yield mean values ranged from 0.462 (in the line W.5-1) to 1.033 (in the line MAR-6) with an overall mean of 0.746 kg/plant, while for F_1 hybrids, the range was from 0.608 (in the cross B.10-22 x W.5-1) to 1.151 (in the cross B.23-5 x MAR-6) with a general value of 0.867 kg/plant. Also, the overall mean value of the F_1 crosses exceeded that of the parental lines by 16.22%. However, the line MAR-6 was considered the top parent and the hybrids "B.23-5 x MAR-6", "B.23-5 x L.S.5-14", "B.23-5 x L.S.2-2", "T.S.6-3 x MAR-6", "B.23-5 x L.S.5-14" and "L.S.5-14 x L.S.2.2" were the best cross combinations, since they showed the highest early yields (more than 1.00 kg/plant). Compared with the two commercial hybrids, the line MAR-6 and the mentioned six superior hybrids significantly exceeded the commercial hybrid S.107 (long fruited type), while no significant differences were detected among of them and the commercial hybrid Top star (Balady fruited type).

Concerning total yield, also a great variations among the studied entries (lines and crosses). Fruit yield of lines ranged from 1.233 to 2.823 kg/plant, while for F_1 crosses the range was from 1.923 to 3.223 kg/plant. The line B.23-5 was considered top parent (TP) which showed the highest value (2.823 kg/plant). The crosses "B-23-5 x T.S.6-3", "B.23-5 x MAR-6", "T.S.6-3 x MAR-6" and "MAR-6 x L.S.5-14" considered the best hybrids, since they produced the highest values of total yield (2.940, 3.223, 3.057 and 2.813 kg/plant, respectively). In general, the resulted F_1 hybrids performed better total yield than those of the lines, since their overall mean value (2.481 kg/plant) exceeded that of the parental lines (2.024 kg/plant) by 22.53%. Compared with the top parent (B.23-5) the two crosses "B.23-5 x MAR-6" and "T.S.6-3 x MAR-6" significantly exceeded that of the top parent by 14.17% and 8.29%, respectively. While, compared with the commercial hybrid (CH1) Top star (Balady fruited type), insignificant differences were observed between the three crosses "B-23-5 x T.S.6-3", "B.23-5 x MAR-6" and "T.S.6-3 x MAR-6" and Top star F_1 hybrid (CH1). On the other hand, except the cross "B.10-22 x L.S.5-14" the remaining 27 hybrids produced total yield higher than that of the commercial hybrid (CH2) S.107 (long fruited type). However, only the cross "L.S.5-14 x L.S.2.2" produced long fruited type and significantly exceeded the commercial hybrid S.107 (CH2).

For average fruit weight (Table 1), the parental lines mean values ranged from 23.47 gm (in the line L-S-2-2) to 94.32 gm (in the line T.S.6-3) with an average of 56.08 gm. Concerning the crosses, their range was from 30.91 gm (in the cross "MAR-6 x L.S-2-2") to 92.88 gm (in the cross "B-23-5 x T.S.6-3" with an average of 56.09 gm. Obtained data, showed that, the parental lines as well as their hybrids varied widely in this trait, while in contrast, no difference was detected between the overall mean value of the parents and their hybrids for average fruit weight. Compared with the line T.S.6-3 (the top parent), as expected, most of the resulted crosses produced fruits lower in weight than those of the top parent. While, 7 and 25 F_1 hybrids significantly exceeded the commercial hybrids Top star and S.107, respectively, for average fruit weight.

Regarding fruit length and diameter (Table 1), the same behavior was detected since, among the parental lines or the crosses a wide range was observed, while no difference was detected between their overall mean values. Fruit length mean values in the lines ranged from 7.53 to 19.50 with an overall mean of 13.11 cm, while a range from 8.30 to 19.13 with a mean value of 12.75 cm of the crosses. Also, fruit diameter mean values ranged from 2.33 to 7.17 with a mean of 5.07 cm in the lines, while ranged from 3.23 to 6.97 with a mean of 5.38 cm in the crosses. The lines L.S.5-14, L.S.2-2 and the cross between of them (L.S.5-14 x L.S.2-2) produced the longest and thinnest fruits. They showed fruit with length of 19.50, 17.37 and 19.13 cm, respectively, and diameter of 3.77, 2.33 and 3.23, respectively.

Generally, the obtained results indicated that, for the Balady fruited type, the cross "B.23-5 x MAR-6" considered the best promising hybrid, since showed high performing values for the most studied traits compared with the remaining hybrids ,as well as, the commercial F_1 hybrid Top star (balady fruited type). Also, the cross "L.S.5-14 x L.S.2.2" considered the best promising hybrid (as long sweet fruited type) compared with the commercial F_1 hybrid S.107 for most desirable traits. Significant differences among F_1 hybrids and lines/cultivars were also previously reported by Kansouh (1997), Patel *et al*. (2001 & 2004), Geleta and Labuschagne (2004), Shrestha *et al*. (2010) and Singh *et al*. (2012) for plant height, number of primary branches, early and total yield, average fruit weight, fruit length and diameter.

B.Average degree of heterosis (ADH%) and dominance state:

For plant height (Table 2), of the studied 28 F_1 hybrids, three ones showed insignificant ADH% values based on mid-parents (MP), suggesting no-dominance for the trait in these crosses.

While, the remaining 25 hybrids showed significant positive mid-parent heterosis (MPH%) values ranging from 8.05% (in the cross T.S.6-3 x MAR-6) to 49.74% (in the cross B.10-22 x Z.M.3-6), suggesting different degrees of dominance (partial, complete and over) towards the taller parent. The estimated better parent heterosis (BPH%) as heterobeltiosis for these 25 crosses showed complete and over-dominance for the taller parent in 12 and 13 hybrids, respectively, since they recorded insignificant and significant positive (BPH%) values. Relative to the top parent (TP), i.e., B23-5 as top heterosis (TH%) and the commercial hybrids Top star (CH1) and S.107 (CH2) as standard heterosis (SH%), seven crosses showed TH% and SH%, since they gave significant positive values relative to TP and CH1. While, the majority of the hybrids (21 ones) reflected SH% relative to CH2. The cross "MAR-6 x L.S.5-14" recorded the highest top and standard heterosis values (28.57, 30.97 and 50.00%, respectively).

Regarding number of primary branches per plant (Table 3), most hybrids (17 ones) showed insignificant MPH% values, suggesting no-dominance for the trait. The remaining eleven crosses showed dominance toward the high number of branches, since they recorded significant positive MPH% values ranged from 17.44% (in the cross L.S.5-14 x W.5-1) to 42.61% (in the cross B.23-5 x MAR-6). The estimated BPH% values for these crosses showed heterobeltiosis in five ones, which reflected significant positive values. A complete dominance for the large number of branches was also detected in the remaining six crosses, since they showed insignificant BPH% values. The cross "B.23-5 x MAR-6" recorded the highest BPH% value (37.36%). Estimated average degree of heterosis relative to TP, CH1 and CH2, showed that, 2 and 14 crosses, respectively, expressed TH% and SH%. In this respect, the two crosses "B.23-5 x MAR-6" and "L.S.5-14 x L.S.2.2" expressed the same direction for maximum heterosis expression, since they showed TH% of 19.39% and SH% of 62.34% relative to the TP and CH2, respectively.

Table (2): Average degree of heterosis (ADH%) based on mid-parents (MP), better parent (BP), top parent (TP), commercial hybrid (CH) and dominance type for plant height.

	ADH%					Dominance type
	MP	BP	TP	CH1	CH2	
B.10-22 x B.23-5	24.48**	4.29	-	6.24	21.67**	Complete dominance
B.10-22 x Z.M.3-6	49.74**	35.94**	-8.17	-6.45	7.14	Over dominance
B.10-22 x T.S.6-3	22.69**	5.86	-	0.62	15.24**	Complete dominance
B.10-22 x MAR-6	21.69**	8.25	-	-4.37	9.53	Complete dominance
B.10-22 x L.S.5-14	22.76**	6.43	-	-0.21	14.29**	Complete dominance
B.10-22 x L.S.2-2	13.16**	-0.47	-	-9.78*	3.33	Complete dominance
B.10-22 x W.5-1	33.39**	26.85**	1.22	3.11	18.10**	Over dominance
B.23-5 x Z.M.3-6	32.11**	2.49	-	4.37	19.53**	Complete dominance
B.23-5 x T.S.6-3	1.27	-	-	-0.21	14.29**	No-dominance
B.23-5 x MAR-6	26.78**	18.37**	18.37**	20.58**	38.10*	Over dominance
B.23-5 x L.S.5-14	18.81**	14.08**	14.08**	16.22**	33.10**	Over dominance
B.23-5 x L.S.2-2	31.31**	24.07**	24.07**	26.39**	44.76**	Over dominance
B.23-5 x W.5-1	15.77**	4.08	-	6.02	21.42**	Complete dominance
Z.M.3-6 x T.S.6-3	31.33**	4.38	-	-0.62	13.81**	Complete dominance
Z.M.3-6 x MAR-6	43.31**	17.18**	1.63	3.53	18.57**	Over dominance
Z.M.3-6 x L.S.5-14	19.83**	-4.22	-	-10.19**	2.85	Complete dominance
Z.M.3.6 x L.S.2-2	25.78**	1.83	-	-7.70	5.71	Complete dominance
Z.M.3-6 x W.5-1	36.15**	15.08**	-8.17	-6.45	7.14	Over dominance
T.S.6-3 x MAR-6	8.05*	4.15	-	-0.84	13.57**	Complete dominance
T.S.6-3 x L.S.5-14	13.76**	12.89**	5.51	7.48	23.10**	Over dominance
T.S.6-3 x L.S. 2-2	5.60	-	-	-1.87	12.39*	No dominance
T.S.6-3 x W.5-1	6.25	-	-	-6.24	7.39	No dominance
MAR-6 x L.S.5-14	43.84**	39.68**	28.57**	30.97**	50.00**	Over dominance
MAR-6 x L.S.2-2	18.47**	16.97**		6.02	21.43**	Over dominance
MAR-6 x W.5-1	34.31**	28.94**	11.83**	13.92**	30.47**	Over dominance
L.S.g-14 x L.S.2-2	32.58**	30.37**	19.99**	22.24**	40.00**	Over dominance
L.S.5-14 x W.5-1	15.90**	8.19	-	1.45	16.19**	Complete dominance
L.S.2-2 x W.5-1	37.84**	30.73**	16.32**	18.50**	35.71**	Over dominance

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

Table (3): Average degree of heterosis (ADH%) based on mid-parents (MP), better parent (BP), top parent (TP), commercial hybrid (CH) and dominance type for number of primary branches.

	ADH%					Dominance type
	MP	BP	TP	CH1	CH2	
B.10-22 x B.23-5	24.40*	7.94	-	-17.71**	18.18	Complete dominance
B.10-22 x Z.M.3-6	10.57	-	-	-41.86**	-16.49	No-dominance
B.10-22 x T.S.6-3	4.67	-	-	-35.17**	-6.88	No-dominance
B.10-22 x MAR-6	24.57*	4.72	-	-13.83	23.76	Complete dominance
B.10-22 x L.S.5-14	7.60	-	-	-27.67**	3.90	No-dominance
B.10-22 x L.S.2-2	8.82	-	-	-17.99	17.79	No-dominance
B.10-22 x W.5-1	10.46	-	-	-31.28	-1.30	No-dominance
B.23-5 x Z.M.3-6	9.67	-	-	-31.28	-1.30	No-dominance
B.23-5 x T.S.6-3	-0.06	-	-	-28.03	3.38	No-dominance
B.23-5 x MAR-6	42.61**	37.36**	19.39*	13.02	62.34**	Over dominance
B.23-5 x L.S.5-14	18.95*	17.30	-	-8.05	32.08**	Complete dominance
B.23-5 x L.S.2-2	6.88	-	-	-8.68	31.17**	No-dominance
B.23-5 x W.5-1	31.33**	24.56*	0.29	-5.06	36.36**	Over dominance
Z.M.3-6 x T.S.6-3	9.82	-	-	-35.80**	-7.79	No-dominance
Z.M.3-6 x MAR-6	42.19**	13.52	-	-6.60	34.16**	Complete dominance
Z.M.3-6 x L.S.5-14	12.07	-	-	28.57**	2.60	No-dominance
Z.M.3.6 x L.S.2-2	15.72	-	-	-16.82*	19.48	No-dominance
Z.M.3-6 x W.5-1	15.47	-	-	32.19**	-2.60	No-dominance
T.S.6-3 x MAR-6	2.41	-	-	-23.15**	10.39	No-dominance
T.S.6-3 x L.S.5-14	15.40	-	-	-15.64*	21.17*	No-dominance
T.S.6-3 x L.S. 2-2	7.96	-	-	-12.30	25.97*	No dominance
T.S.6-3 x W.5-1	1.86	-	-	-30.65	-0.39	No dominance
MAR-6 x L.S.5-14	24.93**	21.98*	6.02	0.36	44.16**	Over dominance
MAR-6 x L.S.2-2	18.55*	10.79	-	4.88	50.65**	Complete dominance
MAR-6 x W.5-1	35.65**	24.18**	7.92	2.17	46.75**	Over dominance
L.S.g-14 x L.S.2-2	30.62**	19.39*	1.39*	13.02	62.34**	Over dominance
L.S.5-14 x W.5-1	17.44*	9.92	-	-13.83*	23.77*	Complete dominance
L.S.2-2 x W.5-1	12.36	-	-	-8.41	31.56**	No dominance

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

For early yield, data (Table 4) showed that, all the studied crosses distributed between the no-dominance and dominance toward the high early yield, since 15 and 13 hybrids, respectively, showed insignificant and significant positive MPH% values. Relative to the better parent (BP), five crosses reflected heterobeltiosis with BPH% values ranging from 13.74% (in the cross "B.23-5 x L.S.5-14") to 45.57% (in the cross ""B.10-22 x Z.M.3-6"), suggesting hybrid vigour (over-dominance) for high early yield. Complete dominance for high early yield was also detected in seven hybrids, where they recorded insignificant BPH% values.

The remaining cross "MAR-6 x W.5-1" reflected partial dominance for the high early yield, since showed significant positive and negative heterosis values relative to MP (19.20%) and BP (-13.75%), respectively. Relative to the top parent and the first commercial hybrid (CH1) no top heterosis (TP%) or standard heterosis (SH%) was detected since insignificant and significant negative values were recorded . In this respect , SH % relative to second commercial hybrid (CH2) was reported by eight crosses, where they showed significant positive SH% values ranging from 16.34 % (in the cross "B.10-22 x MAR-6") to 42.57% (in the cross "B.23-5 x MAR-6").

Table (4): Average degree of heterosis (ADH%) based on mid-parents (MP), better parent (BP), top parent (TP), commercial hybrid (CH) and dominance type for early yield.

	ADH%					Dominance type
	MP	BP	TP	CH1	CH2	
B.10-22 x B.23-5	17.48*	-2.18	-	-18.45**	11.01	Complete dominance
B.10-22 x Z.M.3-6	50.25**	45.57**	-14.04*	-19.27**	9.90	Over dominance
B.10-22 x T.S.6-3	19.45*	2.59	-	-20.73**	7.92	Complete dominance
B.10-22 x MAR-6	14.42*	-9.00	-	-14.55*	16.34*	Complete dominance
B.10-22 x L.S.5-14	-1.43	-	-	-40.73**	-14.31*	No-dominance
B.10-22 x L.S.2-2	6.19	-	-	-31.36**	-6.56	No-dominance
B.10-22 x W.5-1	13.43	-	-	-44.73**	-24.75**	No-dominance
B.23-5 x Z.M.3-6	11.22	-	-	-24.73**	2.47	No-dominance
B.23-5 x T.S.6-3	-1.53	-	-	-20.91**	7.67	No-dominance
B.23-5 x MAR-6	18.15**	11.52	11.52	4.73	42.57**	Complete dominance
B.23-5 x L.S.5-14	27.98**	13.74*	0.96	-5.18	29.08**	Over dominance
B.23-5 x L.S.2-2	16.83*	10.14	-	-8.18	25.00**	Complete dominance
B.23-5 x W.5-1	3.99	-	-	-34.82**	-11.26	No-dominance
Z.M.3-6 x T.S.6-3	10.13	-	-	-28.82**	-3.09	No-dominance
Z.M.3-6 x MAR-6	0.93	-	-	-26.36**	0.25	No-dominance
Z.M.3-6 x L.S.5-14	46.47**	32.26**	-8.71	-14.27*	16.71*	Over dominance
Z.M.3.6 x L.S.2-2	7.22	-	-	-32.55**	-8.17	No-dominance
Z.M.3-6 x W.5-1	30.64**	0.82	-	-22.09**	6.06	Complete dominance
T.S.6-3 x MAR-6	10.78	-	-	-5.18	29.08**	No-dominance
T.S.6-3 x L.S.5-14	4.93	-	-	-25.45**	1.49	No-dominance
T.S.6-3 x L.S. 2-2	8.66	-	-	-17.91**	11.75	No dominance
T.S.6-3 x W.5-1	-0.45	-	-	-40.64**	-19.18*	No dominance
MAR-6 x L.S.5-14	14.89*	-2.90	-	-8.81	24.13**	Complete dominance
MAR-6 x L.S.2-2	0.49	-	-	-16.54**	13.61	No dominance
MAR-6 x W.5-1	19.20*	-13.75*	-	-19.00**	10.27	Partial dominance
L.S.g-14 x L.S.2-2	36.00**	27.71**	0.38	-5.72	28.34**	Over dominance
L.S.5-14 x W.5-1	55.40**	28.05**	-11.62*	-17.00**	12.99	Over dominance
L.S.2-2 x W.5-1	13.81	-	-	-34.09**	-10.27	No dominance

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

Data obtained for total yield (Table 5) showed that, the majority of the studied hybrids (23 F_1's) reflected different degrees of dominance towards the high total yield, since they recorded significant positive MPH% values. From these crosses, 13 ones showed BPH% values, suggesting hybrid vigour (over dominance) for total yield. The cross "B.10-22 x L.S.2-2" followed by "B.10-22 x W.5-1" revealed the highest BPH% (heterobeltiosis) values

(48.91% and 45.64%, respectively). Respecting the remaining ten crosses, six and four ones showed, respectively, insignificant and significant negative BPH% values, suggesting complete and partial dominance for the high total yield. In contrast, no-dominance for the trait was observed in three crosses, where they showed insignificant MPH% values. Relative to the TP (B.23-5), only the two crosses “B.23-5 x MAR-6” and “T.S.6-3 x MAR-6” significantly outyielded the TP with top heterosis (TH%) values of 14.17 and 8.29%, respectively. Compared with the two commercial hybrids Top star (CH1) and S.107 (CH2), none of the crosses showed SH% relative to CH1, while all the resulted crosses, except “B.10-22 x L.S.5-14” significantly outyielded CH2 and showed SH% values ranged from 12.49% to 87.17%. In this respect, the three crosses “B.23-5 x T.S.6-3”, “B.23-5 x MAR-6” and T.S.6-3 x MAR-6” recorded insignificant values (-3.35, 5.95 and 0.49%, respectively) relative to CH1 and the highest SH% values (70.73, 87.17 and 77.52%, respectively) relative to CH2.

Table (5): Average degree of heterosis (ADH%) based on mid-parents (MP), better parent (BP), top parent (TP), commercial hybrid (CH) and dominance type for total yield.

	ADH%					Dominance type
	MP	BP	TP	CH1	CH2	
B.10-22 x B.23-5	7.69	-	-	-22.65**	36.64**	No-dominance
B.10-22 x Z.M.3-6	44.19**	30.34**	-11.58**	-17.95**	44.95**	Over dominance
B.10-22 x T.S.6-3	31.43**	4.03	-	-9.27*	60.28**	Complete dominance
B.10-22 x MAR-6	36.30**	13.09*	-6.02	-12.78**	54.07**	Over dominance
B.10-22 x L.S.5-14	7.61	-5.13	-	-36.79**	11.67	Complete dominance
B.10-22 x L.S.2-2	53.71**	48.91**	-12.96**	-19.23**	42.68**	Over dominance
B.10-22 x W.5-1	62.09**	45.64**	-20.19**	-25.93**	30.83**	Over dominance
B.23-5 x Z.M.3-6	16.63**	-2.13	-	-9.17*	60.45**	Complete dominance
B.23-5 x T.S.6-3	7.38*	4.14	-	-.35	70.73**	Complete dominance
B.23-5 x MAR-6	24.70**	14.17**	14.17**	5.95	87.17**	Over dominance
B.23-5 x L.S.5-14	2.14	-	-	-18.57**	43.84**	No-dominance
B.23-5 x L.S.2-2	8.51	-	-	-20.22**	40.94**	No-dominance
B.23-5 x W.5-1	16.03**	-16.64**	-	-22.65**	36.64**	Partial dominance
Z.M.3-6 x T.S.6-3	5.602	-	-	-20.71**	40.07**	No-dominance
Z.M.3-6 x MAR-6	29.12**	17.26**	-2.55	-9.57*	59.76**	Over dominance
Z.M.3-6 x L.S.5-14	18.21**	14.95*	-17.46**	-23.41**	35.31**	Over dominance
Z.M.3.6 x L.S.2-2	29.42**	20.47**	-18.28**	-24.16**	33.97**	Over dominance
Z.M.3-6 x W.5-1	24.52**	2.34	-	-35.57**	13.82*	Complete dominance
T.S.6-3 x MAR-6	22.30**	15.23**	8.29*	0.49	77.52**	Over dominance
T.S.6-3 x L.S.5-14	18.50**	4.52	-	-8.84*	61.03**	Complete dominance
T.S.6-3 x L.S. 2-2	11.87*	-9.27*	-	-20.87**	39.78**	Partial dominance
T.S.6-3 x W.5-1	17.44**	-13.98**	-	-24.98**	32.52**	Partial dominance
MAR-6 x L.S.5-14	28.65**	19.91**	-0.35	-7.53*	63.35**	Over dominance
MAR-6 x L.S.2-2	37.48**	17.09**	-2.69	-9.69*	59.52**	Over dominance
MAR-6 x W.5-1	15.45*	-11.93*	-	-32.08**	19.97**	Partial dominance
L.S.g-14 x L.S.2-2	37.23**	24.47**	-10.63*	-17.06**	46.52**	Over dominance
L.S.5-14 x W.5-1	18.83**	-4.44	-	-36.32**	12.49*	Complete dominance
L.S.2-2 x W.5-1	40.13**	22.42**	-28.44**	-33.60**	17.31*	Over dominance

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

The obtained results are in agreement with those of Kansouh (1997), Nayaki and Natarajan (2000), Rajesh-Kumar *et al*. (2001), Patel *et al*. (2001), Mamedov and Pyshnaja (2001), Kumar *et al*. (2005) and Farag and Khalil (2007) who found heterobeltiosis for plant height, number of primary branches, early and total yield. Also, agreement with those of Geleta and

Labuschagne (2004), Singh *et al*. (2012) and Sharma *et al*. (2013) who reported heterobeltiosis, top heterosis and standard heterosis in F_1 hybrids studied for plant height, number of branches, early and total yield in pepper .

For average fruit weight (Table 6), all the studied crosses showed no-dominance for the trait, since they gave insignificant MPH% values, and therefore, no BPH% and TH% was obtained. On the other hand, eight and 25 crosses showed SH% for the trait, since they reflected significant positive values relative to CH1 and CH2, respectively.

Table (6): Average degree of heterosis (ADH%) based on mid-parents (MP), better parent (BP), top parent (TP), commercial hybrid (CH) and dominance type for average fruit weight .

	ADH%					Dominance type
	MP	BP	TP	CH1	CH2	
B.10-22 x B.23-5	5.59	-	-	13.53	145.99**	No-dominance
B.10-22 x Z.M.3-6	-4.27	-	-	-1.95	112.43**	No-dominance
B.10-22 x T.S.6-3	3.40	-	-	23.12**	166.76**	No-dominance
B.10-22 x MAR-6	4.71	-	-	-22.08**	68.81**	No-dominance
B.10-22 x L.S.5-14	0.65	-	-	-20.04**	73.23**	No-dominance
B.10-22 x L.S.2-2	0.45	-	-	-45.23**	18.67	No-dominance
B.10-22 x W.5-1	12.83	-	-	-20.79**	71.61**	No-dominance
B.23-5 x Z.M.3-6	11.40	-	-	60.04**	246.74**	No-dominance
B.23-5 x T.S.6-3	5.57	-	-	69.24**	266.68**	No-dominance
B.23-5 x MAR-6	-0.18	-	-	15.43	150.10**	No-dominance
B.23-5 x L.S.5-14	5.50	-	-	27.31**	175.84**	No-dominance
B.23-5 x L.S.2-2	-13.10	-	-	-16.78	80.30**	No-dominance
B.23-5 x W.5-1	-0.76	-	-	10.59	139.60	No-dominance
Z.M.3-6 x T.S.6-3	3.93	-	-	61.32**	249.51**	No-dominance
Z.M.3-6 x MAR-6	-2.41	-	-	7.89	133.75	No-dominance
Z.M.3-6 x L.S.5-14	3.75	-	-	19.92	159.81	No-dominance
Z.M.3.6 x L.S.2-2	-17.62	-	-	-25.31	61.82**	No-dominance
Z.M.3-6 x W.5-1	-4.16	-	-	1.91	120.80**	No-dominance
T.S.6-3 x MAR-6	-1.83	-	-	24.87**	170.55**	No-dominance
T.S.6-3 x L.S.5-14	1.30	-	-	33.95**	190.21**	No-dominance
T.S.6-3 x L.S. 2-2	-13.86	-	-	-7.56	100.28**	No-dominance
T.S.6-3 x W.5-1	-13.27	-	-	6.67	131.11**	No-dominance
MAR-6 x L.S.5-14	5.56	-	-	-7.58	100.24**	No-dominance
MAR-6 x L.S.2-2	-10.12	-	-	-43.70**	21.99	No-dominance
MAR-6 x W.5-1	10.28	-	-	-13.63	87.13**	No-dominance
L.S.g-14 x L.S.2-2	4.20	-	-	-29.48**	52.78**	No-dominance
L.S.5-14 x W.5-1	0.61	-	-	-16.14	81.68**	No-dominance
L.S.2-2 x W.5-1	-3.49	-	-	-43.60**	22.19	No-dominance

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

Respecting the order, the three crosses “B.23-5 x MAR-6”, “B-23-5 x T.S.6-3” and “Z.M.3-6 x T.S.6-3” showed the highest SH% values (60.04%, 69.24% and 61.32%, respectively) relative to CH1 and (246.74%, 266.68%, 249.51%, respectively) relative to CH2.

Regarding fruit length (Table 7), the studied crosses showed either no-dominance (26 F_1’s) or dominance (2 crosses) towards the short fruit, since reflected insignificant and significant negative mid-parent heterosis (MPH%) values, respectively. Therefore, no BPH% (heterobeltiosis) or TH% were expected. On the other hand, 23 F_1's and one cross showed standard heterosis (SH%) values relative to CH1 and CH2, respectively. The cross "L.S.5-14 x L.S.2.2" recorded the highest SH% values (110.22%) relative to CH1 and (24.54%) relative to CH2, respectively.

Table (7): Average degree of heterosis (ADH%) based on mid-parents (MP), better parent (BP), top parent (TP), commercial hybrid (CH) and dominance type for fruit length.

	ADH%					Dominance type
	MP	BP	TP	CH1	CH2	
B.10-22 x B.23-5	4.78	-	-	13.19*	-32.94**	No-dominance
B.10-22 x Z.M.3-6	-4.88	-	-	10.22	-34.70**	No-dominance
B.10-22 x T.S.6-3	-3.44	-	-	8.02	-36.00**	No-dominance
B.10-22 x MAR-6	4.01	-	-	-8.79	-45.96**	No-dominance
B.10-22 x L.S.5-14	0.33	-	-	49.01**	-11.72**	No-dominance
B.10-22 x L.S.2-2	5.26	-	-	43.96**	-14.71**	No-dominance
B.10-22 x W.5-1	0.28	-	-	16.04*	-31.25**	No-dominance
B.23-5 x Z.M.3-6	-9.46*	-	-	27.80**	-24.28**	Dominance toward low parent
B.23-5 x T.S.6-3	-7.37	-	-	27.03**	-24.74**	No-dominance
B.23-5 x MAR-6	1.75	-	-	14.95*	-31.90**	No-dominance
B.23-5 x L.S.5-14	-6.23	-	-	62.97**	-3.45	No-dominance
B.23-5 x L.S.2-2	-4.85	-	-	54.18**	-8.66*	No-dominance
B.23-5 x W.5-1	-6.24	-	-	32.20**	-21.68**	No-dominance
Z.M.3-6 x T.S.6-3	-11.10**	-	-	29.80**	-23.63**	Dominance toward low parent
Z.M.3-6 x MAR-6	-3.05	-	-	17.14*	-30.60**	No-dominance
Z.M.3-6 x L.S.5-14	-4.05	-	-	74.29**	3.26	No-dominance
Z.M.3.6 x L.S.2-2	-2.78	-	-	65.16**	-2.15	No-dominance
Z.M.3-6 x W.5-1	-5.28	-	-	40.99**	-16.47**	No-dominance
T.S.6-3 x MAR-6	-4.99	-	-	10.99	-34.25**	No-dominance
T.S.6-3 x L.S.5-14	-2.51	-	-	73.19**	2.60	No-dominance
T.S.6-3 x L.S. 2-2	-2.88	-	-	61.10**	-4.58	No-dominance
T.S.6-3 x W.5-1	-0.38	-	-	44.29**	-14.25**	No-dominance
MAR-6 x L.S.5-14	-1.68	-	-	50.88**	-10.61*	No-dominance
MAR-6 x L.S.2-2	0.27	-	-	42.09**	-15.82**	No-dominance
MAR-6 x W.5-1	-4.74	-	-	14.95	-31.90**	No-dominance
L.S.g-14 x L.S.2-2	3.80	-	-	110.22**	24.54**	No-dominance
L.S.5-14 x W.5-1	-5.18	-	-	72.09**	1.95	No-dominance
L.S.2-2 x W.5-1	-2.04	-	-	66.26**	-1.50	No-dominance

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

Data obtained for fruit diameter (Table 8) illustrated that, the majority of the crosses (24 F_1's) showed no dominance for the trait, since they recorded insignificant MPH% values.

The remaining four crosses "B.10-22 x B.23-5", "B.23-5 x L.S.5-14", "T.S.6-3 x L.S.2-2" and L.S.2-2 x W.5-1" showed partial dominance toward the widest fruit diameter, since recorded significant positive MPH% values (14.43, 14.85, 18.95 and 18.83%, respectively) and significant negative BPH% values (-9.22, -12.57, -20.15 and -13.76%, respectively). Therefore, no heterobeltiosis (over dominance) was obtained and subsequently, no top heterosis was also observed for fruit diameter trait. Compared with the two commercial hybrids (check cvs.), eight and 26 hybrids reflected SH% values. The three crosses “B-23-5 x T.S.6-3”, “B.23-5 x MAR-6” and “Z.M.3-6 x T.S.6-3” recorded the highest SH% values (25.86, 19.89 and 19.89, respectively) relative to CH1 and (115.48, 105.26 and 105.26%, respectively) relative to CH2. Similar results were previously reported by Kansouh (1997), Khalil *et al*. (2004) for average fruit weight and by Nayaki and Natarajan (2000) and Burli *et al*. (2001), regarding absent of heterosis for these traits, since the crosses showed lower values than their better parent for these fruit traits.

Table (8): Average degree of heterosis (ADH%) based on mid-parents (MP), better parent (BP), top parent (TP), commercial hybrid (CH) and dominance type for fruit diameter.

	ADH%					Dominance type
	MP	BP	TP	CH1	CH2	
B.10-22 x B.23-5	14.43**	-9.22*	-	17.54*	101.24**	Partial-dominance
B.10-22 x Z.M.3-6	9.58	-	-	2.35	75.23**	No-dominance
B.10-22 x T.S.6-3	-1.27	-	-	-1.80	68.11**	No-dominance
B.10-22 x MAR-6	8.64	-	-	-9.04	55.73**	No-dominance
B.10-22 x L.S.5-14	8.04	-	-	-22.24**	33.13**	No-dominance
B.10-22 x L.S.2-2	17.30	-	-	-30.74**	18.57	No-dominance
B.10-22 x W.5-1	8.97	-	-	-7.78	57.89**	No-dominance
B.23-5 x Z.M.3-6	-3.24	-	-	16.27*	99.07**	No-dominance
B.23-5 x T.S.6-3	-0.28	-	-	25.86**	115.48**	No-dominance
B.23-5 x MAR-6	8.51	-	-	19.89**	105.26**	No-dominance
B.23-5 x L.S.5-14	14.85*	-12.57*	-	13.20*	93.81**	Partial-dominance
B.23-5 x L.S.2-2	8.11	-	-	-7.23	58.82**	No-dominance
B.23-5 x W.5-1	5.52	-	-	17.54**	101.24**	No-dominance
Z.M.3-6 x T.S.6-3	2.55	-	-	19.89**	105.26**	No-dominance
Z.M.3-6 x MAR-6	1.16	-	-	2.35	75.23**	No-dominance
Z.M.3-6 x L.S.5-14	7.78	-	-	-3.62	65.02**	No-dominance
Z.M.3.6 x L.S.2-2	4.72	-	-	-19.89**	37.15**	No-dominance
Z.M.3-6 x W.5-1	2.03	-	-	4.16	78.33**	No-dominance
T.S.6-3 x MAR-6	3.37	-	-	10.85	89.78**	No-dominance
T.S.6-3 x L.S.5-14	0.95	-	-	-3.62	65.02**	No-dominance
T.S.6-3 x L.S. 2-2	18.95**	-20.15**	-	-1.80	68.11**	Partial-dominance
T.S.6-3 x W.5-1	4.18	-	-	12.66*	92.88**	No-dominance
MAR-6 x L.S.5-14	9.52	-	-	-12.66*	49.53**	No-dominance
MAR-6 x L.S.2-2	7.17	-	-	-28.39**	22.60*	No-dominance
MAR-6 x W.5-1	2.93	-	-	-4.88	62.85**	No-dominance
L.S.g-14 x L.S.2-2	6.07	-	-	-41.59**	-	No-dominance
L.S.5-14 x W.5-1	-2.91	-	-	-21.70**	34.06	No-dominance
L.S.2-2 x W.5-1	18.83*	-13.76*	-	-16.51*	37.77**	Partial-dominance

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

C.Average degree of heterosis in relation to dominance type:

The mean performance of any hybrid reflected its degree of heterosis which could be considered as an indicator of specific combining ability (SCA) effects. High SCA effects also show high degrees of dominance (non-additive effects). Therefore, the high degree of heterosis reflected presence of high non-additive effects, meanwhile absence of heterosis (no dominance) could be considered as a criterion of additive effects. Estimated average degree of heterosis relative to mid-parents (MP) and better parent (BP) of the 28 crosses studied showed that, for plant height (Table 2) three ones reflected no-dominance, while 25 F_1's showed different degrees of dominance, suggesting presence of additive and non-additive effects. However, since a majority of these crosses (25 F_1's) showed over or complete dominance, the non-additive effects play the main role in the inheritance of this trait, and heterosis breeding programme would be more realistic. For number of primary branches per plant (Table 3) additive and non-additive effects are important in this trait with prevalence of additive ones since 17 and 11 crosses, respectively, reflected no-dominance and dominance (complete and over) relative to their MP and BP values, and pedigree selection or pure line selection is more effective for this trait since desirable segregates are expected. For early yield (Table 4), the magnitude and incidence of heterosis in the studied crosses are indicative of additive and non-additive effects, with the same role, in the inheritance of this trait, since 15 and 13 F_1's recorded no-dominance (additive effects) and different degrees of dominance (non-additive effects) towards the high early yield, suggesting possibility of improvement of this trait through selection as well as hybrid breeding programmes. Regarding total yield (Table 5), additive and non-additive were involved in the inheritance of this trait. However, most crosses (23 F_1's) showed dominance towards the high total yield suggested that, the non-additive effects play the main role and this trait may be improved mainly by hybrid vigour breeding programme. For average fruit weight, fruit length and diameter traits, (Tables 6-8) the same role of the inheritance was observed. The magnitude and incidence of heterosis in the studied crosses indicative of no-dominance for these three traits. The incidence of no-dominance observed indicated that, additive effects controlled the inheritance of these traits, and may be improved by varietal breeding by selection. These results are in accordance with those of Sprague (1966), Simmonds (1979), Goyal and Kumar (1988) and Mohanty and Mishra (1999) who reported that, phenotypic performance is considered as one of the modern practices of inbred evaluation for heterosis and the mean performance of hybrid could be considered as a criterion of specific combining ability effects. They also reported that, significant heterosis in a hybrid indicates the existence of non-additive gene action. Kansouh (-----) used the same lines in 8 x 8 half-diallel to study the combining ability and gene action effects and found the same results regarding additive and non-additive effects for these traits.

D.Performance, heterosis manifestation and promising hybrid vigour relations:

From data illustrated in Table (9), we can observe relationships between the best parents and the best hybrids based on their performance for all the studied traits. Except the cross "5 x 6" for plant height, all the best hybrid performances involved at least one parent from the best parents and high performing parents having better performance in hybrids. Also, we can see relationships between the mean performance of hybrids and the heterosis manifestation based on top parent (TH) or commercial hybrid (SH%), since all the best hybrids based on mean performance were the best ones showed top parent heterosis and standard heterosis.

Table (9): Heterosis (ADH%) over the better parent, the best parents and the best hybrids based on performance, better parent heterosis (BPH%), top parent heterosis (TPH%) on standard heterosis (SH%).

Character	ADH %	Best parent	Best hybrids based on			
			Performances	BPH%	TPH%	SH%
Plant height	23.97	2, 4	2x7 5x6	1x3 5x6	2x7 5x6	2x7 5x6
No. of branches	16.79	7, 5	2x5 6x7	2x5 2x8	2x5 6x7	2x5 6x7
Early yield	16.21	2, 5	2x5 2x6	1x3 3x6	2x5 4x5	2x5 4x5
Total yield	22.53	2, 4	2x5 4x5	1x7 1x8	2x5 4x5	2x5 4x5
Av. fruit weight	0.02	2, 4	2x4 3x4	- -	2x4 3x4	2x4 3x4
Fruit length	-2.81	6, 7	3x6 6x7	- -	- 6x7	- 6x7
Fruit diameter	6.06	2, 4	2x4 2x5	- -	2x4 2x5	2x4 2x5

(1), B.10-22; (2) B.23-5; (3) Z.M.3-6; (4) T.S.6-3; (5) MAR-6; (6) L.S.5-14; (7) L.S.2-2 and (8) W.5-1

On the contrary, no relationship was detected between the mean performance of hybrids and average degree of heterosis based on better parents (BPH%) as heterobeltiosis or over dominance. Since, except the cross “2 x 5” for number of branches, all the crosses which showed the highest BPH% values not the best hybrids based on performance. For total yield, as example, (Tables 1 and 5) the two hybrids “B.10-22 x L.S.2-2” and “B.10-22 x W.5-1”, i.e., 1 x 7 and 1 x 8, which considered the best crosses based on BPH% (over-dominance) since showed the highest significant positive values (48.91 and 45.64%, respectively), gave total yield of 2.457 and 2.253 kg/plant, respectively. Meanwhile, the crosses “B.23-5 x MAR-6” and “T.S.6-3 x MAR-6”, i.e., 2 x 5 and 4 x 5, which showed BPH% values of 14.17 and 15.23%, respectively, recorded the highest total yield (3.223 and 3.057 kg/plant, respectively), and standard heterosis (SH%) values of 87.17 and 77.52%, respectively and considered the best hybrids based on the promising hybrid vigour. Moreover, the two crosses “B.23-5 x L.S.5-14” and “B.23-5 x L.S.2-2”, i.e. 2 x 6 and 2 x 7, which showed insignificant heterosis values (2.14 and 8.51%, respectively) relative to their mid-parents (no-dominance) recorded the same total yield (2.477 and 2.426 kg/plant, respectively) of the superior mentioned crosses based on better parent heterosis . Therefore, the recommendation of hybrid for commercial production must depend on its actual high productivity (mean performance) as an indicator of standard heterosis rather than its average degree of better parent heterosis (heterobeltiosis or over-dominance).

E.Promising hybrids:

As mentioned before two superior F_1 hybrids, i.e. “B.23-5 x MAR-6” (balady fruit type) and “L.S.5-14 x L.S.2.2” (long sweet fruited type) were chosen and grown with two commercial F_1 hybrids “Top star” and “S.107” in large scale experiments.

Data in Table (10) showed that, the hybrid “B.23-5 x MAR-6” produced early yield of 13.377 ton/fed., compared with 13.267 ton/fed., in the commercial hybrid Top star (CH1), indicating no significant difference was recorded between them. While, significant difference was observed between the two crosses for total yield, since yield of 34.183 and 31.240 ton/fed. were produced by “B.23-5 x MAR-6” and “Top Star”, respectively. However, the breed hybrid “B.23-5 x MAR-6” significantly outyielded the commercial hybrid “Top Star” with standard heterosis of 9.42%.

Table (10): Early and total yield (ton/fed.) of the evaluated superior two F_1 hybrids with check hybrids.

Hybrids	Early yield		Total yield	
	Mean, ton/fed	SH %	Mean, ton/fed	SH %
“B.23-5 x MAR-6” Top star F_1	13.377 13.267	0.83	34.183 31.240	9.42
“L.S.5-14 x L.S.2.2” S.107	11.050 9.613	14.95	27.217 21.067	29.19

Regarding the cross “L.S.5-14 x L.S.2-2” significant differences between the breed hybrid and the commercial hybrid “S.107” (CH2) for both early and total yield. The cross “L.S.5-14 x L.S.2.2” produced early and total yield of 11.050 and 27.217 ton/fed., respectively, compared with 9.613 and 21.067 ton/fed., respectively, for the commercial hybrid “S.107”, and recorded standard heterosis value of 14.95 and 29.19%, respectively.

Generally, it is very good when the local hybrids yielding similar or more than the commercial imported hybrids, and could be considered are good as local hybrids can be used efficiently to improve yield in sweet pepper in Egypt. However, the cross “B.23-5 x MAR-6” as balady fruited type and the cross “L.S.5-14 x L.S.2.2” as long sweet fruited type are succeeded in the general evaluation at the central administration for seed certification, Ministry of Agriculture. They under recognized by names of “Freska” and “Thouria sweet”.

F.Breeding strategy:

Phenotypic performance of the hybrids is considered as one of the modern practices of evaluation for heterosis. The recommendable F_1 pepper hybrid for commercial production must be depended on the standard heterosis which reflected its high productivity rather than its average degree of heterosis based on better parent, since the hybrid which showed the highest ADH% value not necessary produce the highest mean performance among the studied crosses. Significant average degree of heterosis in a hybrid indicates the extence of non-additive effects, and heterosis breeding programme would be more realistic, while absence of heterosis (no-dominance) could be considered as a criterion of additive effects, and pedigree selection or pure line selection (varietal breeding) was more effective, since desirable segregates are expected. The hybrid breeding method based on standard heterosis can be used efficiently to improve pepper yield and quality in Egypt.

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العلاقة بين آداء الهجن ودرجة قوة الهجن ونوع السيادة فى الفلفل

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أجريت هذه الدراسة خلال الموسم الصيفى فى الفترة من ٢٠٠٨-٢٠١١ حيث استخدمت ٨ سلالات من الفلفل الحلو فى دائرة تلقيحه من إتجاه واحد لإنتاج ٢٨ هجين جيل أول . درجة قوة الهجين تم تقديرها على أساس كل من متوسط الأبوين ـ الأب الاحسن ـ الأب القمى ـ الهجين التجارى لبعض الصفات النباتية والثمرية.

أظهر تحليل التباين وجود فروق معنوية بين التراكيب تحت الدراسة (الأباء والهجن). قوة الهجين على أساس الأب الأعلى ظهرت فى عدد ١٣ هجين فى صفة طول النبات والمحصول الكلى بينما ظهرت فى عدد ٥ هجن فى صفتى عدد الفروع والمحصول المبكر. وظهرت قوة الهجين على أساس الأب القمى فى عدد ٧ هجن فى صفة طول النبات وفى عدد ٢ هجين فى صفتى عدد الفروع والمحصول الكلى. لم يعطى أى من الهجن قوة هجين سواء على أساس متوسط الأبوين أو الأب الأحسن أو الأب القمى فى صفات الثمرة وهى متوسط وزن الثمرة ـ طول وقطر الثمرة بينما قوة الهجين القياسية (على أساس الهجين التجارى) ظهرت فى كل الصفات

أظهرت الدراسة أن تأثيرات عوامل الفعل الإضافى والفعل الغير إضافى للجينات موجودة فى صفات طول النبات والمحصول الكلى لكن التأثير الغالب كان لعوامل الإضافة ... بينما صفات الثمرة (الوزن ـ الطول ـ القطر) يحكمها بشكل كلى عوامل الاضافة ٠على أساس تعبير قوة الهجين الاساسية كمقياس فإن الهجين بى ٢٣-٥ × إم ايه أر -٦ كنموذج لثمار الفلفل البلدى والهجين "ال اس ١٤-٥ × ال اس ٢-٢ كنموذج للثمار الطويلة الحلوة وجدت متفوقة على الهجن التجارى ويمكن استخدامها فى الإنتاج التجارى حيث أنها تعتمد على الإنتاجية العالية الحقيقية بدلا من الاعتماد على درجة قوة الهجن