HETEROSIS, COMBINING ABILITY AND GENE ACTION ESTIMATIO IN PEA (*Pisum sativa* L.) USING FULL DIALLEL CROSSES

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ABSTRACT

This study was carried out at the experimental field, College of Agriculture, University of Duhok, during 2013- 2015, using six genotypes of pea. The objective of this experiment to investigate heterosis and several genetic parameters by using full diallel cross. The results revealed that general combining ability were significant in all studied traits except No. of grain pod^{-1}, also special combining ability and reciprocal were significant in all traits at probability 5%.

Keywords: Pea, heritability, combining ability, gene action

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قوة الهجين وتقدير قابلية الائتلاف و الفعل الجيني في البزاليا (*Pisum sativum* L.) باستخدام التهجينات التبادلية الكاملة.

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المستخلص

أجريت هذه الدراسة في الحقل التجريبي، كلية الزراعة، جامعة دهوك، خلال 2013 – 2015، وذلك باستعمال ستة تراكيب وراثية من البازلاء باستخدام التهجينات التبادلية الكاملة. لوحظ أن قدرة العامة على الائتلاف كانت معنوية في جميع الصفات المدروسة عدا عدد حبوب بالقرنة، وكذلك قدرة الخاصة على الائتلاف والهجن العكسية كانت معنوية في جميع الصفات عند الاحتمال 5٪.

كلمات مفتاحية: بزاليا، نسبة التوريث، قابلية التالف، الفعل الجيني

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INTRODUCTION

Pea (*Pisum sativum* L.) is one of the most annual herbaceous legume crop belongs to the family fabaceae (leguminosae) (20). Pea crop originated it Near East and Mediterranean regions. It is the one of the world oldest crops cultivated as early as 9,000 years ago for human food and animals feed (18).Hybridization is one of the plant breeding programs and the most successful approach for increasing the productivity of the vegetable crops. Selecting of the best parents and crosses one of the main important of aim of the plant breeders for developing high yielding genotype through breeding programs , in a breeding process it's necessary to identify a highest combining ability parents crossing to the expand the genetic variability for selection of superior genotypes (17). Some researchers (14) observed that general combining ability variance was lower than specific combining ability for number of pods plant^{-1}, number of seeds pod^{-1}, the weight 100 seeds and seed yield plant^{-1} while, for number of days to 50% flowering, the general combining ability to specific combining ability variances ratio was lower than one for all the traits, indicating that predominant role for non-additive gene action in the expression of traits in pea. Some researchers were found in their research on heterosis from F_1 to mid parents and best parent and their results showed that positive heterosis for seed yield, green pods plant^{-1} and negative heterosis for days to 50% flowering (10; 14 , 21). Abbas (1) found informations from full diallel analysis in pea and reveled that days to 50% flowering was controlled by partial dominance. Sirohi and Singh(22) indicate in their program of chlorophyll content that both additive and non-additive gene actions were important for controlling total chlorophyll in pea. This experiment was aimed to investigate the effect of GCA of parents and SCA of hybrids and their variation estimation the heterosis as comparing with the best parent and mid parent.

MATERIAL AND METHODS

This study was carried out at the experimental field at the Faculty of Agriculture, University of Duhok, during 2013- 2015, using six different cultivars pea (Tendrilla, Hurst green, Jumbo, Boogie and Kelvedoa from UK and Local cultivar (Determinate) from Duhok university.

Planting dates and experimental design

The full diallel program was conducted by planting six parents cultivars during Nov. 2013 and at flowering times full diallel cross was carried out in next season during November 2014, the F_1hybrids with parents were arranged in Randomized Complete Block Design (R.C.B.D) with three replications at the experimental field, each block was consisted of 36 treatment (6 parents + 30 hybrids). Each genotypes planted in rows of 2.5m long at 0.75m between rows (1 row for dry seed yield and 2 other rows for vegetative measurement). One seed per hole were sown with spacing 0.25m within the rows. At maturity three individual plants were taken at random from each entry and data for the following traits were recorded: day to 50% flowering, plant high (cm), number of branchs/plant, number of pods/plant, number of seeds/pod, dry seed yield/ plant (g), 100 dry seeds weight(g) and total chlorophyll percentage (it was determine by chlorophyll measurement device((chlorophyll meter)) spad-502 plus.. Heterosis was calculated for the F1 according to mid parents using:

$$\boldsymbol{Heterosis(H)\% = \frac{\overline{F1} - \overline{M.P}}{\overline{M.P}} \times 100g}$$

Where

$\bar{F}$ =Mean of hybrid

$M.P$ =Mid-parents

RESULTS AND DISCUSSION

Table 1 shows the result of analysis of variance for genotype, general combining ability and specific combining ability reciprocal combining ability effects. It is clear that significant differences were reveal among genotypes for all the studied traits except weight 50 grains. General combining ability were significant in all studied trait except No. of grain pod^{-1}, also specific combining ability and reciprocal were significant in all the traits at probability 1%.This results are agree with those found by some researchers (2 , 23).

Table 1. analysis of variance (mean squares values) for different characters according to method1 Griffing (1956) (15) genotypes (parents and hybrids) in Fulldiallel cross

S ource of variation	C haracters d f	Mean squares Grain yield	No. grain pod-1	Weigh t plant-1	No. of tillers	plant height	Chlor ophyll	No.po d plant-1	weigh t 50 grain	flower ing 50%
R eplication		2 6.41	4 .01	35.39	2 .92	70.31	6. 47	.73	4 9145.98	3 .86
G enotypes	5	3 04.64**	3 .94**	048.63**	2 .53**	1.42**	2.71**	70.63**	2 9255.42	3 7.36**
G CA		5 2.03**	4 .21	48.78**	5 .41**	7.12**	7.38**	4.47**	4 0950.00**	1 4.39**
S CA	5	1 9.38**	7 .81**	08.68**	5 .62**	4.33**	8.72**	6.36**	8 1284.80**	1 .94**
R eciprocal	5	1 43.56**	1 .41**	01.77**	9 .43**	9.95**	2.03**	09.30**	1 5597.15**	1 1.54**
σ^2 e	0	7 0.50	2 .57	9.99	6 .35	8.85	.76	3.93	2 9242.42	3 2.22

Table 2 reveal the mean values of parents and their hybrids for nine studied characters. The result shows that parent 5 produced highest seed yield (41.20 gm plant^{-1}) and parent 1 gave the lowest value 27.63 , and hybrid (1x2) produced highest seed yield (66.87) and hybrid (6x4) gave lowest value 23.83. The results indicat that the largest number of seeds pod $^{-1}$ ranged between 6.13 to 8.13 in parents 5 and 4, respectively and ranged between 5.50 and 9.10 for hybrid (6x2) and (6x3), respectively. It can be noticed that parent 5 was the highest for weight gm plant^{-1} (132.63) and parent 1 gave lowest value 66.63 and ranged between 60.63 to 150.00 for hybrid (1x6) and (6x5) respectively. The No. of tillers was restricted between (2.33) for (5) and (3.40) for parent (2) and hybrid (5x2) gave highest value (5.00) and lowest value was produced from plant highest by hybrid (1x5) (2.27).The results shows that the parent 2 was the longest (77.00 cm) and the parent 6 was the shortest (65.93) and the hybrid (2x5) (76.30 cm), while the hybrid (4x1) had the sorters plant (56.30) cm.The highest and lowest chlorophyll % produced by the plants of the parents 6 and 4 and produced 45 and 29.53, respectively and ranged between 50.43 and 35 for hybrids (6x2) and (5x4), respectively .The results indicated that the No. of pod plant $^{-1}$ ranged between 33.13 to 11.10 in parents (5) and (3), respectively and reached 49.80 pods plant $^{-1}$ in both hybrids (5x6) and (4x2).The highest 50 grains weight obtained was 18.60 gm in parent (2) and lowest weight 12.22gm in parent (1), and ranged between 22.68gm and 7.92gm for hybrids (3x6) and (1x4), respectively. It can be noticed that parent (4) and (1) was give the highest and lowest value of flowering 50% (136.67) and (131.67) , respectively and lowest and high value in this trait (129.00) and (141.33) was found in hybrid (5x1) and (6x4) respectively. These results are agreement with those obtained by (7, 8 ,12 ,19). Table 3 shows estimation of general and specific combining ability effect for each parent and hybrid for the studied traits. For seeds yield it is clear that parent (5) was good combiner for general combining ability and gave (2.33). Parent (1) was the good combiner for No. seeds pod^{-1} , on the other hand the parent (5) was significantly good combiner in the desirable direction for seeds weight plant $^{-1}$(9.45). It was found that parent (2) was good combiner for No. of tillers and gave (0.31). As for plant height the parent (2) was the good combiner and gave highest value (1.83). For chlorophyll and No. pod plant^{-1} the parent (6) and parent (2) was the best combiner and gave highest value (2.33) and (1.91) respectively. The parents (5) and (6) were the good combiner for weight of 50 seeds and gave (38.96). For flowering 50% the parent (4) was significantly good combiner in the desirable direction and gave (1.22). Hybrid (6x4) showed specific combining ability effect for seeds yield and gave highest value (13.48). For No. of grain pod^{-1}and weight plant^{-1} trait the hybrid (6x2) and (6x4) was the best combiner in the desirable direction and gave (1.40) and (26.83) respectively. Combining ability effect in the desirable direction for No. of tillers and plant height in hybrid (5x6) and 5x2) gave (1.26) and (7.93) respectively. The effects of specific combining ability in hybrids (2x1) and (1x4) for chlorophyll and No. of pod plant^{-1} showed significant effect in desirable direction and gave (7.52) and (10.80) respectively. As for hybrid (5x6) and hybrid (4x2) that had desirable specific combining ability effect for weight of 50 seeds and flowering 50% trait that gave (247.16) and (48.3) respectively. These results are similar with those found by (9 , 13).

Table 2. Mean performance for studied character in genotypes (parents and hybrids) in Fulldiallel cross

Characters / genotypes	Grain yield	No. grainpod^{-1}	Weightplant^{-1}	No. of tillers	plant height	chlorophyll	No.pod Plant^{-1}	weight 50 grain	flowering 50%
1	7.63	.10	6.63	.90	0.43	1.80	5.63	2.22	31.67
2	1.73	.13	8.30	.40	7.00	6.13	6.00	8.58	34.00
3	7.90	.93	6.63	.77	6.50	2.93	1.10	8.39	33.33
4	9.20	.13	8.60	.67	0.43	9.53	0.93	5.34	36.67
5	1.20	.13	32.63	.33	7.23	6.20	3.13	5.40	32.33
6	9.23	.43	06.60	.23	5.93	5.00	8.63	6.94	33.67
1x2	6.87	.50	08.60	.70	4.30	0.33	2.30	.64	33.00
1x3	6.90	.43	3.30	.80	8.93	7.40	8.63	.57	32.33
1x4	0.00	.50	0.00	.93	1.13	3.53	9.10	.92	35.33
1x5	2.80	.93	1.63	.27	9.60	6.53	6.00	2.18	37.67
1x6	6.23	.30	0.00	.93	2.13	7.40	1.80	0.24	38.00
2x3	1.50	.50	03.30	.37	8.53	4.33	3.80	6.95	35.00
2x4	2.55	.60	9.93	.17	1.30	7.10	0.80	2.38	38.67
2x5	3.30	.80	14.57	.50	6.30	3.73	1.60	6.85	33.00
2x6	8.50	.30	18.30	.57	2.23	6.20	8.30	3.44	37.33
3x4	7.83	.63	5.00	.13	2.63	9.53	7.43	7.45	37.33
3x5	3.26	.63	38.30	.17	4.43	7.73	9.13	6.35	35.67
3x6	8.64	.93	4.93	.50	4.40	7.93	6.93	2.68	35.33
4x5	7.40	.30	6.63	.73	0.30	6.07	3.63	5.80	35.00
4x6	0.80	.30	45.30	.87	1.80	2.30	6.13	8.69	36.00
5x6	0.70	.10	43.30	.80	8.63	9.60	9.80	7.25	36.67
2x1	7.13	.13	35.00	.10	8.13	5.30	4.50	8.04	35.00
3x1	3.20	.10	29.93	.00	2.80	4.20	9.93	4.17	35.00
4x1	8.60	.63	16.70	.63	6.30	1.80	1.10	5.59	37.33
5x1	4.13	.30	09.93	.80	6.93	5.83	4.50	8.74	35.00
6x1									

	5.23	.63	24.93	.70	6.80	4.60	4.63	6.76	31.00
3x2	5.23	.43	45.00	.50	9.30	2.70	8.63	8.14	29.00
4x2	9.73	.80	34.80	.00	2.50	1.20	9.80	7.13	29.00
5x2	4.90	.43	1.63	.47	0.43	8.70	1.13	2.19	31.33
6x2	3.00	.50	6.43	.53	9.53	0.43	5.60	4.09	31.33
4x3	9.70	.30	04.93	.20	1.50	2.53	1.30	2.85	31.33
5x3	4.00	.60	29.93	.07	9.80	8.53	2.10	4.11	36.33
6x3	6.73	.10	6.67	.37	6.80	7.30	1.43	6.43	38.67
5x4	4.20	.43	28.30	.37	4.80	5.00	3.93	7.43	39.67
6x4	3.83	.30	1.63	.90	6.63	8.20	8.30	8.28	41.33
6x5	3.20	.50	50.00	.47	7.43	9.83	8.80	7.93	39.67
L.s.d %5	.32	.00	3.39	.94	.95	.16	.83	11.02	.59
L.s.d %1	.76	.00	7.60	.24	.13	.47	0.29	16.25	.35

Table 3. Estimation of general and specific combining ability effects of parents and hybrids for studied characters

Characters / Genotypes	Grain yield	No. grain pod^{-1}	Weight plant^{-1}	No. of tillers	plant height	chlorophyll	No.pod Plant^{-1}	weight 50 grain	flowering 50%
1	3.00	.25	8.98	0.19	1.39	.06	0.15	21.96	0.56
2	.15	0.03	.09	.31	.83	.54	.91	19.21	1.58
3	0.79	0.01	3.88	0.19	.46	0.65	3.66	17.76	0.58
4	.89	0.13	2.56	.03	1.24	2.46	.66	19.36	.22
5	.33	0.03	.45	.03	.71	1.82	.95	8.96	.42
6	0.58	0.06	0.12	.01	1.36	.33	.29	8.96	.08
SE (gi-gj)	.44	.07	.81	.06	.42	.25	.47	9.06	.34
1x2	2.82	0.79	0.44	.45	0.44	1.10	.84	0.03	.17
1x3	2.19	.13	.22	0.05	.58	.07	.30	6.02	0.17
1x4	.38	.06	0.63	.62	4.87	.75	0.80	8.09	.69
1x5	1.89	.50	13.94	0.64	2.27	0.37	4.35	36.53	.50
1X6	6.71	0.11	2.69	0.34	4.00	.29	5.72	38.49	1.00
2x1	4.87	.68	13.20	0.20	1.92	.52	3.90	4.20	1.00
2 x3	.98	.62	7.68	0.02	0.59	.31	0.82	9.71	0.81
2 x4	.07	0.53	.58	.41	4.91	0.25	.94	8.61	0.78
2 x5	0.41	.29	16.70	.31	0.39	.18	0.29	39.94	1.64
2X6	5.85	0.39	12.86	0.60	0.80	.13	4.05	40.70	0.14
3x1									

	8.15	**.67**	**33.32**	**0.10**	**1.93**	**.60**	**0.65**	**2.80**	**1.33**
3x2	**1.87**	**0.47**	**20.82**	**0.07**	**0.38**	**.82**	**2.42**	**0.59**	**.00**
3 x4	**2.36**	**0.78**	**12.86**	**.00**	**.63**	**.82**	**.58**	**7.47**	**1.28**
3 x5	**3.93**	**0.74**	**4.29**	**.45**	**1.27**	**0.72**	**0.46**	**35.77**	**.19**
3X6	**.04**	**.20**	**14.46**	**0.22**	**0.71**	**0.39**	**.76**	**36.45**	**.53**
4x1	**4.30**	**.93**	**13.35**	**0.85**	**.42**	**.87**	**1.00**	**3.84**	**1.00**
4x2	**13.59**	**.90**	**17.43**	**0.92**	**0.60**	**2.05**	**14.50**	**2.38**	**.83**
4x3	**10.93**	**0.83**	**19.97**	**0.03**	**4.43**	**1.50**	**11.93**	**.30**	**.00**
4 x5	**.55**	**.14**	**13.69**	**0.34**	**.86**	**.49**	**6.62**	**37.69**	**.72**
4X6	**4.02**	**.11**	**6.88**	**.01**	**.60**	**0.94**	**2.52**	**35.83**	**.39**
5x1	**5.67**	**0.18**	**9.15**	**0.27**	**3.67**	**.35**	**.75**	**3.28**	**.33**
5x2	**0.80**	**.18**	**1.47**	**.52**	**.93**	**.52**	**.23**	**.33**	**.83**
5x3	**.63**	**.02**	**.18**	**.55**	**2.68**	**0.40**	**.52**	**3.88**	**0.33**
5x4	**.60**	**.93**	**30.38**	**0.32**	**7.25**	**.53**	**0.15**	**0.82**	**2.33**
5X6	**.18**	**.01**	**0.56**	**.26**	**.47**	**2.11**	**.27**	**47.16**	**.69**
6x1	**4.50**	**0.17**	**32.47**	**.12**	**.67**	**.40**	**1.42**	**3.26**	**.50**
6x2	**.75**	**.40**	**0.93**	**.52**	**2.68**	**2.12**	**.35**	**0.33**	**.00**
6x3	**0.96**	**1.58**	**10.83**	**.57**	**1.20**	**4.68**	**.75**	**.13**	**1.67**
6x4	**3.48**	**.00**	**6.83**	**.48**	**2.42**	**.05**	**.92**	**.21**	**2.67**
6x5	**.75**	**.80**	**9.15**	**.17**	**.60**	**0.12**	**0.50**	**41.87**	**1.50**
SE (Si-Sj)	**.23**	**.20**	**.28**	**.16**	**.18**	**.71**	**.33**	**3.91**	**.95**

Table 4 shows the estimation of heterosis for all studied traits that are calculated according to the difference between average value of the hybrids and the mid parents value. For seeds yield it is clearly observed that significant and positive heterosis obtained for fourteen hybrids (1x2), (2x4),(3x4), (3x5), (3x6), (5x6), (2x1), (3x1), (4x1), (5x1), (3x2), (4x2), (5x2) and (4x3) at level 1% and one hybrid (1x4) at level 5%, the other hybrids didn't attained to significant level and revealed positive and negative values . No significant differences were found in negative or positive direction for no. of seeds pod^{-1} for all hybrids. Hybrids (2x1), (3x1), (4x1), (5x1), (6x1), (3x2),(4x2), (4x3), and (5x4) showed a significant increase for weight/ plant at level 1%, while another hybrids did not reached to significant level. For no. of tillers eleven hybrids showed significant and positive heterosis (1x2), (2x4), (3x4), (3x5), (3x6), (5x6), (2x1), (4x1), (4x2), (5x4) and (6x5) at level 1% and hybrid (1x4) at level 5%, and other hybrids gave not significant positive and negative values. Three hybrids (2x4), (3x6) and (5x6) were superior in the desirable direction and significant for plant height plant at level 1% and hybrid (5x4) at level 5%, and hybrids (1x2), (1x4), (3x4) and (3x5) exhibited significant decrease, while other hybrids showed no significant positive or negative values. As for chlorophyll hybrids (1x2), (3x4), (3x5), (3x6), (5x6), (3x1), (4x1), (3x2), (4x2), (6x2), (4x3), and (6x3) gave significant and desirable positive increase at level 1% and at level 5% for hybrids (1x4), (2x4) and (5x3) but did not reached significant level in remaining hybrids. In no. pod/ plant hybrids 3x1, 4x1, 3x2, 4x2 and 4x3 showed a significant and positive heterosis, while other hybrids gave non significant positive and negative values. No significant differences were noticed in negative or positive direction in all hybrids for weight of 50 seeds. Hybrids (6x3), (5x4), and (6x4) showed a significant increase for flowering 50% at level 5% and

Table 4. Estimation of heterosisat mid parents for hybrids by fulldiallel crosses.

cha racters / hyb rids	Grain yield plant^{-1}	No. of grain pod^{-1}	Weight plant^{-1}	No. of tillers	Height of Plant	Chloro phyll	No.pod plant^{-1}	Weight of 50 grain	Floweri ng of %50
1x2		1	-		1	-	2	1	-
	25.27 **	1.53	1.69	7.46 **	12.77 **	9.17 **	51.24	37.40	.13
1x3		-	5		-	0	2	1	-
	17.90	.20	11.63	1.18	.68	6.85	14.21	43.98	0.13
1x4		1	4		5	-	2	1	-
	9.70*	.72	5.95	.39 *	13.20*	2.06 *	13.86	42.53	.87
1x5		-	1		-	-	1	6	-
	4.70	1.48	28.10	13.38	13.41	9.32	.63	11.80	.29
1x6		-	-		-	-	9	-	-
	21.54	6.01	30.73	4.35	8.87	.22	1.51	29.77	.02
2x3		-	0		2	-	7	1	-
	6.52	.88	4.25	.70	14.56	.43	2.13	33.01	.74
2x4		2	1		4	3	3	3	-
	2.09 **	5.28	2.60	8.35 **	.50 **	3.20*	4.66	0.64	1.72
2x5		5	2		2	0	2	-	-
	.58	5.13	.45	4.42	.16	7.74	4.28	20.89	.13
2x6		-	-		-	-	-	-	-
	21.56	22.65	36.55	5.53	12.36	2.55	36.18	1.74	.62
3x4		2	3		0	-	4	4	-
	2.96 **	.32	19.35	.61 **	11.93 **	7.49**	7.55	6.31	.00
3x5		2	1		5	-	2	6	1
	8.45 **	8.01	8.87	1.63 **	7.58 **	2.37**	3.38	0.64	.38
3x6		5	5		6	3	1	1	3
	7.39 **	.42	6.41	0.00 **	.65 **	.63**	50.67	872.47	.37
4x5		9	1		1	-	9	-	2
	.78	6.36	0.62	2.00	2.76	.03	9.37	1.93	.37
4x6		-	-		-	-	1	-	3
	10.16	1.93	8.01	8.47	16.70	9.68	0.61	.84	3.08
5x6		2	7		1	7	4	3	-
	3.58 **	.62	12.28	4.97 **	.38 **	.76**	3.73	20.53	1.25
2x1		2	-		3	-	-	1	1
	5.10 **	19.55	3.69**	0.15**	7.56	9.41	7. 67	7.14	.63
3x1		3	-		6	6	1	1	-
	1.82 **	11.47	1.39**	.00	.32	8.27**	23.93**	7.38	.88
4x1		4	-		6	-	1	1	1
	5.42 **	18.22	0.34**	6.54**	20.06	7.18**	24.83**	3.04	.36
5x1		3	1		6	-	-	0	3
	2.04 **	6.57	0.33**	.87	2.76	8.12	.49	5.69	.27
6x1		5	-		-	-	2	1	1
	.38	1.67	4.23**	12.05	16.69	.76	1.29	4.95	1.25
3x2		2	1		1	-	2	5	-
	9.89**	1.95	5.77**	3.63	3.41	3.66**	4.33**	1.83	3.49
4x2		6	-		6	-	2	1	1
	8.39 **	23.98	4.24**	5.01**	15.21	5.49**	12.18**	.00	4.67
5x2		2	2		2	-	6	5	-
	3.11 **	7.14	20.63	0.90	16.19	.99	.30	28.25	1.37
6x2		-	-		-	-	2	-	-
	6.98	24.45	25.39	23.49	16.69	4.32**	6.29	20.66	1.86
4x3		2	-		1	4	3	1	-
	8.92 **	9.09	6.90**	7.64	.42	6.18**	58.00**	23.78	2.71
5x3		-	-		2	4	1	-	4
	14.39	6.11	4.18	0.39	.38	1.48*	0.09	2.74	.63
6x3		-	1		-	0	2	7	-
	4.77	8.48	.51	21.00	.87	1.37**	.90	6.96	.87*
5x4		9	-		3	8	6	-	1
	.95	9.81	5.98**	4.80**	.67*	.48	11.46	3.40	.84*
6x4		-	-		-	-	2	-	1
	39.24	19.02	6.11	1.69	2.27	.49	26.15	3.25	.56*
6x5		7	-		6	1	-	-	1
	.40	4.12	12.22	0.43**	.27	1.89	6.73	0.88	.01**

at level 1% for hybrid (6x5), while other hybrids showed non significant positive and negative values. The differences value for heterosis might be due to genetic diversity of the parents with non-allelic interaction which increase or decrease the expression of heterosis (16) .These results are agree with those founded by (3;4;11 and 24).

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