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Heterosis and Combining Ability Estimation for Yield,Yield Components and Grains Quality Traits in Maize *(Zea mays* L.)

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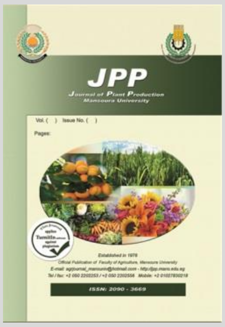

ABSTRACT

In Experimental Farm of Agronomy Department, Faculty of Agriculture, Mansoura University, Egypt, season 2020, Heterosis and compining ability was studied in ten F_1 single crosses with five parents (Sd_{12} , Inbred bo_{12} , 72 , Rg_8 ,and 56) planted in a Randomized complete Block Design (RCBD) with 3 replicates. The analysis of variance showed highly significant mean squares of general combining ability (GCA) and specific combining ability (SCA) for all studied traits, *i.e.* length of ear, weight of ear, No. of grains per ear, 100-grain weight, shelling % and grain yield for each plant, protein %, carbohydrate % and oil %, except GCA for ear diameter and GCA and SCA for cub diameter. The proportion of GCA/SCA was fewer than unity for all considered traits. GCA effects achieved that inbred lines P_1 (Sd_{12}) and P_4 (Rg8) they were perfect general combiners for grain/plant yield. Highly significant rates of SCA effects showed that the best F1 cross combinations were P_1 xP_3, P_1 xP_4, P_2 xP_5 and P_3×P_4 for grain yield / plant .The most of cross combinations manifested positive and very significant heterosis over mid and better parents for all traits studied except number grain per ear and carbohydrates percentage for better parent and shelling percentage for over mid and better parents. Highest positive significant value of heterotic effects relative to mid and better parents for grain yield per plant were obtained by P_1xP_4.

Keywords: Heterosis, Specific combining ability (SCA), General combining ability (GCA), Maize, *Zea mays*.

INTRODUCTION

Corn is the second most important crop in the world after wheat and rice, and its original home is southern Mexico and Guatemala, and the Native Americans used it as a source of flour, then European colonists spread it throughout the ancient world .

Maize is popularly known as the queen of cereals' Singh and Devi (1998) because it's has high yield potential as compared to other cereal crops . Maize (*Zea mays* L., 2n =20) is belongs to the Maydeae tribe of the grass family *Poaceae*. It has become one of the leading agricultural crops and is used in food, forage, fuel and fiber in many parts of the world, in temperate, tropical and sub-tropical regions. Maize is one of the most hetergenous cultivated plants, and since the concept of hybrid varieties, breeding programs have sought to make best use of heterosis to produce the best-performing hybrids Lariepe *et al*. (2017). Heterosis and combining ability is prerequisite for the development of a good economically viable open pollinated hybrid variety or hybrid variety. Information on the heterosis and combining ability of maize germplasm is essential in maximizing the effectiveness of hybrid development Nedi *et al*. (2017). Successful development of hybrid maize depends on the ability of the breeding program to rapidly isolate lines that combine well in hybrid combinations and to identify appropriate heterotic combinations to maximize hybrid vigor Abu Shosha and Habouh (2019). Line behavior in hybrid combination is estimated by estimating of general combining ability (gca) and specific combining ability (sca) effects. Combining ability analysis is substantial method for estimating the prepotency of cultures for used in a breeding program and for estimating gene action involved in different traits in order to design an appropriate and effective breeding method Abu Shosha and Habouh (2019). Thus, a study was undertaken to raise breeding maize to improve and increase the productivity and improve the quality of the grains by reaching the best genotypes resulting from hybridization between pure line and recommending the cultivation of new hybrids resulting from this study.

MATERIALS AND METHODS

Five parental inbred lines were studied: Sd $_{12}$, Inbred bo $_{12}$, 72, Rg $_8$ and 56. Has been crossed five inbred lines using a half diallel to get 10 crosses in the summer of 2019 on the farm of faculty of agriculture, El Mansoura University, Egypt during 2020 summer season, evaluated parents and their 10 F_1 hybrids) using Randomized Complete Black Desigen (RCBD) with three replications. The grains were manually sown in hill using 3-4 grains and after emergence, thinned for two plants per hill. Each replication contained 15 ridge each ridge is one genotype.

In each replication, data were registered on the following characters, Ear Length (EL), Ear Diameter (ED), Ear weight (EW), Cub diameter (CD), number of grains.ear^{-1} (GE), 100-Kernel Weight (KW), shelling% and grain yield.plant^{-1} (YG) for yield and yield component traits and protein %, Carbohydrate % and Oil % for quality traits which was modified for 15.5% moisture content (estimated in and ardab/fed, one ardab equal 140 kg grains).

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Statistical analysis : Data recorded from experiments conducted in 2020 maize growing season were exposed to statistical combined analysis of randomized complete block design using plot means as describ it (Gomez and Gomez 1984).

The least significant differences test(L.S.D) was used to compare the means at 0.05 and 0.01 levels of probability Snedecor and Cochran (1980).

Diallel analysis for:

1- Estimates of General Combining ability and Specific Combining ability:

There were 10 single crosses include a half diallel amongst 5 inbred parents. The sum squares of crosses was divided into general and specific combining ability, Table 1 showed that the next method 2 model 1 (fixed) of (Griffing., 1956).

Table 1. Analysis of variance and expected mean squares for combining ability analysis.

S.V	d.f	M.S	E.M.S
Genotypes	c-1= 14		
GCA	p-1= 4	Mg	σ2e + (n-2\n-1)∑i g2i
SCA	10	Ms	σ2e+ (2\n(n-3))∑∑ s2ij
Erorr	28	Me	σ2e

The effect of GCA to inbred line and The effect of SCA to cross combinations and were caculated their standard errors used the formula at (Singh *et al*., 1985).

2-Estimates of Heterosis:

Heterosis as suggested by (Mather and Jinks.,1982). was set for particular cross as the percentage variation of F1 means from mid-parents (MP) and better-parent (BP) means and distincted as percentages,

Heterosis over the mid-parents % (M¯P) = [(F¯1- M¯P)/ M¯P] x 100

Heterosis over the better-parent % (B¯P) = [(F¯1- B¯P)/ B¯P] x 100

Where:

F_1: Mean value of the first generation.

M¯P: Mean of the mid-parents calculated by using average mean of the two parents.

B¯P: Mean of the better parent.

The significance of the effect of heterosis for F1 values from the mid-parents and better-parent were tested according to the following formula:

LSD for mid-parents = t0.05 x (3MSe /2r) $^{1/2}$

LSD for better-parents = t0.05 x (2MSe /r) $^{1/2}$

RESULTS AND DISCUSSION

In Table 2 the results observed that mean squares for general combining ability (GCA), was highly significant for yield and yield component traits expect ear and cub diameter and protein percentage, carbohydrates percentage and oil percentage for quality traits. Specific compining ability (SCA), was highly significant for yield and yield component and quality traits. The obtained results showed that both types of additive and non additive gene effects were participate in the inheritage of these traits. All studied traits showed ratio of GCA/SCA was less than correct one. These results indicate that non-additive genetic effects were more significant and played the main role in all traits under study. Therefore, selection procedure in late or advanced generations will be very important to improve this traits Similar results were obtained by Abdel-Moneam *et al.* (2009) and Hemada *et al.* (2020).

Table 2. Mean squares of general combining ability GCA and Specific combining ability SCA for studied maize yield and yield components and Quality characters.

S.O.V	D.f	Ear Length	Ear Diameter	Ear Weight	Cub Diameter	Number of Grains.Ear^{-1}	100-Kernal Weight
G.C.A	4	8.90**	0.03	2922.29**	0.11	11701.21**	17.81**
S.C.A	10	4.18**	0.04**	8056.80**	0.06	8025.38**	12.86**
Error	28	0.89	0.01	231.19	0.05	2477.74	2.17
G.C.A/S.C.A ratio		0.81	0.56	0.42	0.79	0.74	0.73

*** significant at 5% and** significant at 1% probability levels.**

Table 2. cont……

S.O.V	D.f	Grain yield. Plant^{-1}	Shelling%	Protein%	Carbohydrates%	Oil%
G.C.A	4	1574.69**	68.35**	8.90**	0.77**	9.28**
S.C.A	10	2449.42**	123.83**	4.18**	0.01**	0.54**
Error	28	96.58	1.61	0.89	0.00	0.02
G.C.A/S.C.A Ration		0.56	0.52	0.81	0.99	0.97

*** significant at 5% and** significant at 1% probability levels.**

Effect of general combining ability (gi):

As shown in Table 3 sd_{12} inbred line (P_1) showed significantly high positive effects of GCA (best general combiner) for ear weight, cub diameter, 100-kernel weight, grain yield.plant^{-1}, shelling percentage carbohydrate percentage and oil percentage.Inbred bo $_{12}$ inbred line (P_2) showed significantly high positive effects of GCA (best general combiner) for ear diameter, ear weight, number of grains.ear^{-1}, carbohydrate percentage, and oil percentage. Rg_8 inbred line (P4) indicated high significant positive GCA effects (best general combiner) for ear length, grain yield.plant^{-1}, shelling percentage and protein percentage. 56 inbred line (P5) showed significantly high positive effects of GCA (best general combiner) for shelling percentage. Abdel-Menaem *et al*. (2009) and Aly (2013).

Table 3. General combining ability (GCA) effects of inbred parents for maize yield and yield components and quality traits

traits parents	Ear Length	Ear Diameter	Ear Weight	Cub Diameter	Number of Grains/Ear	100-Kernal Weight
P1(sd_{12})	0.59	0.05	16.35**	0.21**	-21.32	1.60**
P2(inbred bo_{12})	0.21	0.06*	14.08**	-0.05	59.82**	1.30*
P3(72)	0.40	0.01	-5.47	-0.02	16.28	0.10
P4(Rg_8)	0.78*	-0.04	8.30	-0.04	-6.31	-2.35**
P5(56)	-1.98**	-0.08**	-33.25**	-0.10	-48.46**	-0.65
LSD gi 5%	0.65	0.06	10.53	0.15	34.47	1.02
LSD gi 1%	0.88	0.08	14.20	0.21	46.50	1.38
LSD gi-gj 5%	1.69	0.15	27.19	0.39	89.00	2.64
LSD gi-gj 1%	2.28	0.20	36.67	0.53	120.06	3.55

*** significant at 5% and** significant at 1% probability levels.**

1, the standard error for an GCA effects.

2, the standard error for the difference between two estimates of GCA effects.

Table 3.cont…

traits Parents	Grain yield per plant	Shelling %	Protein %	Carbohydrates %	Oil %
P1(sd_{12})	20.70**	2.24**	0.59	0.42**	1.37**
P2(inbred bo_{12})	-4.52	-5.22**	0.21	0.29**	1.09**
P3(72)	-4.24	-0.59	0.40	-0.18**	-0.46**
P4(Rg_8)	7.48*	1.89**	0.78*	-0.28**	-1.09**
P5(56)	-19.42**	1.68**	-1.98**	-0.25**	-0.92**
LSD gi 5%	6.81	0.88	0.65	0.03	0.11
LSD gi 1%	9.18	1.19	0.88	0.04	0.15
LSD gi-gj 5%	17.57	2.27	1.69	0.08	0.28
LSD gi-gj 1%	23.70	3.06	2.28	0.10	0.38

*** significant at 5% and** significant at 1% probability levels.**

1, the standard error for an GCA effects.

2, the standard error for the difference between two estimates of GCA effects.

Effect of specific combining ability (Si):

As shown in Table 4 highly significant positive estimates of Specific combining ability (SCA) for ear length were recorded by crosses P1 xP3, P2 xP3, P2 xP5, and P3 xP4. For ear diameter were recorded by crosses P1xP4, P2xP5, P3xP4 and P3xP5. Ear weight were rgestered by crosses P1xP3, P1xP4, P2xP4, P2xP5, P3xP4. The best specific combinations for cub diameter were recorded by P2xP5. Number grain/ear were recorded by crosses P1xP5 and P3xP4. Crosses i.e. P1×P4, P2×P4, P2×P5 and P3×P4 showed positive highly significant SCA effects for 100-kernel weight, indicating that these crosses are the best combinations for improving the weight of 100-kernel. The best specific combinations for grain yield.plant^{-1} were recorded by crosses P1 xP3, P1 xP4, P2 xP5 and P3×P4. The best specific combinations for shelling percentage were recorded by crosses P1 xP4. Best specific combinations for protein percentage were recorded by crosses P1 xP3, P2 xP3, P2 xP5, and P3xP4. Best specific combinations for carbohydrates percentage were recorded by crosses P1 xP3 and P1xP4. The best specific combinations for oil percentage were recorded by crosses P1xP3, P1xP4, P1xP5, P2 xP3, P2 xP4 and P2 xP5. Ahmed *et al*. (2008) and Sultan *et al*. (2010).

Table 4. Specific combining ability (SCA) effects of maize crosses for yield and yield components and quality traits

Traits crosses	Ear Length	Ear Diameter	Ear Weight	Cub Diameter	Number of Grains.ear^{-1}	100-Kernel Weight
P1*P2	-0.11	-0.06	-48.67**	-0.41	-67.37	1.71
P1*P3	2.37**	0.09	81.30**	0.41	41.94	0.31
P1*P4	-0.68	0.31**	113.38**	0.30	30.83	2.88**
P1*P5	0.75	0.09	8.60	-0.05	108.45**	-0.30
P2*P3	2.08**	0.05	-5.04	0.04	39.43	-1.13
P2*P4	1.03	0.04	84.56**	0.04	64.02	3.42**
P2*P5	2.46**	0.15*	112.38**	0.39*	53.73	2.74*
P3*P4	1.84**	0.15*	64.25**	0.09	129.56**	5.84**
P3*P5	-0.73	0.23**	15.23	0.07	26.41	-3.48**
P4*P5	-1.78*	-0.12	-28.84*	-0.02	-37.10	-2.73*
LSD sij 5%	1.34	0.12	21.49	0.31	70.36	2.08
LSD sij 1%	1.80	0.16	28.99	0.42	94.92	2.81
LSD sij-sik 5%	2.53	0.23	40.68	0.59	133.50	3.95
LSD sij-sik 1%	3.42	0.30	55.01	0.80	180.09	5.33
LSD sij-ski 5%	2.31	0.21	37.23	0.54	121.87	3.61
LSD sij-ski 1%	3.12	0.28	50.22	0.73	164.40	4.87

*** significant at 5% and** significant at 1% probability levels.**

1, the standard error for an SCA effects.

2, the standard error for the difference between two SCA effects for a common parent.

3, the standard error for the difference between two SCA effects for a non-common parent.

Table 4. cont…………….

traits crosses	Grain yield .plant^{-1}	Shelling %	Protein %	Carbohydrates %	Oil %
P1*P2	-39.87**	-3.64**	-0.11	-0.18**	-0.76**
P1*P3	37.21**	-4.57**	2.37**	0.17**	0.57**
P1*P4	104.18**	5.50**	-0.68	0.08*	0.84**
P1*P5	-10.51	-7.12**	0.75	0.14	0.92**
P2*P3	4.03	1.12	2.08**	0.00	0.34**
P2*P4	1.03	-15.54**	1.03	0.01	0.55**
P2*P5	61.92**	-3.97**	2.46**	-0.94**	0.63**
P3*P4	17.14*	-9.80**	1.84**	0.02	0.10
P3*P5	3.20	-5.10**	-0.73	-0.10**	-0.75**
P4*P5	-32.72**	-10.39**	-1.78*	-0.11**	-0.83**
LSD sij 5%	13.89	1.79	1.34	0.06	0.22
LSD sij 1%	18.74	2.42	1.80	0.08	0.30
LSD sij- sik 5%	26.36	3.40	2.53	0.11	0.42
LSD sij- sik 1%	35.55	4.59	3.42	0.15	0.57
LSD sij- ski 5%	24.06	3.11	2.31	0.10	0.38
LSD sij- ski 1%	32.46	4.19	3.12	0.14	0.52

*** significant at 5% and** significant at 1% probability levels.**

1, the standard error for an SCA effects.

2, the standard error for the difference between two SCA effects for a common parent.

3, the standard error for the difference between two SCA effects for a non-common parent.

Heterossis studies:

Data presented in table 5 showed the most of cross combinations manifested positive highly significant or significant heterosis better and over mid parents for all traits studied except number grain per ear was non significant and carbohydrates percentage for better parent and shelling percentage for over mid and better parents were negative heterosis. Results showed that the highest positive heterosis effect for ear lenght was exhibited by cross P2×P3 (30.53%) over mid and P2xP5 (36.59%) better parents. Crosses P1xP4 (32.63%) over mid and P3xP5 (26.09%) better parents were highest positive heterosis effect for ear diameter. The highest positive heterosis effect for ear weight was showed by P1xP4 (110.81%) over mid and P3xP4 (86.90%) better parents. The highest positive heterosis effect for cub diameter was showed by P2xP5 (19.84%) over mid and P2xP4 (13.00%) better parents. For number of grains.ear^{-1} (P3xP4%) over mid and P1xP2 (0.19%) better parents were showed positive heterosis. The highest positive heterosis effect for 100-kernel weight was showed by P3xP4 (30.58 and 12.81%) over mid and better parents, respectively. For grain yield.plant^{-1}, P1xP4 (100.58 and 84.58%) over mid and better parents, respectively was showed the highest positive heterosis. The highest positive heterosis effect for protein percentage was showed by P1xP3 (25.49%) over mid and P2xP3 (29.17%) better parents. The highest positive heterosis effect for carbohydrates percentage P1xP3 (5.08%) over mid. For oil percentage, P1xP4 (2.01%) over mid and P3xP5 (1.58%) better parents were showed the highest positive heterosis. These are results confidence with those of, Gissa *et al.* (2007). Patel *et al*. (2010). Gouda *et al*. (2013) and Yosuf *et al.* (2014).

Table 5. Percentage of Heterosis over mid (M.P.) and better parent (B.P.) for crosses of studied maize yield and yield components, and quality traits.

	Ear length		Ear diameter		Ear weight		Cub diameter	
Heterosis	**M.P.**	**B.P.**	**M.P.**	**B.P.**	**M.P.**	**B.P.**	**M.P.**	**B.P.**
P1*P2	10.89**	19.15**	5.77**	1.85**	11.82	11.53	-13.41**	-21.05**
P1*P3	25.49**	33.33**	20.83**	16.00**	81.28**	62.87**	7.62**	-3.10**
P1*P4	0.00	3.70**	32.63**	26.00**	110.81**	83.94**	13.99**	1.34**
P1*P5	9.47**	26.83**	18.28**	10.00**	41.21*	16.68	1.42**	-11.66**
P2*P3	30.53**	31.91**	14.00**	5.56**	35.55	21.50	5.34**	3.88**
P2*P4	14.29**	27.66**	11.11**	1.85**	93.85**	68.76**	5.93**	3.01**
P2*P5	27.27**	36.59**	17.53**	5.56**	97.04**	62.48**	19.84**	13.01**
P3*P4	18.87**	31.25**	25.27**	23.91**	96.29**	89.90**	10.98**	9.41**
P3*P5	5.62**	14.63**	30.34**	26.09**	51.37*	37.67	9.97**	5.93**
P4*P5	-9.09**	9.76**	4.55**	2.22**	37.06	28.55	7.13**	4.64**
LSD 5%	2.37	2.74	0.21	0.24	38.15	44.05	0.55	0.64
LSD 1%	3.20	3.69	0.29	0.33	51.46	59.42	0.75	0.86

*** significant at 5% and** significant at 1% probability levels.**

Table 5. cont…………………….

	Number of Grains.Ear^{-1}		100-Kernel Weight		Grain yield.plant^{-1}		Shelling %	
Heterosis	**M.P.**	**B.P.**	**M.P.**	**B.P.**	**M.P.**	**B.P.**	**M.P.**	**B.P.**
P1*P2	-3.26	0.19	13.76**	10.94**	-6.80	-12.14	-16.64**	-21.60**
P1*P3	30.60	-19.27	5.55**	3.27	52.41**	35.81*	-15.82**	-16.61**
P1*P4	25.64	-31.68	22.20**	3.65	100.58**	84.58**	-5.71**	-11.07**
P1*P5	45.91	-4.78	-0.27	-0.72	12.79	-3.18	-20.84**	-24.37**
P2*P3	23.71	-1.51	2.91	2.57	19.48	12.51	-13.00**	-17.44**
P2*P4	26.60	-1.47	26.70**	9.77**	21.70	18.60	-38.39**	-45.14**
P2*P5	24.37	-0.92	10.59**	8.33**	57.38**	42.40**	-21.96**	-29.67**
P3*P4	56.03	-23.38	30.58**	12.81**	41.97**	37.04*	-28.05**	-32.74**
P3*P5	31.90	-2.86	-12.24**	-13.75**	19.91	14.91	-21.18**	-25.37**
P4*P5	12.61	-1.43	-4.59*	-18.77**	-3.86	-10.93	-29.78**	-30.72**
LSD 5%	124.88	1.00	3.70	4.27	24.65	28.47	3.18	3.68
LSD 1%	168.46	1.00	4.99	5.76	33.26	38.40	4.29	4.96

*** significant at 5% and** significant at 1% probability levels.**

Table 5. cont …………..

	Protein %		Carbohydrate %		Oil %	
Heterosis	**M.P.**	**B.P.**	**M.P.**	**B.P**	**M.P.**	**B.P**
P1*P2	10.89**	3.70**	-3.27**	-4.03**	-0.24	-0.36
P1*P3	25.49**	18.52**	5.08**	-6.36**	1.46**	-0.67**
P1*P4	0.00	03.45*	2.80**	-10.01**	2.01**	-1.17**
P1*P5	9.47**	-3.70**	3.73**	-8.18**	1.86**	-0.83**
P2*P3	30.53**	29.17**	-0.46**	-10.68**	0.85**	-1.15**
P2*P4	14.29**	3.45*	-0.62**	-12.40**	1.31**	-1.74**
P2*P5	27.27**	19.15**	-1.22**	-11.96**	1.17**	-1.39**
P3*P4	18.87**	8.62**	1.15**	-0.88**	0.49*	-0.58*
P3*P5	5.62**	-2.08	-2.23**	-2.98**	-1.02**	1.58**
P4*P5	-9.09**	-22.41**	-3.02**	-4.25**	-1.00**	-1.49**
LSD 5%	2.37	2.74	0.11	0.12	0.39	0.46
LSD 1%	3.20	3.69	0.14	0.16	0.53	0.61

*** significant at 5% and** significant at 1% probability levels.**

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تقدير القدرة على الائتلاف وقوة الهجين لصفة المحصول ومكوناته وصفات جودة الحبوب في الذرة الشامية

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الملخص

يهدف هذا البحث إلى تقييم بعض سلالات الذرة الشامية والهجن الفردية الناتجة منها ، وتقدير القدرة العامة والخاصة على التألف لهذه السلالات وتقدير قوة الهجين. استخدم فى هذه الدراسة خمسة سلالات نقية من الذرة الشامية وهى.Sd12,inbred bo 12, 72, RG8, 56: وقد أجريت جميع التهجينات المتبادلة الممكنة بين هذه السلالات فى صيف 2019 دون الهجن العكسية وذلك فى مزرعة قسم المحاصيل – كلية الزراعة- جامعة المنصورة حيث تم الحصول على الحبوب الهجينية لعشرة هجينا فرديا وتم تقييم السلالات النقية والهجن الفردية الناتجة منها فى عام2020 فى تصميم القطاعات الكاملة العشوائية فى ثلاثة مكررات. أخذت البيانات على صفات: عدد كيزان النبات الواحد ، عدد صفوف الكوز ، عدد حبوب الصف ، قطر الكوز ، وزن ١٠٠ حبة ، محصول حبوب النبات ، ونسبة التفريط ، والنسبة المئوية للبروتين ، والنسبة المئوية للزيت ، والنسبة المئوية للكاروتين. وقد تم تحليل النتائج وراثيا تبعا للطريقة الرابعة الموديل االول للعالم جريفينج (١٩٥٦) ويمكن تلخيص نتائج البحث فيما يلى: كان التباين الراجع لكل من القدرة العامة والخاصة على التألف معنويا لكل الصفات المحصولية وصفات الجودة ماعدا القدرة العامة على التألف لصفة قطر الكوز والقدرة العامة والخاصة على التألف لصفة قطر القولحة . أظهرت النسبة ما بين القدرة العامة والخاصة على التألف أهمية التأثير الغير مضيف فى وراثة كل الصفات المحصولية ، كما أظهرت هذه النسبة أهمية التأثير الغير مضيف فى كل صفات جودة الحبوب وصفات الجودة. أظهرت السلالات sd12, Rg8 أفضل قدرة عامة على التالف لصفة محصول الحبوب/نبات. أظهرت الهجن P1xP3, P1xP4, P2xP5 and P3xP4 أفضل قدرة خاصة على التألف لصفة محصول الحبوب/نبات .أظهر الهجين P1xP4 أعلى قيم لقوة الهجين بالنسبة لمتوسط االاباء وأفضل الاباء لصفة محصول النبات الفردى .