Heterosis and combining ability for yield and its components in soybean top crosses

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ABSTRACT

This investigation aimed to evaluate heterosis percentage as well as general and specific combining abilities (gca and sca) by using top crosses-system between four genotypes of soybean (*Glycine max* (L.) Merr.), namely, Giza22, Giza111, Crawford and Clark, were used as females top crossed to each of the three different male testers, namely, L86-K-73, PI-416.937 and Hartwig. The following characters were measured: plant height, number of branches per plant, number of days to flowering, number of days to maturity, number of pods per plant, number of seeds per plant, 100-seed weight and seed yield per plant.

Genotypes, parents, crosses and parent vs. cross mean squares were found to be highly significant for all the studied traits. Relative estimates of variance due to general combining ability (σ^2 gca) and specific combining ability (σ^2 sca) indicated that (σ^2 sca) played a major role in the inheritance of all traits. The male tester L86-K-73 gave the highest positive significant ($\hat{g}$i) effect than the other two testers for number of pods per plant, number of seeds per plant and seed yield per plant. The female Giza111 behaved as a good combiner for number of branches per plant, number of pods per plant, number of seeds per plant and seed yield per plant and it was the second for 100-seed weight. The desirable inter- and intra-allelic interactions were represented by crosses (L86-K-73 x Giza22), (PI-416.937 x Clark) and (Hartwig x Clark) for number of pods per plant, number of seeds per plant and seed yield per plant. Highly significant positive (sca) effects were detected for seed yield per plant in top crosses (L86-K-73 x Giza22), (L86-K-73 x Giza111), (L86-K-73 x Crawford), (PI-416.937 x Clark) and (Hartwig x Clark). All top crosses showed highly significant positive heterotic effects relative to mid and better parent values for number of pods per plant, number of seeds per plant, 100-seed weight and seed yield per plant. The top cross (L86-K-73 x Giza111) exhibited the highest significant values for mean of yield and its components.

INTRODUCTION

The plant breeder is interested in the determination of gene effects to establish the most advantageous breeding programs for the improvement of the desired characters (Tawar *et al.*, 1990) especially for soybean because it is an important source of protein and good quality oil free of cholesterol, its seeds contain about 14 to 24% or more oil and about 45 to 48% protein (Brim and Burton, 1979). It is widely used in Egypt for human and poultry consumption. Therefore, Egyptian plant breeders have intensified their efforts to increase soybean yield and yield components to meet the increasing demand for oil and protein production.

The combining ability analysis gives very useful information with regard to selection of parents based on performance of their hybrids for the development of hybrids. Moreover, the combining ability analysis gives the nature and magnitude of various types of gene action involved in the expression of quantitative traits (El-Hosary *et al.*, 1994 and Mansour *et al.*, 2003).

The performance of F_1 hybrids in comparison with that of the parents provides the first opportunity in the sequence of events in hybrid populations to obtain information of gene action. Heterosis effects ranged from significantly positive to significantly negative values. These differences in percent heterosis might be due to genetic differences of the parents used and or non-allelic interactions which can either increase or decrease the expression of heterosis (Bond, 1966 and Bastawisy *et al.*, 1997).

The present investigation was carried out to: i) estimate the relative importance of general combining ability "gca" and specific combining ability "sca", and ii) determine the magnitude of heterosis for yield and its components and other agronomic characters in a set of top crosses involving new local genotypes and exotic parental strains.

MATERIALS AND METHODS

The present study was carried out in the summer growing season of 2004 and 2005 at Etay El-Baroud Research Station, Beheira Governorate, Egypt. In the first season, four female lines of soybean were top-crossed to each of three different male testers. The lines were Giza22, Giza111, Crawford and Clark. The testers were L86-K-73, PI-416.937 and Hartwig. The parental genotypes are briefly described in Table (1).

Table (1): Maturity group, pedigree, growth habit, flower colour and origin of the soybean genotypes.

Genotype	Maturity group	Pedigree	Growth habit	Flower colour	Origin
Tester					
L86-K-73	I	L73-4673 x L76-0132	Indeterminate	White	U.S.A
PI-416.937	V	An Introduction from U.S.A.	Determinate	Purple	U.S.A
Hartwig	V	Forrest x PI437-654	Indeterminate	White	U.S.A
Line					
Giza22	IV	Crawford x Forrest	Indeterminate	Purple	Egypt
Giza111	IV	Crawford x Celest	Indeterminate	Purple	Egypt
Crawford	IV	Williams x Columbus	Indeterminate	Purple	U.S.A
Clark	IV	Lincoln x (Lincoln x Richland)	Indeterminate	Purple	U.S.A

In the second season, seven parental genotypes and twelve top crosses were evaluated in a randomized complete block design with three replications. Each plot consisted of three ridges of 3 m length and 60 cm width. Hills were spaced 20 cm with one seed per hill in one side of the ridge. All the recommended cultural practices were applied. Flowering time (in days) was recorded at 50% flowering of plants and maturity time (in days) was recorded at 95% pods maturity. At harvest, ten individual guarded plants were taken at random from each experimental plot to provide measurements for the following characteristics: plant height (cm), number of branches per plant, number of pods per plant, number of seeds per plant, 100-seed weight (g) and seed yield per plant (g).

Combining ability analysis and the estimation of various effects were conducted based on procedure developed by Kempthorne (1957). The heterotic effects of F_1 crosses were estimated as percentage of over mid and better parents (Mather and Jinks, 1971).

RESULTS AND DISCUSSION

Results of statistical analysis in Table (2) revealed highly significant differences among tested genotypes: parents, crosses and parent vs. cross for all the studied characters. Mean squares due to females were highly significant for all traits except number of days to maturity and 100-seed weight. In addition, male mean squares were significant for all the studied characters except number of branches per plant. Highly significant differences of females x males interaction were obtained, indicating that females (lines) were not similar in their expression for the performance of their crosses with each male (tester). These results confirmed the existence of genetic variability for all variables in the selection material for study.

The estimates of the variance due to general combining ability (σ^2gca) and specific combining ability (σ^2sca), presented in Table (2), showed that highly significant mean squares due to both (gca) and (sca) were obtained for all studied traits except (gca) for 100-seed weight. Such results indicated that both additive and non-additive gene effects played an important role in the inheritance, for all of the studied traits. However, 100-seed weight, which represents non-additive type of gene action, was involved in determining the performance of top crosses progenies. These results were in accordance with the findings of Cruz *et al.*(1987), Jockovic *et al.*(1988), Harer and Deshmukh (1991) and Mansour *et al.*(2003).

General combining ability (gca) effects ($\hat{g}i$) for individual lines (females) and testers (males) in each trait are presented in Table (3). The male (tester) L76-K-73 was the superior combiner for all studied traits because it expressed highly significant ($\hat{g}i$) effects except number of branches per plant which showed no significant ($\hat{g}i$) effects, followed by the tester Hartwig next the tester PI-416.937. Therefore, the tester L86-K-73 could be considered as an excellent tester in breeding for high yield potentiality. The female (line) Giza22 behaved as good combiner for all characters studied, except number of branches per plant, number of days to maturity and 100-seed weight, followed by female Crawford. Moreover, the female Clark expressed highly significant negative ($\hat{g}i$) effects for number of branches per plant and number of pods per plant. On the other hand, the female Giza111 expressed highly significant positive ($\hat{g}i$) effects for number of branches per plant, number of pods per plant, number of seeds per plant and seed yield per plant. These results suggested that a greater opportunity for selection would be possible for yield and its components.

The estimated specific combining ability effects ($\hat{s}ij$) of the top crosses were computed for all the studied traits as shown in Table (4). The data indicated that four top crosses: (L86-K-73 x Giza22), (L86-K-73 x Crawford), (PI-416.937 x Clark) and (Hartwig x Clark) had the highest and highly significant positive ($\hat{s}ij$) effects for number of seeds per plant and seed yield per plant. On the other hand, the respective crosses had highly significant negative ($\hat{s}ij$) effects for same traits. However, the cross (PI-416.937 x Clark) expressed highly significant positive ($\hat{s}ij$) effects for all traits, except number of days to flowering which was highly significant negative and no significant effect for number of days to maturity.

A great deal of interest was devoted to select crosses combining both good general combining parents and crosses involving one good and one poor combining parent with ($\hat{s}ij$) effects as well as high heterosis. In addition, it is worthwhile for breeder to initiate his program using parents characterized by good (gca) for seed yield and its components. These results are in accordance with those obtained by Cruz *et al.*(1987), Harer and Deshmukh (1991), El-Hady *et al.*(1991) and Mansour *et al.*(2003).

Results in Table (5) presented means of parents and their F_1 for the studied characters. It is clear that parental Clark recorded the highest parent with respect to plant height (106.87 cm), number of pods per plant (176.26), number of seeds per plant (422.4) and seed yield per plant (45.75 g). However, the parental PI-416.937 had the lowest value for the same traits (75.05, 85.46, 221.86 and 22.49), respectively. The parental tester L86-K-73 behaved as the earliest for maturity (95 days), however, tester

Hartwig was the latest one (134.67 days). The mean performances of top crosses are presented in Table (5). The obtained results indicated that top cross (L86-K-73 x Giza111) gave the highest value for number of pods per plant, number of seeds per plant and seed weight per plant (273.86, 668.22 and 98.23 g), respectively. However, the top cross (Hartwig x Clark) had the lowest value for the same traits (194.66, 453.79 and 70.81 g), respectively. The top cross (L86-K-73 x Clark) was the earliest for flowering and maturity date (34 and 115 days), however, the top cross (Hartwig x Clark) was the latest one (50 and 129.67 days). The top cross (PI-416.937 x Clark) gave the highest value for plant height (115.11 cm) and number of branches per plant (4.6).

Heterosis expressed as the percentage deviation of F_1 mean performance from its mid and better parent average values for all the studied traits, are presented in Table (6). All top crosses expressed highly significant positive heterotic effects relative to mid and better parent values for number of branches per plant, number of pods per plant, number of seeds per plant, 100-seed weight and seed yield per plant. All top crosses also showed highly significant positive heterotic effects relative to better parent only for flowering date, however, three top crosses exhibited significant positive heterotic effects relative to mid and better parents for maturity date. For plant height, six and two top crosses expressed significant positive and negative heterotic effects relative to mid parent.

Different values of heterosis might be due to genetic diversity of the parents with non-allelic interactions, which increase or decrease the expression of heterosis (Hyman, 1957). Even in the absence of epitasis multiple alleles at a locus could lead to either positive or negative heterosis (Cress, 1966). These results are in agreement with those obtained by Paschal and Wilcox (1975), Mehta *et al.*(1984), Tawar *et al.*(1990), El-Hady *et al.*(1991), Ibrahim *et al.*(1996) and Mansour *et al.*(2001).

Hence, it could be concluded that these top crosses offer possibility for improving seed yield in soybean. These findings revealed that a hybridization program based on these materials would be useful.

Table (2): Mean squares from the ordinary analysis of variance and estimates of the general and specific combining ability variances (σ^2gca and σ^2sca) for all studied traits in soybean.

S.O.V.	d.f.	Plant height (cm)	No. of branches /plant	No. of days to flowering	No. of days to maturity	No. of pods /plant	No. of seeds /plant	100-seed weight (g)	Seed yield /plant (g)
Replications	2	5.701	0.018	2.369	2.86	94.629	83.977	0.3	8.647
Genotypes	18	255.674**	1.622**	210.749**	223.577**	7918.855**	33141.263**	14.841**	1053.163**
Parents	6	343.963**	0.713**	432.825**	463.937**	3953.292**	38415.821**	4.536**	311.483**
Crosses	11	169.637**	0.432**	104.687**	95.747**	4143.899**	31078.664**	1.823**	529.456**
Lines (females)	3	31.056**	0.37**	4.667**	7.213	3200.667**	27574.65**	0.291	689.807**
Testers (males)	2	589.179**	0.022	529.862**	496.861**	4703.028**	41758.03**	3.668**	401.516**
Line x tester	6	110.25**	0.601**	12.972**	6.417	4429.139**	29270.882**	1.96**	491.926**
Parent vs. cross	1	671.138**	20.123**	44.966**	177.545**	73236.65**	24179.569**	219.972**	11264.021**
Error	36	5.553	0.034	0.757	28.267	54.724	431.567	0.16	4.918
δ^2gca		5.258**	0.08*	4.072**	5.829**	18.69**	349.876**	0.009	5.899**
δ^2caσ		34.882**	0.189**	6.053**	7.28**	1458.138**	9613.105**	1.169**	162.336**

* and ** = significant at 0.05 and 0.01 levels of probability, respectively.

Table (3): Estimates of general combining ability effects for the studied traits in soybean.

Parent	Plant height (cm)	No. of branches /plant	No. of days to flowering	No. of days to maturity	No. of pods /plant	No. of seeds /plant	100-seed weight (g)	Seed yield /plant (g)
Male (tester)								
L86-K-73	-7.119**	-0.038	-7.639**	-7.361**	17.694**	67.449**	-0.637**	6.482**
PI-416.937	6.889**	-0.006	3.195**	2.805	4.028*	-41.961**	0.29*	-4.638**
Hartwig	0.23	0.044	4.445**	4.555**	-21.722**	-25.487**	0.347**	-1.844**
S.E. $(\hat{g}i)$	0.68	0.053	0.251	1.535	2.13	5.997	0.115	0.64
S.E. $(\hat{g}i - \hat{g}j)$	0.962	0.075	0.355	2.171	3.02	8.481	0.163	0.905
Female (line)								
Giza22	2.095*	-0.07	1.00**	0.722	-17.00**	-55.652**	0.155	-8.258**
Giza111	0.083	0.3**	-0.333	0.164	19.333**	74.303**	0.144	12.187**
Crawford	-2.428**	-0.085	-0.666*	-1.27	13.00**	-23.46**	-0.083	-3.624**
Clark	0.25	-0.145**	0.00	0.387	-15.333**	-4.811	-0.212	-0.305
S.E. $(\hat{g}i)$	0.785	0.061	0.291	1.772	2.46	6.925	0.133	0.739
S.E. $(\hat{g}i - \hat{g}j)$	1.111	0.087	0.41	2.506	3.49	9.793	0.189	1.045

* and ** = significant at 0.05 and 0.01 levels of probability, respectively.

Table (4): Estimates of specific combining ability effects for the top crosses studied in soybean.

Crosses	Plant height (cm)	No. of branches /plant	No. of days to flowering	No. of days to maturity	No. of pods /plant	No. of seeds /plant	100-seed weight (g)	Seed yield /plant (g)
L86-K-73 x Giza22	-3.404**	0.25*	-0.25	1.361	19.75**	91.597**	-0.969**	7.622**
L86-K-73 x Giza111	-4.525**	0.35*	0.749	-0.083	43.417**	17.062	0.272	4.337**
L86-K-73 x Crawford	3.386**	-0.061	0.749	0.028	-5.916	52.153**	0.33	9.348**
L86-K-73 x Clark	4.141**	-0.539**	-1.25*	-1.306	-57.251**	-160.813**	0.365	-21.307**
PI-416.937 x Giza22	-0.656	-0.45**	-1.084*	-1.805	-10.25*	-31.093**	0.115	-3.172*
PI-416.937 x Giza111	-0.333	-0.316**	1.249*	1.084	-12.25**	10.512	-0.605**	-2.683*
PI-416.937 x Crawford	-3.222**	0.204	1.249*	0.862	-8.917*	-52.342**	-0.144	-8.446**
PI-416.937 x Clark	4.1**	0.562**	-1.418**	-0.139	31.416**	72.921**	0.631**	14.301**
Hartwig x Giza22	3.947**	0.199	1.344**	0.445	-9.5*	-60.504**	0.853**	-4.449**
Hartwig x Giza111	4.858**	-0.033	-2.00**	-0.999	-31.156**	-27.575*	0.331	-1.654
Hartwig x Crawford	-0.564	-0.144	-2.00**	-0.888	14.823**	0.188	0.189	-0.903
Hartwig x Clark	-8.242**	-0.022	2.666**	1.449	25.833**	87.89**	-0.994**	7.006**
S.E. ($\hat{s}ij$)	1.361	0.106	0.502	3.07	4.27	11.994	0.231	1.28
S.E. ($\hat{s}ij - \hat{s}kl$)	1.924	0.151	0.71	4.341	6.04	16.962	0.327	1.811

* and ** = significant at 0.05 and 0.01 levels of probability, respectively.

Table (5): Mean performance of 12 top crosses between 4 lines and 3 testers for the studied characters in soybean.

Genotypes	Plant height (cm)	No. of branches /plant	No. of days to flowering	No. of days to maturity	No. of pods /plant	No. of seeds /plant	100-seed weight (g)	Seed yield /plant (g)
L86-K-73	94.64	2.27	30.00	95.00	109.34	262.68	9.36	25.78
PI-416.937	75.05	3.20	49.67	129.33	85.46	221.86	9.64	22.49
Hartwig	99.71	3.47	63.00	134.67	140.09	350.22	12.71	45.72
Giza22	93.59	3.57	38.00	119.33	121.97	297.61	10.90	36.44
Giza111	104.66	2.50	40.33	120.33	132.46	309.96	11.39	37.30
Crawford	102.00	2.73	38.33	118.00	129.00	336.69	12.19	41.04
Clark	106.87	2.97	28.00	120.67	176.26	422.40	10.83	45.75
L86-K-73 x Giza22	95.32	4.33	36.00	118.00	213.39	554.81	13.62	76.66
L86-K-73 x Giza111	92.21	4.80	35.66	116.00	273.86	668.22	14.85	98.23
L86-K-73 x Crawford	98.00	4.00	35.33	114.67	217.65	576.77	14.69	82.73
L86-K-73 x Clark	101.03	3.47	34.00	115.00	221.52	511.71	14.59	76.68
PI-416.937 x Giza22	112.28	3.67	46.00	125.00	195.77	458.10	15.64	72.67
PI-416.937 x Giza111	110.40	4.17	47.00	127.33	230.60	598.43	14.91	89.12
PI-416.937 x Crawford	105.00	4.30	46.67	125.67	227.36	553.88	15.14	81.87
PI-416.937 x Clark	115.11	4.60	44.67	126.33	239.41	597.15	15.78	94.15
Hartwig x Giza22	110.03	4.37	49.67	129.00	201.64	490.44	16.43	86.77
Hartwig x Giza111	108.93	4.50	45.00	127.00	212.38	530.95	15.89	89.36
Hartwig x Crawford	101.00	4.00	44.67	125.67	224.36	560.94	15.15	82.97
Hartwig x Clark	96.09	4.07	50.00	129.67	194.66	453.79	14.21	70.81
L.S.D 0.05	3.89	0.30	1.44	8.77	12.21	34.28	0.66	3.47
L.S.D 0.01	5.20	0.41	1.92	11.74	16.33	45.86	0.88	4.65

Table (6): Percentage values of heterotic effects relative to mid and better parents for all the studied traits in soybean.

Crosses	Plant height (cm)		No. of branches /plant		No. of days to flowering		No. of days to maturity		No. of pods /plant		No. of seeds /plant		100-seed weight (g)		Seed yield /plant (g)	
	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P
L86-K-73 x Giza22	1.23	0.69	48.29**	21.29**	5.88**	20.00**	10.11**	24.21**	84.42**	74.95**	98.04**	86.42**	34.45**	24.95**	146.42**	110.37**
L86-K-73 x Giza111	-7.45**	-11.91**	101.47**	92.00**	1.41	18.87**	7.74*	22.11**	126.41**	106.75**	138.52**	115.58**	43.06**	30.38**	211.44**	163.35**
L86-K-73 x Crawford	-0.34	-3.92*	60.00**	46.52**	3.42	17.76**	7.67*	20.71**	82.55**	68.72**	92.46**	71.31**	38.27**	20.50**	147.62**	101.58**
L86-K-73 x Clark	0.26	-5.46**	32.44**	16.84**	17.24**	21.43**	6.64	21.05**	55.06	25.68**	49.39**	21.14**	44.53**	34.72**	114.37**	67.61**
PI-416.937 x Giza22	33.03**	19.78**	8.42*	2.8	4.94**	21.05**	0.54	4.75	88.78**	60.51**	76.38**	53.93**	52.29**	43.49**	146.61**	99.42**
PI-416.937 x Giza111	22.89**	5.47**	46.32**	30.31**	4.44**	16.54**	2.01	5.82	111.75**	74.09**	125.05**	93.07**	41.70**	30.82**	198.08**	138.93**
PI-416.937 x Crawford	18.64**	2.94	45.03**	34.38**	5.96**	21.76**	1.62	6.50	112.15**	76.25**	98.33**	64.51**	38.72**	24.20**	157.71**	99.49**
PI-416.937 x Clark	26.46**	7.61**	49.11**	43.75**	15.03**	9.54**	1.06	4.69	83.04**	35.83**	85.38**	41.37**	54.18**	45.71**	175.94**	105.79**
Hartwig x Giza22	13.82**	10.39**	24.15**	22.41**	-1.64	30.71**	1.57	8.10*	53.89**	43.94**	51.41**	40.04**	39.18**	29.27**	111.22**	89.79**
Hartwig x Giza111	6.62**	4.07*	50.75**	29.68**	-12.90**	11.58**	-0.39	5.54	55.84**	51.60**	60.85**	51.60**	31.87**	25.02**	115.27**	95.45**
Hartwig x Crawford	0.15	-0.98	29.03**	15.27**	-11.83**	16.54**	-0.53	6.50	66.75**	60.15**	63.32**	60.17**	21.69**	19.20**	91.26**	81.47**
Hartwig x Clark	-7.04**	-10.17**	26.40**	17.29**	9.89**	78.57**	1.57	7.46*	22.75**	10.16**	17.47**	7.43*	20.73**	11.80**	54.81**	54.78**

* and ** = significant at 0.05 and 0.01 levels of probability, respectively.

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الملخص العربى

قوة الهجين والقدرة على الإئتلاف للمحصول ومكوناته للهجن القمية فى فول الصويا

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أجرى هذا البحث بهدف دراسة قوة الهجين والقدرة على التآلف الخاصة والعامة لمجموعة من الهجن القمية فى فول الصويا بين ثلاث كشافات هى: L86-K-73 و PI-416.937 و Hartwig إستخدمت كآباء مع أربعة أصناف هى جيزة٢٢ وجيزة١١١ و Crawford و Clark إستخدمت كأمهات، وذلك بمحطة إيتاى البارود للبحوث الزراعية للموسمين الصيفيين ٢٠٠٤ و ٢٠٠٥. فى الموسم الزراعى الأول تم عمل التهجينات القمية بين الآباء والأمهات السابق ذكرهم وتكون لدينا إثنى عشر هجين قمى. وفى الموسم الزراعى الثانى تم تقييم الجيل الأول الهجين مع كل من الآباء والأمهات حيث شملت الدراسة صفات طول النبات – عدد فروع النبات – ميعاد التزهير – ميعاد النضج – عدد قرون النبات – عدد

البذور لكل نبات – وزن ١٠٠ بذرة ووزن بذور النبات. وتم تحليل البيانـات إحـصائياً طبقـاً لطريقـة كمبثورن Kempthorne (١٩٥٧). ويمكن تلخيص النتائج المتحصل عليها كالآتى:

١- كان التباين الراجع إلى الآباء والأمهات والهجن وأيضاً التفاعل بينهم معنوياً لجميع الصفات تحـت الدراسة.

٢- أسهم التباين الراجع للعوامل المضيفة والتفاعل بينها وبين العوامل الغير مضيفة بدور كبيـر فـي وراثة كل الصفات المدروسة.

٣- أوضحت قيم القدرة العامة على التآلف أن الكشاف (الأب) L86-K-73 أفضل من الكـشافين PI-416.937 و Hartwig لجميع الصفات تحت الدراسة عدا صفة عدد الفروع للنبات. وأن أفـضل الأمهات كانت جيزة١١١ حيث كانت القيم موجبة وأعلا من الأمهاتين الأخراتين لصفات المحصول ومكوناته.

٤- أوضحت قيم القدرة الخاصة على التآلف أن الهجيـن (L86-K-73 x Giza22) والهجيـن (PI-416.937 x Clark) والهجين (Hartwig x Clark) كانت قيمها موجبة وعالية المعنوية لكـل من الصفات: عدد قرون النبات – عدد بذور النبات ووزن بذور النبات.

٥- كان الهجين القمى (L86-K-73 x Giza111) أعلا الهجن القمية فى صفات المحصول ومكوناته وكان الأكثر تفريعا.

٦- كانت قيم قوة الهجين موجبة وعالية المعنوية لكل الهجن القمية لصفات المحصول ومكوناته.