A 5 X5 Diallel Cross Analysis for Pea (*Pisum sativum*, L.) Cultivars and Estimations of some Genetic Parameters for some Growth Characters, Yield and its Components

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ABSTRACT

Two field experiments were conducted during the winter seasons of 2000/2001 and 2001/2002 on five pea cultivars and their all possible hybrid combinations, using a diallel cross system with reciprocals, in order to detect the general performances of the different 25 genetic populations; to estimate the heterosis percentages, based on both mid-and better-parents; to estimate the general and specific combining abilities, and the reciprocal effects; and to calculate the heritability percentages in broad and narrow senses. The results, generally, indicated that the parental cultivars reflected wide ranges in their characteristics with significant differences among the means of most studied characters. The obtained results reflected generally that all of the first hybrid generations, including the reciprocal crosses, tended to show values either higher than those of their respective lower parental values or deviated towards their higher parental values for the vegetative growth characters. The results indicated also that all of the F_1 hybrid populations were either more than their mid-or better- parental values for total yield and all its components characters. Positive heterosis estimates, relative to mid-parents, were detected in most of the F_1 hybrids for vegetative growth characters; but, those, relative to better-parents, were found negative. Concerning total yield and its components, positive heterotic effects were noticed on all of the first hybrid generations, including reciprocals, with just few exceptions. The results indicated also that both G.C.A. (additive effects) and S.C.A. (non-additive effects) appeared to be important in controlling the expression of all studied characters; but with relatively more important roles for S.C.A. effects. This result was also confirmed by the estimates of broad and narrow senses heritabilities. The results indicated also that the parental cultivar Progress No. 9 (P_5) could be considered as a good general combiner for the characters plant height, number of leaves, number of pods per plant. Cultivar Master (P_1) was the best general combiner for the characters seeds weight per pod, number of seeds per pod, pod length and pod width. The cultivars Little Marvel (P_2) and Lincoln (P_3) appeared to be good combiners for pod weight and number of branches, respectively. The best hybrid combinations, that possessed the highest positive estimates of S.C.A. effects for the characters : plant height; both number of leaves and pod length; number of branches; both pods weight per plant and pod weight; were found to be $P_3 \times P_4$, $P_1 \times P_2$, $P_1 \times P_3$ and $P_1 \times P_4$; respectively. The results showed also that the beast hybrid combinations appeared to be the crosses $P_2 \times P_5$ for number of pods per plant, $P_1 \times P_5$ for seeds weight per pod and $P_2 \times P_4$ for number of seeds per pod; since, their estimated S.C.A. values appeared to be positive and desirable. The results indicated that the reciprocal crosses $P_3 \times P_1$ for the plant height character and $P_4 \times P_2$ for pod width character reflected higher positive values than those of the other F_1 crosses.

INTRODUCTION

Pea (*Pisum sativum*, L.) is one of the most important legume vegetable crops, that is grown in winter season in Egypt. It is characterized by high a protein content, and relatively high percentages of some vitamins and minerals, necessary for human nutrition.

To improve any crop, it is essential to know as much as possible about the genetic systems controlling the expression of yield, quality and their related characters for this crop. Information about the genetics of the quantitative characters can be obtained by analyzing sets of diallel crosses. These analyses offer the opportunity to test the effects of both general and specific combining abilities of the lines or cultivars and their crosses, respectively. They, also, allow for estimating some other important genetic parameters; such as the variance components of additive and non-additive effects as well as heritability percentages in both broad and narrow senses. Such information may assist the plant breeders to chose the efficient breeding methods for improving pea plants. Many researchers used diallel crossing system in pea for estimating different genetic parameters (Snoad and Arthur, 1973; Gritton, 1975; Ranalli and Nannetti, 1983; Sarawat *et al.* 1994; Faris *et al.* 1997; Zayed *et al.* 1999; Swidan, 2000, and Bourion *et al.* 2002).

Information about the types and importance of gene action effects, controlling the total yield and its related characters, as an important purpose for improving pea, were studied by several investigators; such as Syr'eva, 1981; Gupta and Dahiya, 1986; Singh *et al.* 1997; Zayed, 1998; Zayed and Faris, 1998; Ahmed, 1999; Swidan, 2000; and Swidan *et al.* 2000. They mentioned that both additive and non-additive gene effects were important in the genetic expression of most studied characters of pea.

Heritability percentages in broad and narrow senses of some important characters of pea were estimated by many workers; such as Shalaby, 1974; Gad and El-Sawah, 1985; Gupta and Dahiya, 1986; Singh and Singh, 1989; Faris *et al.* 1997; Gupta *et al.* 1998; Ahmed and Ismail, 1999; and Singh, 1999.

Heterosis is of great importance to be employed in plant breeding to obtain high yielding genotypes. Recently, much intrest has developed in producing and growing F_1 hybrids of several normally self-pollinated species, where a considerable amount of F_1 yield heterosis had been demonstrated. Accordingly, heterosis on the F_1 hybrids were detected on some important characters of pea by several researchers; such as Shalaby, 1974; Gritton, 1975; Sarawat, 1994; Faris *et al.* 1997; Ahmed *et al.* 1998; and Tyagi and Srivastava, 1999.

Therefore, this investigation was undertaken to: 1) evaluate the general performances of five parental pea cultivars and all their possible F_1 hybrids; 2) obtain estimates for general and specific combining ability, and the reciprocal effects; 3) estimate the heritability percentages in both narrow and broad senses; and 4) calculate the amount of heterosis; for number of pea traits.

MATERIALS AND METHODS

The experiments of the present study were carried out at the Experimental Station Farm (at Abies) of the Faculty of Agriculture, Alexandria University; during the two winter seasons of 2000/2001 and 2001/2002.

Genetic Materials:

Five pea (*Pisum sativum* L.) cultivars; namely, Master (P_1), Little Marvel (P_2), Lincoln (P_3), Victory Freezer (P_4) and Progress No 9 (P_5); were used as parents for the present genetical study. Seeds of these cultivars were obtained from Vegetable Research Division, Institute of Horticultural Res., Agric. Res. Center, Ministry of Agriculture and Land Reclamation, A.R.E.

Experimental Methods:

2000/2001 Season:

Growing of the parental cultivars:

Seeds of each of the parental genotypes (five cultivars) were separately sown on October 15, 2000. Each of the parental cultivar was represented by twenty rows. The row was 4m. long and 70cm. wide, with inter-plant spacing of 20cm. All cultural practices were performed as usually recommended for the commercial pea growing.

Diallel crossing system:

At blooming stage, ten plants from each parental cultivar were chosen to made intercrossing among the five parental cultivars, in all possible combinations including reciprocals, using a 5 x 5 full-diallel crossing system. In addition some floral buds on each parental cultivar were bagged by paper bags to obtain new selfed seeds of the five parental cultivars. At pods maturity stage, enough seeds of each of the various required genetic populations were harvested.

2001/2002 Season:

Growing of the different genetic populations:

Seeds of all tested genetic populations; 5 parental cultivers , 10 F_1's and 10 reciprocal F_1's; were sown on October 15, 2001; in a randomized complete blocks design with three replicates. Each experimental unit contained three rows, 4m. long and 70cm. wide, with a spacing of 20cm. between plants. All agricultural practices were similarly carried out for all entries under study and as, commonly, recommended for pea crop production.

Collecting data for diallel analysis:

Measurements from the different genetic populations; 5 parents, 10 F_1 hybrids and their 10 reciprocal F_1's; for the characters under consideration were taken on an individual plant basis. The studied characters were plant height (cm), number of leaves and branches per plant, number of pods per plant, pods fresh weight per plant (g), pod fresh weight per plant, seeds weight per pod (g), number of seeds per pod, and pod length and width (cm).

Statistical procedures:

The recorded data of the studied characters were arranged and statistically analyzed, using the standard method of the randomized complete block design. The differences among the various means were tested, using Duncan's multiple range test (L.S.R.). Estimates of general combining ability (G.C.A.), specific combining ability (S.C.A.) and reciprocal effects (R.E) were estimated according to Griffing's (1956) approach; model two of method one which depends on the use of parents, F_1's and their reciprocals. The analysis of variance of the used method is presented in Table (1).

Table 1: Analysis of variance used for calculating the components of genotypic variance.

Sources of variation (S.O.V.)	Degrees of freedom (D.F.)	Sum of squares (S.S.)	Mean squares (M.S.)	Expected mean square (E.M.S.)
General combining ability (G.C.A.)	n-1 = 4	Sg	Mg	$\sigma^2_e + 2\,(n-1)/p \times \sigma^2_s + 2n\,\sigma^2_g$
Specific combining ability (S.C.A.)	n (n-1) / 2 = 10	Ss	Ms	$\sigma^2_e + 2(n^2-n+1)/n^2 + \sigma^2_s$
Reciprocal effects (r)	n (n-1) / 2 = 10	Sr	Mr	$\sigma^2_e + 2\,\sigma^2_r$
Error (e)	(r-1) (p-1) = 48	Se	Me	σ^2_e

p : number of populations = 25
r : number of replications = 3
n : number of parental cultivars = 5

Mg : mean square of (G.C.A.)
Ms : mean square of (S.C.A.)
Mr : mean square of reciprocal
Me : mean square of error

Heterosis percentages; relative to either mid-parental (M.P) or better-parental (B.P) values, for the studied characters; were calculated, according to the used formula by Sarawat *et al.* (1994) as follows:

$$\text{Heterosis (M.P.)\%} = \overline{F_1} - \overline{M.P.} \,/\, \overline{M.P.} \times 100$$

$$\text{Heterosis (B.P.)\%} = \overline{F_1} - \overline{B}.P. \,/\, \overline{B}.P. \times 100$$

Where : $\bar{F_1}$ is the mean of the F_1 population, $\bar{M.P.}$ is the mean of the two parental means values and B.P. is the mean value of the peter parent.

Heritability in broad and narrow senses, h^2_{bs} and h^2_{ns}, were estimated according to the formula used by Simmonds (1979) as follows:

$$h^2_{b.s.}\% = \frac{\sigma^2_A + \sigma^2_D}{\sigma^2_A + \sigma^2_D + \sigma^2_e} \times 100$$

$$h^2_{n.s.}\% = \frac{\sigma^2_A}{\sigma^2_A + \sigma^2_D + \sigma^2_e} \times 100$$

RESULTS AND DISCUSSIONS

Mean Performances of the Parental and F_1 Hybrid Generations:

The results of the comparisons among the mean performances of the parental cultivars for the vegetative growth characters, in Table (2), illustrated generally that the differences among the means of the parents appeared to be significant; but with different magnitudes. The cultivar Progress No.9 (P_5) gave the significant highest mean values for plant height and number of leaves per plant; while, the cultivar Master (P_1) reflected the lowest mean value for the two mentioned characters. For number of branches per plant, the results revealed that the cultivar Lincoln (P_3) reflected the significant highest mean; whereas, Little Marvel (P_2) cultivar showed the lowest one. These results seemed to agree with the findings of Gritton (1974), Shalaby (1974) and Ahmed *et al.* (1998) for plant height; Gad and El-Sawah (1985) and Swidan *et al.* (2000) for number of leaves and branches. They found a wide range of genetic variation among the parental genotypes for these three characters.

The comparisons among the vegetative growth characters means of the F_1 hybrids, in Table (2), demonstrated generally that all of the first hybrid generations tended to be either higher than their respective lower parent or deviated towards the higher parent. Similar results were reported in pea by Gad and El-Sawah (1985) for plant height and number of leaves per plant, and by Sarawat *et al.* (1994) for branches number per plant. They reported that most of the F_1 hybrids gave higher values than their lower or mid parental values for those characters. The highest plant height value of all F_1 hybrids was given by the F_1 hybrid P_3 x P_4, followed by the F_1 of the cross P_4 x P_6, without a significant difference; whereas, the lowest value was given by the reciprocal F_1 hybrid P_3 x P_1, with significant differences between this hybrid and all other

Table 2: Mean performances of the different evaluated genetic populations for some vegetative growth characters of pea.

Characters / Genotypes	Plant height (cm)	Number of leaves per plant	Number of branches per plant
Master (P_1)	58.55 l	25.45 m	1.62 hi
Little Marvel (P_2)	83.91 hi	34.75 k	1.27 l
Lincoln (P_3)	92.71 de	50.68 cd	3.07 a
Victory Freezer (P_4)	92.21 d-f	43.06 f-h	1.50 ik
Progress No. 9 (P_5)	104.90 a	63.44 a	2.11 e
$P_1 \times P_2$	81.41 ij	32.05 kl	1.34 l
$P_1 \times P_3$	89.95 e-g	42.39 g-i	2.72 b
$P_1 \times P_4$	82.94 hi	38.25 j	1.55 ij
$P_1 \times P_5$	92.71 c-e	50.60 cd	1.85 fg
$P_2 \times P_3$	85.19 g-i	39.15 ij	2.32 d
$P_2 \times P_4$	87.09 f-h	40.81 h-j	1.37 kl
$P_2 \times P_5$	96.91 b-d	47.21 de	1.60 hi
$P_3 \times P_4$	104.10 a	46.15 ef	2.19 de
$P_3 \times P_5$	98.28 bc	58.28 b	2.75 b
$P_4 \times P_5$	103.50 a	55.98 b	1.84 fg
$P_2 \times P_1$	78.48 j	29.87 l	1.30 l
$P_3 \times P_1$	72.78 k	44.73 e-g	2.54 c
$P_4 \times P_1$	86.15 g-i	38.61 j	1.71 gh
$P_5 \times P_1$	94.48 b-e	51.96 c	1.77 fg
$P_3 \times P_2$	84.78 g-i	38.24 j	2.33 d
$P_4 \times P_2$	89.70 e-g	39.20 ij	1.42 j-l
$P_5 \times P_2$	92.28 d-f	45.11 e-g	1.58 hi
$P_4 \times P_3$	98.38 b	47.57 de	2.08 e
$P_5 \times P_3$	94.55 b-e	55.32 b	2.56 c
$P_5 \times P_4$	96.23 b-d	58.59 b	1.89 f

Values having the same alphabetical letter (s) within each column, don't significantly differ from one another, using Duncan's multiple range test at 0.05 level.

F_1's. Concerning the numbers of leaves and branches per plant, the highest mean values were reflected by the reciprocal cross $P_5 \times P_4$ and the F_1 hybrid $P_3 \times P_5$, respectively; while, the hybrid $P_1 \times P_2$ and its reciprocal cross gave the lowest mean values for these two characters. Such high performances of the mentioned F_1 hybrid populations could be related to the types of gene action involved on the inheritance of these characters, that reflected some importance for the roles of additive and non-additive gene effects; but with different magnitudes. Similar results were reported by Gad and El-Sawah (1985) for number of leaves per plant; and by Ahmed and Ismail (1999) for plant height and branches number; who found that both the additive and non-additive gene effects were involved on the inheritance of these characters; but, the non-additive gene effects played a more important role than additive effects. However, the additive gene action was also reported to play a considerable role on the inheritance of these characters, as mentioned by Singh (1997) for plant height; and by Gad and El-Sawah (1985) for branches number per plant.

The results concerning the comparisons among the general performances of the parental cultivars and their all F_1 hybrid generations for pea yield and its components are listed in Table (3). Among the parental cultivars, Progress No.9 cultivar gave the significant highest mean value of yield per plant; as expressed by number of pods and pods weight per plant; whereas, cultivar Master (P_1) reflected the lowest mean values for these two characters. Cultivar Little Marvel (P_2) reflected the highest mean value for pod weight and the cultivar Master (P_1) gave the highest mean values for seeds-weight and-number per pod, and for pod-length and- diameter. While, cultivars Victory Freezer (P_4) and Lincoln (P_3) produced the lowest mean values for number of seeds per pod and for the other four characters of pod, respectively. Such results reflected a general agreement with those obtained by Swidan (2000) for the characters pod weight per plant, seeds weight per pod and pods weight; by Ahmed (1999) for number of pods per plant, number of seeds per pod and pod length; who showed that their evaluated parental cultivars varied in their general performances for the mentioned characters.

The results in Table (3) reflected generally that all F_1 hybrid populations produced averages that tended to be either more than their respective mid-or better-parental values for total yield and all its components characters, with some few exceptions. Such a result suggested that the F_1 hybrid generations reflected general superiority on their yield and its components, which could be generally expected on the basis of hybrid vigour expression, predominantly contributed by the non-additive gene effects. This result agreed with the findings of Zayed *et al.* (1999) for number of pods per plant, number of seeds per pod and pod length; and of Swidan (2000) for pod width, pods weight per plant and seeds weight per pod. They found that though both additive and non-additive gene effects were involved in the inheritance of the characters, the non-additive gene effects were found to play more important roles. Among the ten F_1 hybrids and their ten reciprocal F_1's, the highest mean values were found to be those of the F_1 hybrids $P_2 \times P_5$ and $P_3 \times P_6$ and the reciprocal F_1's $P_4 \times P_3$ and $P_5 \times P_2$ for the characters number of pods and pods weight per plant, respectively. The mean values of $P_1 \times P_5$ and $P_3 \times P_2$ were the highest for pod weight, $P_1 \times P_5$ and $P_5 \times P_4$ gave the highest means for seeds weight per pod. $P_1 \times P_2$ and $P_3 \times P_1$ were the highest for number of seeds per pod, and $P_1 \times P_2$ and its reciprocal cross showed the highest means for both pod length and width. These results are in harmony with the findings of Nassar (1992) for the characters number of

Table 3: Mean performances of the different evaluated genetic populations for yield and components characters of pea.

Characters / Genotypes		Yield per plant		Pod characters				
		Number of pods	Pods weight (g)	Weight (g)	Seeds weight (g)	Number of seeds	Length (cm)	Wi… (cm
Master	(P1)	20.43 n	101.30 l	4.87 ij	2.50 d-i	8.10 a-d	8.06 c-f	1.62 a
Little Marvel	(P2)	25.35 m	136.30 kl	5.37 f-i	1.86 jk	7.02 e-g	7.95 c-f	1.30
Lincoln	(P3)	32.07 l	143.90 k	4.49 j	1.77 k	6.38 gh	6.34 g	1.22
Victory Freezer	(P4)	41.47 fg	186.50 h-j	4.50 j	2.12 i-k	5.69 h	7.22 f	1.30 h
Progress No. 9	(P5)	45.86 de	233.00 c-g	5.08 h-j	2.12 i-k	6.97 fg	7.81 d-f	1.57 b
$P_1 \times P_2$		26.68 m	168.70 i-k	6.33 a-c	2.58 d-i	8.49 ab	9.40 a	1.68 a
$P_1 \times P_3$		37.25 i-k	210.10 f-h	5.64 b-h	2.93 a-c	8.45ab	8.45 b-e	1.64 a
$P_1 \times P_4$		43.36 ef	275.10 a-c	6.34 ab	2.79 a-e	7.73 b-f	8.82 a-c	1.47 f
$P_1 \times P_5$		40.67 f-i	262.00 a-d	6.45 a	3.21 a	7.88 b-d	8.46 b-e	1.60 b
$P_2 \times P_3$		38.23 g-j	215.80 e-h	5.65 b-h	2.73 d-f	8.40 a-c	8.30 b-e	1.39 i
$P_2 \times P_4$		48.11 b-d	278.50 ab	5.81 a-h	2.35 f-i	8.35 a-c	8.09 c-f	1.53 c
$P_2 \times P_5$		54.29 a	302.20 a	5.59 c-i	2.24 g-j	7.47 d-f	8.66 a-d	1.52 d
$P_3 \times P_4$		37.73 h-j	198.60 g-i	5.28 f-i	2.40 e-i	6.96 fg	7.62 ef	1.40 h
$P_3 \times P_5$		51.25 ab	265.80 a-d	5.18 g-j	2.63b-g	7.87 bd	8.23 b-e	1.39 i
$P_4 \times P_5$		47.41 cd	264.90 a-d	5.59 b-i	3.00 ab	7.82 b-e	8.35 b-e	1.39 i-
$P_2 \times P_1$		27.96 m	167.50 i-k	5.99 a-f	2.55 c-h	8.44 ab	9.14 ab	1.73 a
$P_3 \times P_1$		34.34 kl	152.10 jk	5.43 e-i	2.81 b-e	8.80 a	7.82 d-f	1.72 a
$P_4 \times P_1$		39.65 g-j	234.80 c-g	5.93 a-g	2.82 a-d	7.97 a-d	8.72 a-d	1.44 g-
$P_5 \times P_1$		41.07 f-h	246.30 b-f	6.00 a-f	2.89 a-d	8.42 ab	8.40 b-e	1.48 e-
$P_3 \times P_2$		37.14 jk	230.60d-g	6.19 a-d	2.75 b-f	8.02 a-d	8.50 b-e	1.37 i-
$P_4 \times P_2$		43.30 ef	252.10 b-e	5.82 a-h	2.17 h-j	8.03 a-d	8.29 b-e	1.34 k
$P_5 \times P_2$		49.85 bc	296.20 a	6.18 a-e	2.54 c-h	7.56 c-f	8.75 d-f	1.49 e
$P_4 \times P_3$		49.93 bc	275.40 a-c	5.51 d-i	2.55 c-h	7.67 b-f	7.82 d-f	1.41 g
$P_5 \times P_3$		48.41 b-d	267.20 a-d	5.53 d-i	2.57 c-h	7.86 b-d	8.01 c-f	1.36 j-
$P_5 \times P_4$		46.02 d-e	261.90 a-d	5.17 h-j	2.99 ab	7.55 c-f	8.46 b-e	1.48 e-

Values having the same alphabetical letter (s) within each column, don't significantly differ from or another, using Duncan's multiple range test at 0.05 level.

pods per plant, number of seeds per pod and pod length; and of Swidan (2000) for pods weight per plant, seeds weight per pod and pod diameter. They noticed that most of the first generation hybrids were higher and more vigorous than their parental cultivars.

Heterosis Estimates of the F_1 Hybrid Generations ($H_{m.p.}$% and $H_{b.p.}$%):

The estimated values of heterosis percentages; relative to mid-and better-parents ($H_{m.p.}$% and $H_{b.p.}$%), of the F_1 hybrid populations on the vegetative growth characters; are listed in Table (4). The estimates, relative to mid-parents, reflected desirable heterotic effects, with positive signs, on twelve, thirteen and nine F_1 hybrids for the characters plant height, number of leaves and number of branches per plant, respectively. These results agreed generally with those reported by Gad and El-Sawah (1985) for plant height and number of leaves per plant; since, they found that most of their tested F_1 hybrids exhibited positive heterosis, based on mid-parents, on the two characters, while, the F_1 crosses showed negative heterosis estimates for number of branches per plant.

The results illustrated also that the heterosis percentages, relative to the better-parents, were negative and undesirable in all the F_1 hybrid populations, with the exception of two F_1 hybrids for the plant height character and only one F_1 hybrid for number of branches per plant character. Such negative and undesirable heterotic effects may be due to lower values of one or both parents, suggesting that these crosses tended to have more decreasing alleles for these characters.

The results presented in Table (5) indicated generally that desirable and positive heterotic effects, relative to both mid-and better-parents were reflected on all the F_1 hybrids and their reciprocals for the total yield and all its components, with just few exceptions. Concerning number of pods per plant, all the F_1 populations showed positive hterosis estimates based on mid-parental values and most of them showed also positive heterosis, relative to their respective better-parents. The results illustrated also that, in general, the F_1 hybrids reflected positive (desirable) values, relative to mid and better parents; for the characters pods weight per plant, pod fresh weight, seeds weight per pod, number of seeds per pod and pod length; with only four exceptions which appeared to have negative (undesirable) heterotic effects. The superior F_1 hybrids, which gave the high positive values of heterosis for these characters over the better-parents, might be suggested to be introduced to pea growers for commercial production. The results, of the present study seemed to agree with those obtained by several investigators; such as Shalaby (1974), and Dhillon and Chahal (1983) for number of pods per plant; Gritton (1975) for seed weight; and Nassar (1992) for number of seeds per pod and pod length characters, who found positive (desirable) heterotic effects.

Positive and desirable heterotic effects for pod width character were, also, reflected by sixteen and ten F_1 hybrid generations, relative to mid-and better-parents, respectively. However, negative heterotic effects were reported by Nassar (1992), based on mid-or better-parental values, for pod width on the F_1 hybrids and their reciprocals.

Table 4: Heterosis percentages, relative to mid and better parental values, of all possible hybrid combinations for some vegetative growth characters of pea.

Characters	Plant height (cm)		No. of leaves per plant		No. of branches per plant	
	Heterosis (%)					
Crosses	M.P.	B.P.	M.P.	B.P.	M.P.	B.P.
$P_1 \times P_2$	14.29	-2.98	6.48	-7.77	-6.94	-17.28
$P_1 \times P_3$	18.93	-2.98	11.38	-16.36	13.97	-11.40
$P_1 \times P_4$	10.03	-10.05	11.68	-11.17	-0.64	-4.32
$P_1 \times P_5$	13.45	-11.62	13.86	-20.24	-0.54	-12.32
$P_2 \times P_3$	-3.53	-8.11	-8.33	-22.75	6.91	-24.43
$P_2 \times P_4$	-1.10	-6.06	4.91	-5.22	-0.72	-8.67
$P_2 \times P_5$	2.66	-7.62	-3.83	-25.58	-5.32	-24.17
$P_3 \times P_4$	12.60	12.28	-1.54	-8.94	-3.95	-28.66
$P_3 \times P_5$	-0.53	-6.31	2.14	-8.13	6.18	-10.42
$P_4 \times P_5$	5.02	-1.33	5.13	-11.76	2.22	-12.79
$P_2 \times P_1$	10.18	-0.08	-0.76	-14.04	-9.72	-19.75
$P_3 \times P_1$	-3.78	-21.50	17.52	-11.74	8.55	-17.26
$P_4 \times P_1$	14.29	-6.57	12.73	-10.33	9.61	5.55
$P_5 \times P_1$	15.61	-9.93	16.92	-18.09	-4.84	-16.11
$P_3 \times P_2$	-4.00	-8.55	-10.46	-24.55	7.37	-24.10
$P_4 \times P_2$	1.86	-2.72	0.77	-8.96	2.90	-5.33
$P_5 \times P_2$	-2.24	-12.03	-8.11	-28.89	-6.51	-25.12
$P_4 \times P_3$	6.40	6.11	1.49	-6.14	-11.40	-32.25
$P_5 \times P_3$	-4.30	-9.87	-3.05	-12.80	-1.16	-16.61
$P_5 \times P_4$	-2.35	-8.26	9.91	-7.74	5.00	-10.43

Table 5: Heterosis percentages, relative to their mid and better parental values, of all possible hybrid combination for yield and its components characters of pea.

Characters	Yield per plant				Pod characters									
	Number of pods		Pods weight (g)		Weight (g)		Seeds weight (g)		Number of seeds		Length (cm)		width (cm)	
Crosses	Heterosis (%)								Heterosis (%)					
	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.
$P_1 \times P_2$	16.56	5.25	42.00	23.77	23.05	17.88	18.35	3.20	12.30	4.81	17.50	16.62	15.07	3.70
$P_1 \times P_3$	41.90	16.15	71.37	46.00	20.51	15.81	37.24	17.20	16.71	4.32	17.36	4.84	15.49	1.23
$P_1 \times P_4$	40.10	4.56	91.17	47.51	35.32	30.18	20.78	11.60	12.11	-4.57	15.44	9.43	0.67	-9.26
$P_1 \times P_5$	22.70	-10.56	56.74	12.45	29.65	26.97	38.96	28.40	4.65	-2.72	6.68	4.96	1.26	-1.23
$P_2 \times P_3$	33.16	19.21	54.03	49.96	14.60	5.21	50.41	46.77	25.37	19.66	16.25	4.40	10.32	6.92
$P_2 \times P_4$	43.99	16.01	72.55	49.33	17.73	8.19	18.09	10.85	31.39	18.94	6.73	1.76	17.69	17.69
$P_2 \times P_5$	52.50	18.38	63.66	29.70	6.98	4.10	12.56	5.66	6.87	6.41	9.89	8.93	6.29	-3.18
$P_3 \times P_4$	2.61	-9.02	20.22	6.49	17.46	17.33	23.71	13.21	15.42	9.09	12.39	5.54	11.11	7.69
$P_3 \times P_5$	31.54	11.75	41.04	14.08	8.25	1.97	35.57	24.06	17.99	12.91	16.41	5.38	0.72	-11.46
$P_4 \times P_5$	8.58	3.38	26.29	13.69	16.70	10.04	66.75	41.51	23.54	12.19	11.18	6.91	-2.79	-11.46
$P_2 \times P_1$	22.15	10.29	40.99	22.89	16.99	11.54	16.97	2.00	11.64	4.20	14.25	13.40	18.49	6.79
$P_3 \times P_1$	30.82	7.08	24.06	5.70	16.02	11.50	31.61	12.40	21.55	8.64	8.61	-2.98	21.13	6.17
$P_4 \times P_1$	28.11	-4.39	63.17	26.03	26.57	21.76	22.08	12.80	15.67	-1.60	14.14	8.19	-1.37	-11.11
$P_5 \times P_1$	23.91	-10.44	47.35	5.71	20.60	18.11	25.11	15.60	11.82	3.95	5.93	4.22	-6.33	-8.64
$P_3 \times P_2$	29.36	15.81	64.60	60.25	25.56	15.27	51.51	47.85	19.70	14.24	19.05	6.92	8.73	5.38
$P_4 \times P_2$	29.60	4.41	56.19	35.17	17.93	8.38	9.04	2.36	26.47	14.39	9.37	4.28	3.08	3.08
$P_5 \times P_2$	40.03	8.70	60.41	27.12	18.28	15.08	27.64	19.81	8.15	7.69	11.04	10.06	4.19	-5.09
$P_4 \times P_3$	35.79	20.40	66.71	47.67	22.44	22.28	31.44	20.28	27.09	20.22	15.34	8.31	11.90	8.46
$P_5 \times P_3$	24.24	5.56	41.79	14.68	15.57	8.86	32.13	21.23	17.75	12.77	13.29	2.56	-1.45	-13.37
$P_5 \times P_4$	5.39	0.35	24.86	12.40	7.93	1.77	41.04	41.04	19.27	8.32	12.65	8.32	3.49	-5.73

General and Specific Combining Abilities (G.C.A. and S.C.A.), and Reciprocal Effects:

The results concerning the analyses of variance of combining ability and reciprocal effects on the various studied characters of the five parental cultivars and their all possible hybrid combinations are shown in Table (6). The estimated variances for the effects of both general and specific combining abilities reflected highly significant values for all studied characters, with only one exception which was found significant. This result suggested generally that both additive and non-additive gene effects were important in controlling the expression of all studied characters. In this concern, both G.C.A. and S.C.A. effects were previously shown to be major contributing factors in pea, as illustrated by several researchers; such as Venkateswarlu and Singh (1982), and Ranalli and Naneti (1983) for number of pods per plant; El-Murabaa *et al.* (1988, a and b) for plant height, pod length, pod width, pod weight and number of seeds per pod; and Gad and El-Sawah (1985) for both number of leaves and branches. Also, the results illustrated generally that the mean squares estimates of S.C.A. showed higher values than those of G.C.A. for all the studied characters, suggesting that the non-additive gene effects appeared to have, relatively, more important roles than additive gene effects. Concerning the reciprocal effects, the estimates of mean squares were high enough to be highly significant for only one character and significant for two characters; while, the other estimates of mean squares were not found high enough to be significant. Such a result suggested that reciprocal effects were generally lacking, though some effects on plant height; number of both branches and pods per plant were noted.

The estimated values of the general combining ability (G.C.A.) effects of the parental cultivars, in Table (7) reflected that the best general combiner parent, that appeared to have the significant highest positive value of G.C.A. was found to be Progress No.9 (P_5) cultivar for the characters plant height, number of leaves, number of pods per plant and pods weight per plant. The parental cultivar Master (P_1) was found a good general combiner for the characters seeds weight, number of seeds per pod, pod length and width. The results in Table (7) illustrated also that the parental cultivars Little Marvel (P_2) and Lincoln (P_3) appeared to be good combiners for the characters pod weight and number of branches per plant, respectively. From such results, it could be generally concluded that combining ability estimates, can be selected to be involved in hybrid combinations to predict the best hybrids. However, it showed be mentioned that the parents with good G.C.A. do not necessarily produce superior crosses with good S.C.A. in all combinations (Swamy Rao, 1977).

Table 6: Analyses of variance for general and specific combining abilities and reciprocal effects on the different studied characters of the five parental cultivars and their 10 F_1's and 10 reciprocals F_1's.

Sources of variation (S.O.V.)	Degrees of freedom (D.F.)	Mean squares (M.S.)									
		Plant height	No. of leaves	No. of branches	No. of pods per plant	Pods weight per plant	Pod weight	Seeds weight per pod	No. of seeds per pod	Pod length	Pod width
G.C.A.	4	488.12**	514.42**	1.54**	290.74**	7713.69**	0.45*	0.31**	1.09**	1.09**	0.06**
S.C.A.	10	11907.29**	3760.64**	5.92**	2340.73**	69400.76**	44.92**	9.15**	87.22**	98.46**	3.20**
Reciprocals	10	22.24*	1.87	1.35**	11.53*	604.86	0.08	0.013	0.06	0.033	0.004
Error	48	8.60	3.75	0.01	3.45	480.64	0.14	0.043	0.18	0.22	0.004

*Significant at 0.05 level   ** Highly significant at 0.01 level

Table 7: Estimates of general combining ability (G.C.A.) effects on the different studied characters of five parental cultivars of pea.

Characters / Parental cultivars	Plant height (cm)	No. of leaves per plant	No. of branches per plant	No. of pods per plant	Pods weight per plant (g)	Pod weight (g)	Seeds weight per pod (g)	No. of seeds per pod	Pod length (cm)	Pod width (cm)
P_1	-10.09	-6.759	0.127	-7.129	-33.152	0.188	0.206	0.482	0.306	0.126
P_2	-3.320	-6.582	-0.349	-2.687	-6.652	0.233	-0.189	0.124	0.276	-0.009
P_3	1.650	2.624	0.634	-0.471	-14.732	-0.258	-0.068	0.124	-0.484	-0.062
P_4	3.560	0.427	-0.229	3.531	16.358	-0.152	-0.021	-0.410	0.166	-0.068
P_5	8.180	10.291	0.077	6.756	38.178	-0.012	0.079	-0.119	0.067	0.011
L.S.D.$_{0.05}$ $G_i - G_j$	2.656	1.749	0.078	1.672	19.806	0.337	0.187	0.383	0.422	0.056

$G_i - G_j$ = difference between two (G.C.A.) estimates of two parental cultivars.

The comparisons among the estimated values of specific combining ability (S.C.A.), in Table (8), illustrated that most of the F_1 hybrids reflected positive S.C.A. values for plant height character. The best hybrid combination which showed the highest positive value for such a character was found to be the cross P_3 x P_4, indicating that the two parents, P_3 and P_4, can combine well to produce a hybrid with a high general performance for this character. In this respect, it is noteworthy that not only the highest of the parents involved in a cross was important in determining the height of the progeny, but also the S.C.A. effects of the parents involved (Gritton, 1975). This result seemed to agree with the findings of Wally (1982), Zayed (1988 and 1998); and Zayed and Faris (1998), who suggested that over-dominance played a considerable role in the inheritance of plant height character. The results illustrated that the cross P_1 x P_2 could be considered as the best hybrid combination for two characters number of leaves and pod length; since, it showed the highest positive value for S.C.A. effects. For number of branches character, the best hybrid combination was P_1 x P_3, suggesting that these two parents could combine well to produce more branches. In the cases of the characters pods weight per plant, pod weight and pod width, it was noticed that the highest values of S.C.A. were reflected by the cross P_1 x P_4, which appeared to be the best combination for these characters. Concerning number of pods per plant, the results revealed that the best hybrid combination was found to be the cross P_2 x P_5. For seeds weight per pod, the F_1 hybrid P_1 x P_5 gave the best combine well to produce the heaviest seeds per pod. In this concern, the parents P_1 and P_5 gave positive G.C.A. values, which means that the two parents were the good combiners for this character. As for number of seeds per pod, the presented results in Table (8) illustrated that the best combination was given by the cross P_2 x P_4, which showed the highest positive S.C.A. value, indicating that the two parents involved in this cross possessed good genes in general and reacted well to produce a hybrid with a high number of seeds per pod.

Table 8: Estimates of specific combining ability (S.C.A.) effects and reciprocal effects on the different studied characters of the 10 F_1's and their reciprocals F'_1s of five pea cultivar

Characters / Crosses	Plant height (cm)	No. of leaves per plant	No. of branches per plant	No. of pod per plant	Pods weight per plant (g)	Pod weight (g)	Seeds weight per pod (g)	No. of seeds per pod	Pod length (cm)	Pod width (cm)
$P_1 \times P_2$	3.660	10.606	-0.131	-3.177	-17.168	0.142	-0.001	0.103	0.461	0.114
$P_1 \times P_3$	0.112	3.000	0.194	3.082	3.912	0.008	0.180	0.464	0.086	0.151
$P_1 \times P_4$	1.384	-0.933	0.057	4.790	46.672	0.502	0.115	0.022	0.403	0.523
$P_1 \times P_5$	5.811	3.053	-0.069	0.948	24.052	0.452	1.213	0.031	-0.170	-0.071
$P_2 \times P_3$	-3.030	-2.042	0.111	0.530	19.512	0.348	0.445	0.407	0.381	-0.023
$P_2 \times P_4$	-1.532	1.465	0.044	4.548	30.522	0.137	0.918	0.720	-0.147	0.038
$P_2 \times P_5$	0.045	-2.244	-0.067	7.633	43.602	0.067	-0.052	-0.246	0.135	0.029
$P_3 \times P_4$	6.340	-0.886	-0.199	0.457	10.302	0.208	0.012	0.046	0.143	0.061
$P_3 \times P_5$	-3.112	-0.810	0.015	3.232	17.982	0.028	0.038	0.305	0.310	-0.048
$P_4 \times P_5$	-1.580	1.842	0.088	-3.885	-16.208	-0.053	0.385	0.458	0.276	0.018
$P_2 \times P_1$	1.470	1.090	0.020	-0.640	0.600	0.170	0.015	0.025	0.130	-0.025
$P_3 \times P_1$	8.590	-1.170	0.090	1.455	29.000	0.105	0.060	-0.175	0.315	-0.04
$P_4 \times P_1$	-1.610	-0.180	-0.080	1.855	20.150	0.205	-0.015	-0.120	0.050	0.015
$P_5 \times P_1$	-0.890	-0.680	0.040	0.200	7.850	0.225	0.160	-0.270	0.030	0.060
$P_3 \times P_2$	0.210	0.455	-0.005	0.545	-7.400	-0.270	-0.010	0.190	-0.100	0.010
$P_4 \times P_2$	-0.470	0.805	-0.025	2.405	13.200	-0.005	0.090	0.160	-0.100	0.950
$P_5 \times P_2$	-1.220	1.050	0.010	2.220	3.000	-0.295	-0.150	-0.045	-0.045	0.015
$P_4 \times P_3$	2.860	-0.710	0.055	-6.100	-38.400	-0.115	-0.075	-0.355	-0.100	-0.005
$P_5 \times P_3$	1.870	1.480	0.095	1.420	-0.700	-0.175	0.030	0.005	0.110	0.015
$P_5 \times P_4$	3.640	-1.275	-0.025	0.695	1.500	0.210	-0.005	0.135	-0.053	-0.045
L.S.D.-0.05										
$S_{ij} - S_{ik}$	5.314	3.498	0.157	3.347	39.610	0.676	0.371	0.766	0.846	0.11
$S_{ij} - S_{kl}$	4.601	3.030	0.135	2.898	34.303	0.585	0.325	0.664	0.731	0.096
$r_{ij} - r_{kl}$	5.940	3.910	0.175	3.741	44.286	0.755	0.418	0.856	0.945	0.125

$S_{ij} - S_{ik}$ = difference between two (S.C.A.) estimates, of two hybrids, with a common parent.
$S_{ij} - S_{kl}$ = difference between two (S.C.A.) estimates, of two hybrids, with non-common parent.
$r_{ij} - r_{kl}$ = difference between two reciprocal (r) estimates, of two hybrids, with non-common parent.

Concerning the estimated reciprocal values, the results, generally, revealed that few reciprocal F_1 hybrids reflected some positive (desirable) values on only two of all studied vegetative growth, yield and its components characters. The reciprocal crosses $P_3 \times P_1$, for plant height, and $P_4 \times P_2$, for pod width, reflected higher positive values than those of their corresponding F_1's. This result seemed to suggest to that a slight amount of the maternal effects were observed on these two characters and in just the two mentioned cases to be neglected.

Estimates of the Heritability Percentages in the Broad and Narrow Senses for the Various Studied Characters:

The results of the estimated vales of the different components of the total variance; additive, dominant and error variances; and the two heritability percentages in broad and narrow senses ($H_{b.s.}$% and $H_{n.s.}$%) for the various studied characters, are presented in Table (9). The results illustrated generally that the estimates of σ^2_D reflected higher values than those of σ^2_A for all studied characters, suggesting that the non-additive gene effects reflected relatively more important roles than the additive gene effects in controlling the expression of these characters. The estimated percentages of broad sense heritability showed high values for all studied characters. This result seemed to agree with those obtained by Shalaby (1974) for plant height, number of pods per plant and number of seeds per pod; and Nassar (1992) for branches number per plant, pod length and pod width. The narrow sense heritability estimates in Table (9) showed intermediate or relatively low percentages, with values ranged from 19.40, for number of branches per plant to 24.01% for number of seeds per pod. These results indicated clearly that both the additive and the non-additive gene effects appeared important, but with some relative advantage for the non-additive gene effects, for the inheritance of the various studied characters. The estimated values for the narrow sense heritability seemed to agree with those obtained by Gad and El-Sawah (1985) for plant height; and Ahmed and Ismail (1999) for both number of branches and pods per plant, who reached to similar trends in this concern. However, the heritability estimates for these three characters, in the present study, appeared to have relatively lower values than those obtained by Singh (1999) for plant height and number of pods per plant; and by Swidan *et al.* (2000) for number of branches per plant. Also, the estimates of narrow sense heritability, in this study, for the other studied characters showed lower values than those estimated by Gupta and Dahiya (1986) for pod length and pod width; Singh and Singh (1989) for number of seeds per pod; Gupta *et al.* (1998) for pod weight per plant; and Swidan *et al.* (2000) for number of leaves. Such differences in the estimated values of the various genetic parameters could be actually related to the type of the used genetic materials and the methods of genetic analysis and determination.

Table 9: Estimates of genetic variance components and heritability percentages for the studied characters on five parental cultivars and their all possible hybrid combinations in two directions.

Characters	σ^2_A	σ^2_D	σ^2_e	$h^2_{b.s}$%	$h^2_{n.s}$%
Plant height	2409.26	7828.05	8.65	99.91	23.51
No. of leaves/plant	688.92	2471.64	3.75	99.88	21.77
No. of branches/plant	0.938	3.889	0.0075	99.84	19.40
No. of pods/plant	434.67	1537.697	3.43	99.83	22.00
Pods weight/plant	13073.01	45342.18	480.64	99.18	22.20
Pod weight	29.461	93.68	0.14	99.89	23.89
Seeds weight/pod	1.864	5.99	0.043	99.45	23.60
No. of seeds/pod	18.146	57.263	0.18	99.76	24.01
Pod length	20.513	64.633	0.219	99.75	23.75
Pod width	0.662	2.105	0.0038	99.86	23.89

σ^2_A = additive variance.
σ^2_D = dominant variance.
σ^2_e = error variance.
$h^2_{b.s}$% = heritability percentage in the broad sense.
$h^2_{n.s}$% = heritability percentage in the narrow sense.

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الملخص العربى

تحليل تهجينات الداى أليل لخمسة أصناف من البسلة (٥ x ٥) وتقدير بعض المقاييس الوراثية لبعض صفات النمو و المحصول ومكوناته

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استخدمت خمسة أصناف من البسلة وجميع الهجن الممكنة بينها باستخدام نظام التهجينات الداى أليل فى اتجاهين (٥ x ٥) ، فى هذه الدراسة والتى أجريت أثناء الموسمين الشتويين لعامى ٢٠٠٠/٢٠٠١ و٢٠٠١/٢٠٠٢ بمحطة البحوث الزراعية بأبيس و التابعة لكلية الزراعة جامعة الأسكندرية ، و ذلك بهدف التعرف على الأداء العام للتراكيب الوراثية المستخدمة ، وكذلك لتقدير النسبة المئوية لتفوق كل من هجن الجيل الأول على كل من متوسط الأبوين أو الأب الأعلى لكل هجين ، وكذلك لتقدير قدرتى التآلف العامة و الخاصة وتأثير التهجين العكسى ، بالاضافة الى تقدير كفاءة التوريث بمعناها الواسع ومعناها الضيق لصفات النموالخضرى و المحصول الكلى ومكوناته لهذا المحصول البقولى الهام. زرعت بذور الخمسة أصناف الأبوية من البسلة (ماستر – لتل مارفل – لنكولن – فيكتورى فريزر – بروجرس رقم ٩) فى الموسم الشتوى لعام ٢٠٠٠/٢٠٠١، وأجريت كل التهجينات الممكنة بينها عن طريق التلقيح اليدوى باتباع نظام تهجينات الداى‌أليل فى اتجاهين، وذلك للحصول على بذور الهجن الممكنة بين هذه الأصناف ، مع الحصول على بذور جديدة للأصناف ناتجة من التلقيح الذاتى للأصناف الأبوية. و فى الموسم الشتوى لعام ٢٠٠١/٢٠٠٢ تم اجراء تجربة حقلية لتقييم العشائر الوراثية المختلفة (خمسة أصناف أبوية + عشرين هجينا) باستخدام تصميم القطاعات العشوائية الكاملة وباستخدام ثلاث مكررات. أوضحت النتائج أن الأصناف الأبوية المستخدمة تختلف فيما بينها فى معظم الصفات المدروسة. وعكست معظم الهجن الناتجة قيما أعلى لصفات النمو الخضرى من قيم الآباء المنخفضة أومتجهه نحو قيم الآباء الأعلى. كما أظهرت النتائج أن قيم صفات المحصول ومكوناته لجميع الهجن المتحصل عليها كانت أفضل من قيم متوسط الأبوين أو أعلى من أفضل الأبوين المستخدمين فى كل هجين. أما بالنسبة لتقديرات قوة الهجين ، فقد أبرزت النتائج وجود تأثيرات موجبة مرغوبة فى رفع قيم الصفات الخضرية المدروسة لمعظم الهجن وذلك على أساس متوسط الأبوين ، أما بالنسبة لتأثيرات قوة الهجين على أساس أفضل الأبوين فقد عكست النتائج أيضا تأثيرات موجبة مرغوبة على سلوك معظم الهجن فى صفات النمو الخضرى والمحصول الكلى ومكوناته ، مع وجود بعض الاستثناءات القليلة والتى عكست بعض تأثيرات سالبة غير مرغوبة على السلوك العام لبعض الصفات فى قليل من الهجن . أوضحت النتائج أيضا أن كل من تأثيرات القدرة العامة و الخاصة على التآلف و التى تعكس أهمية كل من فعل الجين الاضافى و اللااضافى ، قد أشتركت فى ميكانيكية توريث الصفات المدروسة ، ولكن ظهر أن تأثيرات التفاعل الجينى اللااضافى قد لعبت دورا

أكثر أهمية من دور التفاعلات الاضافية ، حيث انعكس ذلك على القيم المرتفعة نسبيا لتباين السيادة مقارنة بتباين الاضافة ، ولقد تأكدت هذه النتائج كذلك بالقيم المقدرة لكفاءة التوريث بمعناها الضيق و الواسع لكل الصفات المدروسة. ومن الجدير بالذكر، فانه لايمكن الاعتماد على صنف واحد من الأصناف الأبوية المختبرة أو على هجين واحد فقط فى تقييم كل الصفات المدروسة بنفس درجة الكفاءة ، و على الرغم من ذلك ، فقد تميز الصنف الأبوى بروجرس رقم ٩ (P_5) بقدرة تآلف عامة عالية فى اتجاه القيم الموجبة فى كل من صفات ارتفاع النبات و عدد الأوراق و القرون لكل نبات ، و الصنف ماستر (P_1) أظهر قدرة ائتلافية عامة موجبة وعالية لصفات وزن البذور للقرن ، عدد البذور بالقرن ، طول وعرض القرن ، كما تميز الصنفان الأبويان لتل مارفل (P_2) و لنكولن (P_3) بقدرة تآلف موجبة عالية لصفات وزن القرن و عدد الأفرع للنبات على التوالى. أظهرت النتائج أيضا أن أفضل توليفة للهجن و التى تعكس أعلى قيمة موجبة للقدرة الخاصة على التآلف ، كانت للجيل الهجينى الأول $P_3 \times P_4$ (لصفة ارتفاع النبات) و $P_1 \times P_2$ (لعدد الأوراق و طول القرن) $P_1 X P_3$ (لعدد الفروع للنبات) و $P_1 \times P_4$ (لوزن القرن للنبات و متوسط وزن القرن) و $P_2 \times P_5$ (لعدد القرون للنبات) و$P_1 \times P_5$ (لوزن البذور فى القرن) و $P_2 \times P_4$ (لعدد البذور فى القرن). أظهرت النتائج أيضا أن بعض الصفات قد تأثرت فى حالات قليلة جدا بالتهجينات العكسية ، حيث تميز الجيل الأول للهجين العكسى $P_3 \times P_1$ (لصفة ارتفاع النبات) والهجين العكسى $P_4 \times P_2$ (لصفة عرض القرن) عن باقى الهجن ، مما يعكس وجود بعض التأثيرات الأمية بدرجة قليلة على هاتين الصفتين وفى الهجينين المذكورين فقط.