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GENETIC STUDIES ON GROWTH, EARLINESS YIELD AND ITS COMPONENTS, AND SEED QUALITY IN BROAD BEAN (*Vicia faba* L.)

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ABSTRACT

A 4 x 4 diallel cross with reciprocals was performed among four cultivars of broad bean (*Vicia faba,* L.), i.e., two Spanish cultivars named Luz de otono and Reina mora, one local cultivar called Giza planka, and a selected line, cv. (Sabaaty). The four parents and their 12 F_1 hybrids and reciprocal crosses were evaluated in a field experiment designed in a randomized complete block with 3 replicates. This investigation was carried out during the winter seasons of 2005/2006, 2006/2007 and 2007/2008 under field conditions at Sabaheya Horticultural Research Station, Alexandria Governorate, Egypt. The main objectives were to evaluate the average degree of heterosis in the crosses in addition to the estimation of combining ability and its components.

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 F1 hybrid populations were either more than their mid-or high- parental values for total yield and all its components characters. Positive heterosis estimates, relative to mid-parents, were detected in most of the F1 hybrids for vegetative growth characters. Concerning total yield and its components, positive heterotic effects were noticed on most of the first hybrid generations, including reciprocals. The results indicated also that both general combining ability G.C.A. (additive effects) and specific combining ability 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. The results indicated also that the parental cultivar Reina mora (P1) could be considered as a good general combiner for breeding to earliness, vegetative characters and yield and its components. The combinations of P1 X P2, P1 X P3, and P2 X P3 exhibited significant positive values for the most characters of vegetative growth, yield and its components. Correlation values among pairs of characters exhibited that number of pods/plant and pod weight should to be the first concern for improving yield of faba bean.

INTRODUCTION

Broad bean **(***Vicia faba,* L.) is the most important leguminous seed crop in Egypt which it is inexpensive source of protein with high calories and nutritive value (Mahmoud, 1986; Radwan and Wafaa, 2005). The total production in Egypt is still below the demand. To meet the national requirement of this crop, both of the area devoted could be increased and the high yielding cultivars can be planted. Since the cultivated area in Egypt is limited, and to achieve abundant yield, the use of high yielding cultivars and good agricultural practices are recommended.

Heterosis is a great importance to be employed in plant breeding to obtain high yielding genotypes. Recently, much interest has developed in producing growing F1 hybrids of several normally self-pollinated species, where a considerable amount of F1 yield heterosis had been demonstrated. Accordingly, hoterosis on the F1 hybrids were detected on some important characters of faba bean by several researchers (Bond, 1988; Ebmeyer, 1988; El-Refaey *et al.*., 2006; Filippetti *et al.*., 2008) .

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. Such information may assist the plant breeders to chose the efficient breeding methods for improving faba bean. Many researchers used diallel crossing system in faba bean for estimating different genetic parameters (El-Hosary; 1984; Radwan and Darwish, 1989; El-Refaey *et al.*., 2006; Filippetti *et al.*., 2008)

Information about the types and importance of gene action effects, controlling the total yield and its related characters, as an important purpose for improving faba bean, were studied by several investigators; such as (Radwan and Darwish, 1989; El-Refaey *et al.*., 2006; Filippetti *et al.*., 2008). They mentioned that both additive and non-additive gene effects were important in the genetic expression of most studied characters of faba bean.

Since genotypic and environmental factors are components determining yield and quality in plants, a primary aim should be the determination of effect of genotypic factors in selection. As the effect of environment on yield and quality in plants is not hereditable, effects of genotypic factors on yield and quality in plant breeding research need to be examined. When studying with correlations it is of prime importance to recognize the nature of the population under consideration (Dewey and Lu, 1959). In addition, simple correlation does not consider the complex relationship between the various characters related the dependent variables (Mebrahtu *et al.*, 1991). Correlation coefficients show relationships among independent variables and the linear relationship between these variables. But, reasons of the path analysis usage are different. They could be mentioned as follow (Ariena *et al.*, 1986); 1) To indicate the relative importance of certain factors contributing to yield reduction by any factor; 2) to unravel opposing effects between variables along different paths of influence, which may obscure the importance of certain factors along those pads, and; 3) to determine which variables need to be measured to enable faba bean`s biological yield.

Therefore, this investigation was undertaken to: 1) evaluate the general performances of four parental faba bean cultivars and all their possible F1 hybrids; 2) calculate the amount of heterosis for some of faba bean traits; 3) obtain estimates for general and specific combining ability, and the reciprocal effects; and 4) estimate the direct and indirect effects of some characters related to seed production, which would be helpful to plan an appropriate selection program.

MATERIALS AND METHODS

The present investigation was carried out during the winter seasons of 2005/2006, 2006/2007 and 2007/2008 under field conditions at Sabaheya Horticultural Research Station, Alexandria Governorate, Egypt. Plant materials for this study consisted of four cultivars of broad bean (*Vicia faba,* L.), i.e., two Spanish cultivars named Reina mora (P1) and Luz de otono (P2), one local cultivars called Giza planka (P3), and a selected line, Equadols cv. (Sabaaty) (P4), originated from selection and improving of broad bean which was obtained from the local market of Alexandria (Ragheb, 1994). All studied cultivars were selfed 3 times to get the homozygosity of its individuals. The color of mature seeds of all the studied genotypes are white except that of cultivar Reina mora are pink.

A diallel cross with reciprocals was made among the 4 parental cultivars to give 12 F_1 hybrid combinations. The production of hybrids and selfed seeds were obtained in the winter season of 2005/2006 by the technique of pollination as, principally, described by Bhandari (1979). Seeds of the 4 parental cultivars and 6 F_1 hybrids and 6 F_1 reciprocal crosses (from the 4 × 4 full diallel cross) were planted in November 5th during 2006/2007 and 2007/2008 winter seasons. A randomized complete blocks design with 3 replicates was used in this study. Each entry was planted in a single row plot, 4m long and 0.7 m wide. The seeds were planted in hills spaced 40 cm apart at the rate of 1 seed per hill. The 16 entries were, randomly, distributed on the 16 ridges in each replicate. The other normal agricultural practices for faba bean production, i.e., irrigation, fertilization, weeds and pests control were practiced as recommended in the district.

Recorded measurements

Flowering date and fruiting date were determined as the number of days from planting to the first flower opening and fruiting set, respectively. Also, Height of 1st both of flowering node and pod were measured in centimeter. These trait were counted as the mean of 10 plants per entry.

The following growth attributes were measured, 95 days after sowing, using ten random plants from each entry; plant height (cm), number of branches / plant, weight of fresh pods / plant (g). Thirty random fresh pods were used from each entry to measure pod length (cm), width (cm), and weight.

At harvest, on mid May, samples of ten random plants were used, from each entry to record number of seeds/pod, and total seed yield g/plant. Three random samples, 100 seeds each, were used from each entry for calculating weight of 100 seeds (in gram)

Statistical analysis

The collected data were initially, analyzed separately for each experiment, then combined across the experiments after using Bartlelt's test for homogeneity of the variance (Snedecor and Cochran, 1980). In this analysis; genotypes were assumed to be fixed and replicates and seasons assumed to be random.

The average degree of heterosis (ADH%): was calculated as percentage of increase or decrease of the F_1 performance above the mid parent (MP) value and the high parent (HP) value (Sinha and Khanna, 1975).

$$\textbf{ADH\% (in relation to M.P)} = \frac{F_1 - MP}{MP} \times 100$$

$$\textbf{ADH\% (in relation to H.P)} = \frac{F_1 - HP}{HP} \times 100$$

Potence ratio (P.R) was calculated by using the following formula :

$$PR = \frac{F_1 - MP}{{}^1/_2\,(P_2 - P_1)} \times 100$$

where, P_2 and P_1 the highest and the lowest parents, in succession.

The combining ability of the 4 parents and their 12 F_1 hybrids were studied using the diallel analysis, which was computed for all crosses according to Griffing's (1956) model two of method one which depends on the use of parents, F1's and their reciprocals to partition the variation among genotypes into general combining ability (GCA) and specific combining ability (SCA) and reciprocal effects (R.E). Diallel cross analysis of the two experiments were carried out; whenever, homogeneity of variance was detected. This model was considered as an appropriate because the parents were detected on the basis of their characters, so it could not be considered as a random sample of some population and in model 1 all effects are fixed.

Simple correlation coefficients (r) were calculated for different pairs of the studied characters as shown by Dospekhove (1984). Path-coefficient was calculated as described by Dewey and Lu (1959). In the path diagram (Figure 1), the doubled-arrowed lines indicate mutual association as measured by correlation coefficients r_{ij} the single arrowed lines represent direct influence as measured by path-coefficient Pix, and h represents residual factors.

Each normal equation represents a partitioning of correlation coefficient of a predictor variable with the response variable into the component terms, the direct effect or path coefficient for that predictor variable and two indirect effects, each involves the product of a correlation coefficient between two predictor variables and the appropriate path coefficient in accordance with the path diagram.

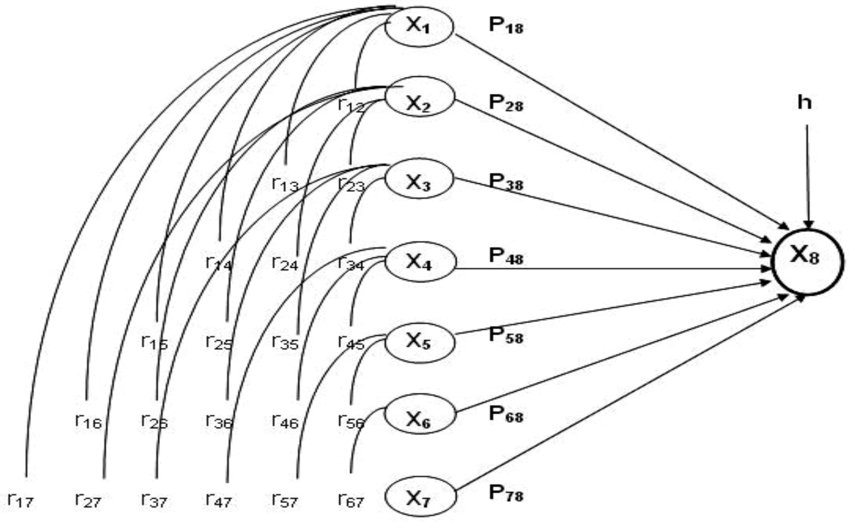

Fig. 1: Path diagram with 7 predictor variables "X_1" to "X_7" and the response variable X_8. The variable "h" is the remainder portion or residual. $(1-R^2)^{½}$

$$P_{18} + r_{12} P_{28} + r_{13} P_{38} + r_{14} P_{48} + r_{15} P_{58} + r_{16} P_{68} + r_{17} P_{78} = r_{18} \quad (1)$$
$$r_{21} P_{18} + P_{28} + r_{23} P_{38} + r_{24} P_{48} + r_{25} P_{58} + r_{26} P_{68} + r_{27} P_{78} = r_{28} \quad (2)$$
$$r_{31} P_{18} + r_{32} P_{28} + P_{38} + r_{34} P_{48} + r_{35} P_{58} + r_{36} P_{68} + r_{37} P_{78} = r_{38} \quad (3)$$
$$r_{41} P_{18} + r_{42} P_{28} + r_{43} P_{38} + P_{48} + r_{45} P_{58} + r_{46} P_{68} + r_{47} P_{78} = r_{48} \quad (4)$$
$$r_{51} P_{18} + r_{52} P_{28} + r_{53} P_{38} + r_{54} P_{48} + P_{58} + r_{56} P_{68} + r_{57} P_{78} = r_{58} \quad (5)$$
$$r_{61} P_{18} + r_{62} P_{28} + r_{63} P_{38} + r_{64} P_{48} + r_{65} P_{58} + P_{68} + r_{67} P_{78} = r_{68} \quad (6)$$
$$r_{71} P_{18} + r_{72} P_{28} + r_{73} P_{38} + r_{74} P_{48} + r_{75} P_{58} + r_{76} P_{68} + P_{78} = r_{78} \quad (7)$$

RESULTS AND DISCUSSION

1. Mean performance

Hybrid P1 × P2 and reciprocal cross P2 × P1 were the earliest genotypes for both of flowering and fruiting set dates. They, also, gave the highest numbers for both of branches and pods/plant (Table 1). There were no significant differences between these crosses and parent P1 (Reina mora cv.) with respect to fruiting set date. Moreover, this parent (P1) had the shortest heights of 1st both of flowering node and pod; meanwhile, it gave the tallest plants. Hybrid P3 × P4 and reciprocal cross P4 × P3 do not differ significantly from parent P1 with regard to height of 1st pod. On the other hand, the highest mean values for plant yield (fresh pods), pod weight, pod width, and plant yield (dry seeds) were obtained by both of hybrid P1 × P3 and reciprocal cross P3 × P1, There were no significant differences between them and the genotypes P2 × P3 and P3 × P2 concerning pod weight; and the genotypes P3 × P4 and P4 × P3 regarding pod width; and the genotypes P1 × P4 and P4 × P1 with respect to plant yield (dry seeds). The latest genotypes had the lengthiest pods. Hybrid P2 × P4 and reciprocal cross P4 × P2 gave the highest mean value for weight of 100 seeds (Table 1).

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2. Heterosis

Regarding flowering date, hybrid P1 × P2 and reciprocal cross P2 × P1 gave high negative heterosis values relative to mid parent and high parent (Table 2). This result suggested an over dominance to the earliest parent. The obtained potence ratio value supported the postulated hypothesis. On the other hand, the same combination had high positive heterosis values to mid parent and high parent for number of branches / plant. The results illustrated, also, that the heterosis percentages of earliness characters were positive in most of the F1 hybrid populations. Such positive is undesirable heterotic effects.

The results presented in Table (3) indicated generally that desirable and positive heterotic effects, relative to both mid-and high-parents were reflected on all the F1 hybrids and their reciprocals for yield and its components, with just few exceptions.

Table 3: Estimates of heterosis (ADH%) based on mid parents (MP) and high parent (HP) and potence ratio for yield and its components of faba bean, combined data over the two seasons, 2006/2007 and 2007/2008

Population	Yield and its components											
	Plant yield (fresh pods)			No. of pods/plant			No. of seeds/pod			Pod weight		
	ADH%		Potence ratio	ADH%		Potence ratio	ADH%		Potence ratio	ADH%		Potence ratio
	MP	HP		MP	HP		MP	HP		MP	HP	
P1XP2	50.29	48.06	4.85	87.63	61.06	5.31	-0.38	-0.51	-3.00	-22.65	-34.30	-1.28
P1XP3	80.03	54.56	33.46	25.10	10.96	1.97	0.90	0.26	-1.40	44.67	39.41	11.84
P1XP4	62.33	53.49	-10.82	67.37	40.71	-3.56	-2.40	-1.28	-2.11	-5.65	-16.54	-0.43
P3XP2	60.92	39.91	4.06	26.87	-1.37	0.94	0.77	0.26	1.50	21.77	6.78	1.55
P4XP2	26.19	17.65	3.61	26.58	23.46	10.50	0.51	-0.75	0.40	-0.59	-5.13	-0.12
P3XP4	47.18	20.60	2.14	48.88	13.70	1.58	0.76	-1.00	0.43	-3.72	-11.93	-0.40
P2XP1	50.99	48.76	-4.88	86.03	59.69	5.22	-0.36	-0.49	-2.83	-22.39	-34.07	1.26
P3XP1	80.52	54.97	33.92	25.35	11.19	-1.99	0.13	-0.51	0.20	45.07	39.79	-11.95
P4XP1	60.52	51.77	10.50	66.78	40.22	3.52	-2.30	-1.18	2.02	-6.19	-17.02	0.47
P3XP2	61.80	40.67	-4.11	25.60	-2.36	-0.89	1.52	1.00	2.96	22.69	7.58	1.62
P4XP2	28.04	19.37	3.86	27.29	24.14	10.78	0.32	-0.94	-0.25	-0.58	-5.12	-0.12
P4XP3	46.76	20.25	2.12	47.58	12.71	1.54	0.66	-1.10	-0.37	-4.42	-12.57	0.47

Population	Pod length			Pod width			Plant yield (dry seeds)			weight of 100 seeds		
	ADH%		Potence ratio	ADH%		Potence ratio	ADH%		Potence ratio	ADH%		Potence ratio
	MP	HP		MP	HP		MP	HP		MP	HP	
P1XP2	35.30	26.51	5.08	-10.83	-5.28	1.85	45.54	13.85	1.64	-15.45	-24.78	-1.25
P1XP3	13.44	13.25	81.13	24.26	27.55	-9.43	29.67	23.31	5.75	4.82	-2.46	0.65
P1XP4	33.73	16.37	2.26	-8.73	-6.32	3.39	52.01	38.71	5.42	-3.75	-10.60	-0.49
P3XP2	15.47	8.13	2.28	-9.62	-12.50	-2.92	0.45	-24.21	0.01	-14.68	-18.73	-2.95
P4XP2	19.73	10.81	2.45	1.21	-2.01	0.37	56.69	31.95	3.02	27.40	6.29	1.38
P3XP4	-24.79	-34.46	-1.68	19.44	19.44	—	35.88	18.49	2.44	-10.40	-22.11	-0.69
P2XP1	35.45	26.65	-5.10	-10.70	-5.14	1.83	44.97	13.40	1.62	-14.96	-24.34	-1.21
P3XP1	13.32	13.14	-80.41	24.63	27.92	-9.57	30.04	23.66	-5.82	4.93	-2.36	0.66
P4XP1	33.66	16.31	-2.26	-8.51	-6.10	3.31	51.80	38.51	5.40	-3.66	-10.50	0.48
P3XP2	15.56	8.22	2.29	-10.27	-13.13	-3.12	0.37	-24.26	-0.01	-14.40	-18.45	2.90
P4XP2	19.80	10.87	-2.46	1.42	-1.81	0.43	57.04	32.25	-3.04	27.53	6.40	-1.39
P4XP3	-24.86	-34.52	1.69	18.86	18.86	—	34.99	17.71	2.38	-10.31	-22.03	0.69

Concerning plant yield (fresh pods), all the F1 populations showed positive heterosis estimates based on mid- and high-parental values. The combinations P1 X P3 and P3 X P1 displayed over dominance because they gave highly positive heterosis over mid and high parents, with relatively high potence ratio. The results illustrated also that, in general, the F1 hybrids reflected positive (desirable) values, relative to mid parents; for number of pods/plant and plant yield (dry seeds). Most of the rest of traits gave negative and undesirable heterosis percentages, relative to the high-parents, in most of the F1 hybrid populations. 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. In this respect, Stelling (1997) reported that, in fresh yield, F1hybrids showed 21 to 54% advantage over the higher yielding parent. Similar results were obtained by Link *et al.*. (1994) and Bond (1988).

3. Mean squares and combining ability

3.1. Mean squares

Data in Table (4) show that mean squares were significant and highly significant for pod length and plant yield (dry seeds), respectively, indicating differences between two seasons concerning those traits only. Significant genotypes' mean squares were detected for all traits. Significant genotype differences by season interaction mean squares were obtained for flowering date, fruiting set date, plant yield (fresh pods and dry seeds), and weight of 100 seeds. Such results indicated that the tested genotypes varied from each other and ranked differently from season to another regarding these traits. The parental cultivars, also, were significantly different in all traits, except number of branches/ plant, number of seeds/pod, and pod width, indicating the wide diversity between the parental materials used in this study. Crosses' mean squares were found herein to be significant in all studied traits except number of seeds/pod. Mean squares for parents *versus* crosses and parents *versus* crosses by season as indicator for average heterosis overall crosses were significant for all studied traits. In this regard, El-Refaey *et al.*., (2006) reported that mean squares of parents vs. crosses were highly significant for all traits under both planting densities except number of seeds / pod. El-Hosary (1984) found that significant years means squares were detected for all traits number of seeds / pod. Mean squares for genotypes, parents and hybrids were highly significant for all traits. Significant parents vs. hybrids mean squares were shown for all traits.

The estimate variances for the effects of both general and specific combining abilities reflected highly significant values for all studied traits (Table 5). This result suggested generally that both additive and non-additive gene effects were important in controlling the expression of all studied traits. Also, the results illustrated generally that the mean squares estimates of specific combining ability (S.C.A.) showed higher values than those of general combining ability (G.C.A.) (ratio of GCA/SCA was greater than the unity) for most studied traits, suggesting that the non-additive gene effects appeared to have, relatively, more important roles than additive gene effects (Swamy Rao, 19770.

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Concerning the reciprocal effects, the estimates of mean squares were not found significant. Such a result suggested that reciprocal effects were generally lacking. These results are in agreement with obtained by El-Refaey *et al.*., (2006).

3.2. General and specific combining abilities effects

The parent P1 (Reina mora cv.) showed significant negative general combining ability effects (GCA) for flowering date, height of 1st flowering node, and fruiting set date (Table 6). This finding indicates that this parent possessed genes for few number of days to first flower anthesis and early fruiting set; therefore the parent P1 may be considered the best combiner for breeding to earliness characters following by P2 (Luz de otono cv.). On the other extreme, significant positive GCA effects were shown by the parent P4 (Equadols cv.), which suggested that, this parent was the worst for earliness characters following by P3 (Giza planka cv.). Regarding specific combining ability effects (SCA), the cross of P1 x P2 had highly significant negative sca for flowering date, fruiting set date, and height of 1st pod as shown in (Table 7). This result indicated that this hybrid was a good combination for these characters. On the other hand, the best general combiner parent that appeared to have the significant highest positive value of GCA was found to be P1 for plant height, number of branches / plant, number of pods/plant, pod length, and plant yield (dry seeds). The results in Table (6) illustrated, also, that the parent (P3) appeared to be a good combiner for number of branches / plant, plant yield (fresh pods), number of pods/plant, pod length, pod width, and weight of 100 seeds. The combinations of P1 X P2, P1 X P3, and P2 X P3 exhibited significant positive values for the most characters of vegetative growth, yield and its components as shown in Table (7). These finding suggesting that these combination were the best hybrids for vegetative characters, yield and its components. 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 hybrid. However, it showed be mentioned that the parents with good GCA do not necessarily produce superior crosses with good SCA in all combinations, Swamy Rao (1977). Significant correlation coefficient values between the parental performance and its GCA effects were obtained for early flowering dates fruiting set date, height of 1st pod, plant yield (fresh pods), and weight of 100 seeds (Table 6). This finding indicated that the intrinsic performance of parental inbred lines gave a good index of their general combining ability effects. Therefore, selection with the tested parental inbred lines for initiating any proposed breeding program could be practiced either on mean performance or GCA effects basis with similar efficiency, as reported by Abdel-Sattar *et al.*. (1999) and El-Hosary *et al.*. (1999).

4. Correlation and path coefficient analysis:

4.1. Correlation coefficient analysis:

Correlation values among pairs of characters for all cross combinations are illustrated in Table 8. There are significant positive correlation among flowering date, height of 1st flowering node, fruiting set date, and height of 1st pod.

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On the other hand, both of plant height and No. of branches / plant exhibited significant negative correlation with flowering date, height of 1st flowering node, and fruiting set date. Meanwhile, height of 1st pod exhibited significant negative correlation with number of branches / plant and number of pods/ plant, and positive correlation with pod weight, length, width, and weight of 100 seeds. Plant height showed positive correlation with number of branches / plant, number of pods/ plant and plant yield (dry seeds), and negative correlation with number of seeds/pod, pod weight and width. Plant yield (fresh pods) exhibited significant positive correlation with height of 1st flowering node, number of pods/ plant, pod weight, pod width, and plant yield (dry seeds) and negative correlation with number of seeds/pod, weight of 100 seeds. However, plant yield (dry seeds) showed positive correlation with all the studied traits except of height of 1st flowering node, number of seeds/pod and pod weight which were negative correlated, but pod length were not correlated. These findings may suggest that number of pods/plant and pod weight showed to be the first concern for improving yield of faba bean. In this regard, Ulukan *et al.*. (2003) stated that negative and significant relationships were determinate statistically between pod length and plant height, between first pod height and plant height; between pod number/ plant and plant height; between pod number and 1st pod height; between grain number and first pod height; between biological yield and pod length; between biological yield and first pod height. Similar results were obtained by Kuraczyk *et al.*. (1989), Katiyar and Singh (1990), Singh (1994), and Gyanendra *et al.*. (1993).

4.2. Path coefficient analysis:

It could be noted that, from Table 9, the direct effect of fruiting set date, plant height, number of branches / plant, number of pods/ plant and pod width seemed to be close to correlations between them and seed yield, so, it may indicate a true relationship and direct selection through these traits may be effective for improving seed yield of faba bean. It worth mentioning that the residual effect for seed yield/plot was low.

Table 9: Direct effects (Diagonal, under line) and indirect effects of some studied traits on seed yield of faba bean genotypes.

Character	Fruiting set date	Plant height	No. of branches / plant	No. of pods/ plant	No. of seeds/pod	Pod weight	Pod width	Total effect
Fruiting set date	<u>0.808</u>	-0.450	-0.165	-0.045	0.095	0.030	0.092	0.365
Plant height	-0.440	<u>0.827</u>	0.202	0.193	-0.221	-0.095	-0.132	0.334
No. of branches/plant	-0.382	0.477	<u>0.349</u>	0.220	-0.148	-0.127	-0.186	0.203
No. of pods/ plant	-0.071	0.312	0.150	<u>0.512</u>	-0.152	-0.063	0.000	0.688
No. of seeds/pod	0.250	-0.596	-0.168	-0.254	<u>0.307</u>	0.059	0.142	-0.262
Pod weight	0.139	-0.452	-0.255	-0.185	0.104	<u>0.173</u>	0.149	-0.327
Pod width	0.205	-0.300	-0.179	0.000	0.120	0.071	<u>0.363</u>	0.280

R = 0.202

Such result indicated that this character may depend on the most of the studied traits, so, it may not be needed to investigate more attributes affecting seed yield in faba bean. Ulukan *et al.*. (2003) reported that grain number pod could be a useful selection criteria because jointed or bilateral relations with this character has been given almost biggest value. Kuraczyk *et al.*. (1989) indicated that seed yield structure was studied by path analysis of 18 yield characteristics of faba bean varieties, number of pods/ plant and number of seeds from the main stem in var. major had the most significant effect on seed yield. Katiyar and Singh (1990) stated that in 40 indigenious and exotic strains positive and significant association among grain yield and number of pods/ plant.

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دراسات وراثية على النمو والتبكير والمحصول ومكوناته وجودة البذور فى الفول الرومى

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أجرى تهجين اليلى (٤ × ٤) مع الهجن العكسية بين أربعة أصناف من الفول ؛ هى : صنفان أسبانيان Luz de otono ، و Reina mora وصنف محلى جيزة بلانكا وسلالة منتخبة من الصنف Equadols (السبعاتى) . وقد قيمت الآباء الأربعة مع للجيل الأول لـ ١٢ هجين والهجن العكسية فى تجربة قطاعات عشوائية كاملة بثلاث مكررات . وقد اجرى هذا البحث فى المواسم الشتوية لأعوام ٢٠٠٥/٢٠٠٦ ، ٢٠٠٦/٢٠٠٧ ،و ٢٠٠٧/٢٠٠٨ بمزرعة بحوث بساتين الصبحية بالإسكندرية، التابعة لمركز البحوث الزراعية. وقد كان الهدف الأساسى هو تقدير قوة الهجين فى الهجن ، بالاضافة الى القدرة على التآلف ومكوناتها.

وقد أوضحت النتائج أن الأصناف الأبوية المستخدمة تختلف فيما بينها فى معظم الصفات المدروسة ، وعكست معظم الهجن قيما أعلى لصفات النمو الخضرى من قيم الآباء . كما أظهرت النتائج أن قيم صفات المحصول ومكوناته لمعظم الهجن المتحصل عليها كانت أفضل من قيم متوسط الأبوين أو أعلى من أفضل الأبوين . أما بالنسبة لتقديرات قوة الهجين ؛ فقد أبرزت النتائج وجود تأثيرات موجبة مرغوبة فى رفع قيم الصفات المدروسة لمعظم الهجن وذلك على أساس متوسط الأبوين . أما بالنسبة لتأثيرات قوة الهجين على أساس أعلى الأبوين فقد عكست النتائج أيضا تأثيرات موجبة مرغوبة على سلوك معظم الهجن على صفات المحصول ومكوناته. أوضحت النتائج أيضا أن كل من تأثيرات القدرة العامة والخاصة على التآلف والتى تعكس أهمية كل من فعل الجين الاضافى واللاضافى ، قد اشتركت فى ميكانيكية توريث الصفات المدروسة، ولكن ظهر أن تأثيرات التفاعل الجينى اللاضافى قد لعبت دورا أكثر أهمية من دور التفاعلات الإضافية. وقد تميز الصنف Reina mora بقدرة عامة عالية على التآلف لمعظم الصفات المدروسة. كما أظهرت الهجن P1 X P2 ، P1 X P3 وP2 X P3 قيم عالية معنوية للقدرة الخاصة على التآلف لمعظم الصفات المدروسة. وقد أظهرتْ قيَم الارتباط بين كل زوجين من الصفات أنه يجب الاهتمام بصفتى عددِ القرون / النبات ، وزنَ القرن لتَحْسين محصولِ الفول .

Table 1: Mean performance of 12 F1 crosses and their parents for the studied traits of faba bean (combined analysis over the two seasons)

Population	Earliness characters				Vegetative characters		Yield and its components							
	Flowering date	Height of 1st flowering node (cm)	Fruiting set date	Height of 1st pod (cm)	Plant height (cm)	No. of branches / plant	Plant yield (fresh pods) (g)	No. of pods/ plant	No. of seeds/ pod	Pod weight (g)	Pod length (cm)	Pod width (cm)	Plant yield (dry seeds) (g)	Weight of 100 seeds (g)
P1	56.3	12.5	82.0	12.0	117.5	7.5	369.14	18.8	6.5	19.77	16.1	1.8	197.99	157.92
P2	57.2	14.8	86.2	16.3	98.2	7.3	380.40	13.5	6.5	28.28	18.5	2.0	111.76	123.09
P3	72.7	15.0	100.5	20.0	108.2	7.8	514.87	24.3	6.4	21.32	16.1	1.9	219.52	135.97
P4	73.8	28.2	100.5	21.7	95.3	5.8	328.91	12.8	6.7	25.70	21.7	1.9	163.33	184.09
P1 X P2	53.2	14.8	83.5	14.0	110.0	17.5	563.24	30.3	6.5	18.58	23.4	1.7	225.41	118.80
P1 X P3	66.3	18.3	93.5	22.0	106.7	6.0	795.76	27.0	6.5	29.72	18.3	2.3	270.70	154.03
P1 X P4	69.8	16.2	102.5	16.0	108.3	10.5	566.58	26.5	6.4	21.45	25.3	1.7	274.62	164.59
P2 X P3	70.7	24.0	94.5	16.0	97.5	3.8	720.34	24.0	6.5	30.20	20.0	1.7	166.39	110.51
P2 X P4	73.7	16.2	102.5	20.0	97.0	6.7	447.56	16.7	6.6	26.83	24.0	1.9	215.51	195.67
P3 X P4	75.5	21.3	102.5	13.0	95.5	5.5	620.93	27.7	6.6	22.63	14.2	2.2	260.11	143.38
P2 X P1	52.8	15.1	83.7	14.0	109.7	17.4	565.87	30.0	6.5	18.65	23.4	1.7	224.52	119.48
P3 X P1	66.5	18.6	93.5	22.0	106.9	5.9	797.89	27.1	6.5	29.80	18.2	2.3	271.45	154.19
P4 X P1	70.0	16.3	102.5	16.0	107.9	10.4	560.24	26.4	6.4	21.33	25.2	1.7	274.23	164.75
P3 X P2	70.8	24.1	94.5	16.0	97.4	3.9	724.29	23.8	6.6	30.43	20.0	1.7	166.26	110.88
P4 X P2	73.9	16.4	102.2	20.0	97.7	6.7	454.09	16.8	6.6	26.84	24.1	2.0	216.00	195.87
P4 X P3	75.7	21.5	102.8	13.0	95.5	5.4	619.15	27.5	6.6	22.47	14.2	2.2	258.40	143.53
L.S.D 5%	0.87	1.32	1.66	1.13	3.52	1.00	31.397	1.67	n.s	1.925	0.59	0.07	8.234	2.722
L.S.D 1%	1.15	1.75	2.20	1.51	4.67	1.33	41.740	2.22	n.s	2.560	0.78	0.09	10.946	3.619

Table 2: Estimates of heterosis (ADH%) based on mid parents (MP) and high parent (HP) and potence ratio for earliness and vegetative characters of faba bean, combined data over the two seasons, 2006/2007 and 2007/2008

Population	Earliness characters												Vegetative characters					
	Flowering date			Height of 1st flowering node			Fruiting set date			Height of 1st pod			Plant height			No. of branches / plant		
	ADH%		Potence ratio	ADH%		Potence ratio	ADH%		Potence ratio	ADH%		Potence ratio	ADH%		Potence ratio	ADH%		Potence ratio
	MP	HP		MP	HP		MP	HP		MP	HP		MP	HP		MP	HP	
P1 XP 2	-6.31	-7.00	8.60	8.54	18.67	-1.00	-0.69	1.83	0.28	-1.18	16.67	0.08	2.01	-6.38	0.22	135.96	133.33	121.00
P1 X P3	2.84	17.75	-0.22	33.33	46.67	-3.67	2.46	14.02	-0.24	37.50	83.33	-1.50	-5.47	-9.22	-1.32	-21.74	-23.40	-10.00
P1 X P4	7.30	23.96	-0.54	-20.49	29.33	0.53	12.32	25.00	-1.21	-4.95	33.33	0.17	1.80	-7.80	0.17	57.50	40.00	4.60
P3 X P2	8.86	23.62	-0.74	60.89	61.80	-109.00	1.24	9.67	-0.16	-11.93	-2.04	1.18	-5.49	-9.86	-1.13	-49.45	-51.06	-15.00
P4 X P2	12.47	28.86	-0.98	-24.81	8.99	0.80	9.81	18.96	-1.28	5.26	22.45	-0.37	0.26	-1.19	0.18	1.27	-9.09	0.11
P3 X P4	3.07	3.90	-3.86	-1.16	42.22	0.04	1.97	1.97	-397.00	-37.60	-35.00	9.40	-6.14	-11.71	-0.97	-19.51	-29.79	-1.33
P2 X P1	-6.58	-7.26	8.96	10.49	20.80	-1.23	-0.47	2.06	0.19	-1.18	16.67	0.08	1.70	-6.67	0.19	134.71	132.10	119.89
P3 X P1	2.96	17.88	-0.23	35.27	48.80	-3.88	1.79	13.28	-0.18	37.50	83.33	-1.50	-5.29	-9.05	-1.28	-22.67	-24.32	10.43
P4 X P1	6.96	23.57	-0.52	-19.84	30.40	0.51	12.30	24.98	-1.21	-4.95	33.33	0.17	1.42	-8.15	0.14	56.11	38.77	4.49
P3 X P2	8.94	23.71	-0.75	61.56	62.47	-110.20	1.20	9.63	-0.16	-11.93	-2.04	1.18	-5.58	-9.95	1.15	-47.95	-49.61	14.54
P4 X P2	12.75	29.19	-1.00	-23.72	10.56	0.76	9.51	18.63	-1.24	5.26	22.45	-0.37	0.65	-0.80	0.44	0.42	-9.85	0.04
P4 X P3	3.30	4.13	-4.14	-0.39	43.33	0.01	2.25	2.25	-452.56	-37.60	-35.00	9.40	-6.18	-11.74	-0.98	-24.21	-33.88	-1.65

Table 4: Mean squares and degree of freedom of 12 F1 crosses and their parents for the studied traits of faba bean (combined analysis over the two seasons, 2006/2007 and 2007/2008)

		Earliness characters				Vegetative characters		Yield and its components							
Source	d.f.	Flowering date	Height of 1st flowering node (cm)	Fruiting set date	Height of 1st pod (cm)	Plant height	No. of branches/ plant	Plant yield (fresh pods) (g)	No. of pods /plant	No. of seeds /pod	Pod weight (g)	Pod length (cm)	Pod width (cm)	Plant yield (dry seeds) (g)	weight of 100 seeds (g)
Seasons (S)	1	0.02	0.47	6.06	0.04	0.002	2.95	2198.4	10.91 *	0.003	0.76	1.13 *	0.001	521.9 **	4.7
Rep./S	4	0.38	2.96	1.84	2.09	15.4	1.77	2757.0	0.85	0.036	2.64	0.43	0.003	27.3	6.3
Genotypes (G)	15	384.75 **	111.01 **	362.38 **	71.29 **	292.93 **	102.37 **	127942.6 **	196.82 **	0.031	111.24 **	87.64 **	0.306 **	14195.0 **	4738.8 **
G×S	15	2.89 **	0.81	5.64 **	0.04	0.90	0.41	1604.3 *	2.43	0.044	0.80	0.35	0.004	290.3 **	14.6 **
Parents (P)	3	273.28 **	150.41 **	276.17 **	55.22 **	306.24 **	2.35	19574.0 **	86.19 **	0.029	46.08 **	21.15 **	0.024	6632.9 **	2146.0 **
Crosses (C)	11	650.17 **	123.51 **	582.51 **	123.76 **	415.87 **	251.08 **	153446.3 **	218.43 **	0.035	229.14 **	175.06 **	0.736 **	18155.4 **	9691.0 **
P vs C	1	953.70 **	276.07 **	908.74 **	180.28 **	738.54 *	257.35 **	319793.2 **	493.22 **	0.064	279.10 *	219.13 **	0.767 **	36706.8 **	11854.0 **
P vs C×S	1	1920.99 **	556.96 **	1846.57 **	361.78 **	1481.79 *	517.36 **	648232.7 **	1002.09 **	0.328	562.42 *	440.39 **	1.553 **	74992.2 **	23781.1 **
Error	62	0.56	1.31	2.06	0.96	9.28	0.76	740.1	2.09	0.048	2.78	0.26	0.004	50.9	5.56

***,** Significant differences at 5% and 1% levels of probability, respectively.**

Table 5: Mean squares and degree of freedom for general and specific combining abilities and reciprocal effects on the studied traits of the four parental cultivars and their 6 F1 crosses and 6 F1 reciprocals (combined analysis over the two seasons, 2006/2007 and 2007/2008).

		Earlness characters				Vegetative characters		Yield and its components							
Source	d.f.	Flowering date	Height of 1st flowering node (cm)	Fruiting set date	Height of 1st pod (cm)	Plant height	No. of branches/ plant	Plant yield (fresh pods) (g)	No. of pods/plant	No. of seeds/pod	Pod weight (g)	Pod length (cm)	Pod width (cm)	Plant yield (dry seeds) (g)	weight of 100 seeds (g)
GCA	3	265.27 **	41.18 **	236.67 **	5.60 **	212.55 **	32.69 **	44151.91 **	58.53 **	0.009	24.27 **	26.90 **	0.059 **	6254.32 **	2228.49 **
SCA	6	26.31 **	25.40 **	33.10 **	27.24 **	16.75 **	26.54 **	31214.60 **	52.92 **	0.006	34.37 **	23.07 **	0.098 **	2990.35 **	861.40 **
Reciprocal	6	0.01	0.02	0.02	0.005	0.06	0.004	8.31	0.02	0.0004	0.01	0.0001	0.00002	0.30	0.02
Error	30	0.19	0.44	0.69	0.32	3.09	0.25	246.69	0.70	0.02	0.93	0.09	0.001	16.97	1.85
GSA/SCA		10.08	1.62	7.15	0.21	12.69	1.23	1.41	1.11	1.500	0.71	1.17	0.596	2.09	2.59

**** Significant differences at 1% levels of probability, respectively.**

Table 6: Estimates of general combining ability effects (gca) of parents and correlation with mean performance for some traits of faba bean, combined analysis over the two seasons, 2006/2007 and 2007/2008.

	Earliness characters				Vegetative characters		Yield and its components							
Parents	Flowering date	Height of 1st flowering node (cm)	Fruiting set date	Height of 1st pod (cm)	Plant height	No. of branches / plant	Plant yield (fresh pods) (g)	No. of pods/ plant	No. of seeds /pod	Pod weight (g)	Pod length (cm)	Pod width (cm)	Plant yield (dry seeds) (g)	Weight of 100 seeds (g)
P1	-6.04 **	-2.81 *	-5.14 **	-0.97	7.52 **	2.36 **	9.10	2.31 *	-0.034	-2.24	-2.19 **	-0.064	23.06 **	0.40
P2	-3.70 **	-0.82	-3.70 *	-0.42	-2.41	0.84	-34.84	-2.25 *	0.010	1.39	-0.69	-0.068	-40.71 **	-11.39 **
P3	3.95 **	1.46	2.24 *	0.73	-1.07	-2.25 **	99.27 **	2.38 *	-0.017	1.36	2.04 **	0.114 *	8.62	-12.47 **
P4	5.80 **	2.17 *	6.60 **	0.67	-4.03	-0.96	-73.53 **	-2.44 *	0.041	-0.51	0.83 *	0.018	9.03	23.46 **
r	0.988 **	0.753	0.943 *	0.969 *	0.934	0.131	0.946 *	0.912	0.762	0.533	0.217	-0.109	0.858	0.959 **
L.S.D. for (gi)														
5%	0.386	0.591	0.741	0.506	1.572	0.450	14.043	0.746	0.113	0.861	0.263	0.033	3.683	1.217
1%	0.921	1.409	1.767	1.206	3.751	1.073	33.493	1.780	0.270	2.053	0.628	0.078	8.784	2.903
L.S.D. for (gi-gj)														
5%	0.631	0.965	1.210	0.826	2.568	0.735	22.931	1.219	0.185	1.405	0.430	0.053	6.014	1.988
1%	1.505	2.301	2.886	1.970	6.125	1.753	54.694	2.907	0.440	3.352	1.025	0.127	14.344	4.741

***,** Significant differences at 5% and 1% levels of probability, respectively.**
r = correlation coefficient between mean performance and general combining ability effects.

Table 7: Estimates of specific combining ability effects (sca) and reciprocal effects of 6 F_1 crosses and their 6 F_1 reciprocals for the studied traits of faba bean, combined analysis over the two seasons, 2006/2007 and 2007/2008.

Crosses	Earliness characters				Vegetative characters		Yield and its components							
	Flowering date	Height of 1st flowering node (cm)	Fruiting set date	Height of 1st pod (cm)	Plant height	No. of branches / plant	Plant yield (fresh pods) (g)	No. of pods/plant	No. of seeds/pod	Pod weight (g)	Pod length (cm)	Pod width (cm)	Plant yield (dry seeds) (g)	weight of 100 seeds (g)
P1XP2	-4.54 **	0.24	-2.96 **	-1.58 **	1.69	6.27 **	26.02	6.82 **	-0.011	-5.16 **	-3.08 **	-0.098 *	22.49 **	-18.54 **
P1XP3	1.09 *	1.46 *	0.44	5.29 **	-2.73	-2.12 **	123.84 **	-0.98	0.039	6.02 **	3.36 **	0.305 **	19.03 **	17.63 **
P1XP4	2.42 **	-1.48 *	5.63 **	-0.65	1.61	1.06 *	63.44 **	3.26 **	-0.090	-0.50	-0.55	-0.199 **	27.04 **	-7.74 **
P2XP3	3.07 **	5.05 **	0.55	-1.37 *	-2.10	-2.67 **	93.67 **	0.43	0.021	2.95 **	3.74 **	-0.217 **	-22.12 **	-13.97 **
P2XP4	4.28 **	-3.42 **	4.07 **	2.78 **	0.47	-1.27 *	-5.56	-1.93 *	0.034	1.34	-0.33	0.096 *	26.87 **	35.13 **
P3XP4	1.55 **	-0.58	-1.60	5.46 **	-2.45	0.44	30.37	4.28 **	-0.005	-2.94 **	1.02 **	0.182 **	21.24 **	-16.08 **
P2XP1	0.07	-0.11	-0.09	-0.03	0.17	0.05	-1.26	0.13	-0.005	-0.02	0.00	0.001	0.15	-0.16
P3XP1	-0.04	-0.12	0.06	-0.06	-0.12	0.05	-0.67	-0.03	0.023	-0.03	-0.01	-0.004	-0.44	-0.01
P4XP1	-0.06	-0.06	0.01	-0.06	0.20	0.05	3.34	0.05	-0.006	0.09	0.00	-0.002	0.07	-0.02
P3XP2	-0.03	-0.03	0.02	0.06	0.05	-0.04	-1.98	0.12	-0.020	-0.11	0.00	0.006	0.17	-0.15
P4XP2	-0.09	-0.11	0.14	-0.03	-0.31	-0.01	-2.73	-0.05	0.007	0.00	-0.01	-0.003	-0.10	-0.02
P4XP3	-0.08	-0.06	-0.14	0.06	0.02	0.04	0.60	0.12	0.007	0.10	-0.01	0.004	0.80	-0.01
L.S.D. for $(s_{ij}-s_{ik})$														
5%	0.823	1.259	1.579	1.078	3.351	0.959	29.925	1.590	0.241	1.834	0.561	0.070	7.848	2.594
1%	1.160	1.774	2.225	1.519	4.722	1.351	42.167	2.241	0.340	2.584	0.790	0.098	11.058	3.655
L.S.D. for $(s_{ij}-s_{kl})$														
5%	0.672	1.028	1.289	0.880	2.736	0.783	24.434	1.298	0.197	1.498	0.458	0.057	6.408	2.118
1%	0.947	1.449	1.816	1.240	3.855	1.103	34.429	1.830	0.277	2.110	0.645	0.080	9.029	2.984
L.S.D. for $(r_{ij}-r_{kl})$														
5%	0.951	1.454	1.823	1.245	3.869	1.107	34.554	1.836	0.278	2.118	0.648	0.080	9.062	2.995
1%	1.339	2.049	2.569	1.754	5.452	1.560	48.690	2.587	0.392	2.984	0.913	0.113	12.769	4.220

***,** Significant differences at 5% and 1% levels of probability, respectively.**
s_{ij}-s_{ik}; difference between two sca estimates, of two hybrids, with a common parent.
s_{ij}-s_{kl}; difference between two sca estimates, of two hybrids, with a non-common parent.
r_{ii}-r_{kl}; difference between two reciprocal estimates, of two hybrids, with a common parent.

Table 8: Correlation coefficient values (r) for pair of characters of the studied traits of faba bean (combined analysis over the two seasons)

	Flowering date	Height of 1st flowering node	Fruiting set date	Height of 1st pod	Plant height	No. of branches / plant	Plant yield (fresh pods)	No. of pods/ plant	No. of seeds/pod	Pod weight	Pod length	Pod width	Plant yield (dry seeds)
Height of 1st flowering node	0.568 **												
Fruiting set date	0.945 **	0.396 **											
Height of 1st pod	0.351 **	0.200 *	0.335 **										
Plant height	-0.647 **	-0.693 **	-0.544 **	-0.182									
No. of branches / plant	-0.694 **	-0.551 **	-0.472 **	-0.324 **	0.577 **								
Plant yield (fresh pods)	0.131	0.244 *	0.053	0.097	0.004	-0.167							
No. of pods/ plant	-0.162	-0.120	-0.088	-0.344 **	0.377 **	0.429 **	0.715 **						
No. of seeds/pod	0.456 **	0.595 **	0.309 **	0.165	-0.721 **	-0.482 **	-0.234 *	-0.497 **					
Pod weight	0.356 **	0.486 **	0.172	0.581 **	-0.547 **	-0.731 **	0.386 **	-0.361 **	0.339 **				
Pod length	-0.133	-0.160	0.065	0.199 *	0.113	0.489 **	-0.186	-0.077	-0.153	-0.092			
Pod width	0.345 **	0.182	0.253 *	0.326 **	-0.363 **	-0.514 **	0.321 **	0.001	0.390 **	0.411 **	-0.627 **		
Plant yield (dry seeds)	0.213 *	-0.207 *	0.365 **	0.022	0.334 **	0.203 *	0.466 **	0.688 **	-0.262 **	-0.327 **	0.035	0.280 **	
Weight of 100 seeds	0.445 **	-0.055	0.542 **	0.480 **	-0.105	-0.200 *	-0.416 **	-0.474 **	0.407 **	0.026	0.314 **	0.201 *	0.285 **

***,** Significant differences at 5% and 1% levels of probability, respectively.**