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HETEROSIS AND GENETIC VARIABILITY OF YIELD AND SOME RELATED COMPONENTS IN FABA BEAN USING SIX POPULATIONS MODEL

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ABSTRACT

The present investigation was carried out at Giza Research Station during the three successive seasons 2005/06,2006/07 and 2007/08 to determine the nature of gene action and relative magnitude of heterosis and inbreeding depression as well as heritability values of yield and some of its components. Three faba bean genotypes were crossed ,producing two main crosses (Giza 716 x Giza 843 and Nubaria 1 x Giza 843). Six populations: P_1, P_2, F_1, F_2, B_{C1} and B_{C2} for each cross were used. Heterosis, potence ratio and genetic advance under selection were estimated. Heterosis percentages were highly significant for most traits in Nubaria 1 x Giza 843 cross. Significant positive inbreeding depression values were observed for all studied traits. Potence ratios exceeded unity for number of pods, number of seeds/ plant in Giza 716 x Giza 843 cross indicating over dominance. On the other hand, the values of potence ratios were less than unity in other cases, indicating partial dominance.

The estimated values of additive variance (1/2 D) were higher than dominance variance (1/4 H) in the two crosses for all studied traits and revealed that both additive and dominance gene effects were important in the performance of these traits. High genetic advance was found to be associated with rather moderate heritability estimates for number of pods and seeds/plant and seed yield/plant as well as 100-seed weight. Therefore, selection for these traits in these populations should be effective and satisfactory for successful breeding purposes.

INTRODUCTION

Faba bean (*Vicia faba* L.) plays a great role in human nutrition as a major source of protein. The crop is generally included in the crop rotation to keep soil fertile and productive through nitrogen fixation. Faba bean is a partially cross-pollinated crop and displays a considerable amount of heterosis and inbreeding depression (Lawes *et al.*,1983). Hybrid vigor for seed yield is associated with manifestation of heterotic effects in main yield components, which might be reflected in yielding ability. Manifestations of heterotic effects in faba bean ranged from significantly negative to significantly positive estimates for yield and its components and was very pronounced in F_1 especially among widely divergent materials and less heterosis response occurred in hybrids between local varieties (Abdalla, 1977; Abdalla and Fischbeck, 1983; Abdalla *et al.*, 2001; and 2001 and Attia *et al.*, 2002 El-Hady *et al.*, 2006 2007 and 2008). Inbreeding depression not only reduces autofertility and hence yield in the absence of pollinators, but also reduces yield through the loss of heterosis. Poulsen (1979) stated that decrease in yield after three generations of selfing occurred due to inbreeding depression and reduced autofertility. He also added that inbreeding depression alone-reduced yield by 11%.Moreower, Abdalla, (1977 and 2001) Attia *et al.*, (2001) and El-Hady *et al.*, (2006 2008) reported that F_2's exhibited generally lower values than F_1's for most faba bean characters with high inbreeding depression.

The success of any breeding program depends upon the presence of sufficient genetic variability among genotypes under investigation to permit effective selection.

In a systematic breeding program, the genetic variance components analysis in terms of type of gene action, heritability and breeding potentials of genetic entries involved in this program are obviously essential. The low heritability and consequent limited genetic advance for yield in response to selection led many scientists to search for characters which are associated with yield which are relatively highly heritable. Bond (1966) reported that components of yield were general nearer to additivety than yield. Poulsen (1979) stated that although the major part of the variation in seed yield was detected as additive genetic variance and the dominance effects play also a considerable role in the inheritance of this trait. On the other hand, Darwish *et al.*, (2005); Attia and Salem, (2006) ; Attia *et al.*, (2006) ; Attia, (2007) and El-Hady *et al.*, (1997, 1998, 2007 and 2008) reported that non-additive effect was more important for number of branches, pods, seeds and seed yield/plant than additive. However, the additive variance was important for 100-seed weight and flowering date. Heritability values were estimated in faba bean using different materials and methods. Abdalla *et al.*, (1999); Abdalla *et al.*, (2001); Mansour *et al.*, (2001) ; Darwish *et al.*, (2005); Attia and Salem, (2006); Attia, (2007) and El-Hady *et al.*, (1997, 2006 , 2007 and 2008) reported that narrow sense heritability values were high for 100-seed weight, as well as flowering date, and low to moderate for seed yield along with number of branches, pods and seeds/plant.

The objective of the present investigation was to determine the nature of gene action, relative magnitude of heterosis and inbreeding depression, in addition to the estimation of heritability values of seed yield/plant along with five traits namely: plant height, number of branches, number of pods/plant, number of seeds/plant and 100-seed weight.

MATERIALS AND METHODS

The present investigation was carried out under insect free cage at Giza Research Station, ARC, Egypt during 2005/06,2006/07 and 2007/08 growing seasons, to study the mode of gene action and estimation of some genetic parameters such as heterosis, inbreeding depression and heritability percentages for seed yield/plant (g) and some of its components. Three faba bean genotypes : Giza 716, Nubaria 1 and Giza 843 were used as parental genotypes. The origin and some important characters of faba bean parental genotypes are shown in Table 1. These genotypes were planted and crossed under screen houses during 2005/06 season to obtain the F_1's seeds of each two crosses (Giza 716 x Giza 843 and Nubaria 1 x Giza 843) .The F_1 plants were selfed and backcrossed to each corresponding parent in 2006/o7 season to produce B_{C1} (F_1 xP_1)and B_{C2} (F_1 x P_2) generations. The six populations of the two crosses P_1, P_2, F_1, F_2, B_{C1} and B_{C2}; were planted in rows (2 m long, 45 cm apart) under screen house at Giza Research Station during 2007/08 season. Seeds were located in single seeded hills; spaced at 20 cm. The parents and F_1's were planted in four ridges each; F_2's in twenty ridges and back crosses in fifteen ridges. A randomized complete block design with 3 replicates was used. Recommended agricultural practices were followed. Data were recorded for all guarded plants: plant height (cm), number of branches/plant, number of pods, seeds, seed yield/plant and 100-seed weight.

Table 1 : Origin and some characteristics of the three faba bean parents

Genotype	Origin	Characters
Giza 716	**FCRI*, ARC, Egypt**	**Early maturing and resistant to foliar diseases**
Nubaria 1	**FCRI, ARC, Egypt**	**Recommended for planting in newly reclaimed lands at Nubaria, large seeded type, and resistant to foliar diseases.**
Giza 843	**FCRI, ARC, Egypt**	**Resistant to *Orobanche***

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All genetic analysis was made using means and variances of six populations. A, B, C and D scaling test of Mather (1949) was used to test the adequacy of the additive-dominance model and to study the non-allelic interaction. Gamble (1962) model was used to separate the epistatic variation. Heterosis, potence ratio and genetic advance under selection were also estimated according to Johnson (1955).

RESULTS AND DISCUSSION

Number of plants, population mean, variance, mean variance and coefficient of variation of parents, F_1's, F_2's and backcrosses for different characters are presented in Table 2.

Table 2: Number of plants (No), population mean ($\bar{X}$), variance (S^2), mean variance (S^2_x) and coefficient of variation (C.V. %) for the six population of the two crosses Giza 716 x Giza 843and Nubaria 1 x Giza 843 among different traits.

Trait	Cross		P_1	P_2	F_1	F_2	BC_1	BC_2
Plant height(cm)	Giza 716 x Giza 843	No	40	40	40	250	150	150
		$\bar{X}$	105.40	116.00	116.60	105.80	99.00	122.20
		S^2	52.30	17.90	9.80	110.30	49.00	106.70
		S^2_x	1.30	0.40	0.20	0.40	0.30	0.70
		C.V.%	6.90	3.70	2.70	9.90	7.10	8.50
	Nubaria 1 x Giza 843	No	40	40	40	250	150	150
		$\bar{X}$	101.10	116.00	126.20	115.40	111.40	116.50
		S^2	14.20	17.90	13.60	39.10	30.70	24.30
		S^2_x	0.40	0.40	0.30	0.20	0.20	0.20
		C.V.%	3.70	3.70	2.90	5.40	5.00	4.20
N. of branches/ plant	Giza 716 x Giza 843	No	40	40	40	250	150	150
		$\bar{X}$	3.90	2.73	3.33	3.00	3.57	3.93
		S^2	0.05	0.01	0.02	0.25	0.12	0.20
		S^2_x	0.00	0.00	0.00	0.00	0.00	0.00
		C.V.%	6.00	3.01	3.57	17.24	8.59	17.85
	Nubaria 1 x Giza 843	No	40	40	40	250	150	150
		$\bar{X}$	6.50	2.73	6.17	3.27	3.97	4.20
		S^2	0.04	0.01	0.04	0.30	0.25	0.25
		S^2_x	0.00	0.06	0.08	0.31	0.15	0.54
		C.V.%	3.10	3.01	3.57	17.24	8.59	17.85
N. of pods/ plant	Giza 716 x Giza 843	No	40	40	40	250	150	150
		$\bar{X}$	11.40	9.83	20.87	10.67	15.67	14.60
		S^2	4.24	0.34	1.21	5.76	3.80	4.27
		S^2_x	0.11	0.01	0.02	0.02	0.03	0.03
		C.V.%	18.10	3.01	3.57	17.24	8.59	17.85
	Nubaria 1 x Giza 843	No	40	40	40	250	150	150
		$\bar{X}$	13.70	9.83	14.03	9.57	11.67	15.90
		S^2	0.82	0.34	0.50	5.30	3.05	4.81
		S^2_x	0.02	0.06	0.08	0.31	0.15	0.54
		C.V.%	6.60	3.01	3.57	17.24	8.59	17.85

Table 2 : Cont

rait	Cross		P1	P2	F1	F2	BC1	BC2
N. of seeds/plant	Giza 716 x Giza 843	No	40	40	40	250	150	150
		X	33.47	30.27	47.97	23.87	36.03	33.60
		S^2	6.08	4.21	6.52	26.09	20.25	22.63
		S^2_x	0.15	0.11	0.13	0.10	0.14	0.15
		C.V.%	7.37	6.78	5.32	21.40	12.49	14.16
	Nubaria 1 x Giza 843	No	40	40	40	250	150	150
		X	41.30	30.27	47.33	27.73	39.27	45.07
		S^2	6.92	4.21	7.86	40.92	29.21	25.01
		S^2_x	0.17	0.06	0.08	0.31	0.15	0.54
		C.V.%	6.40	3.01	3.57	17.24	8.59	17.85
seed yield/plant(g)	Giza 716 x Giza 843	No	40	40	40	250	150	150
		X	29.00	23.30	36.00	18.43	27.03	25.23
		S^2	12.89	3.31	3.81	17.20	11.56	12.70
		S^2_x	0.32	0.08	0.08	0.07	0.08	0.08
		C.V.%	12.40	3.01	3.57	17.24	8.59	17.85
	Nubaria 1 x Giza 843	No	40	40	40	250	150	150
		X	48.10	23.30	47.37	25.00	35.10	54.33
		S^2	8.68	3.31	6.16	38.23	34.69	19.94
		S^2_x	0.22	0.06	0.08	0.31	0.15	0.54
		C.V.%	6.10	3.01	3.57	17.24	8.59	17.85
100-seed weight(g)	Giza 716 x Giza843	No	40	40	40	250	150	150
		X	86.60	76.95	89.32	83.13	84.53	78.13
		S^2	5.73	2.90	7.90	139.29	93.64	72.06
		S^2_x	0.14	0.07	0.16	0.56	0.62	0.48
		C.V.%	2.80	3.01	3.57	17.24	8.59	17.85
	Nubaria 1 x Giza 843	No	40	40	40	250	150	150
		$\overline{X}$	116.40	76.95	100.37	92.80	90.13	121.20
		S^2	5.90	2.90	14.87	217.72	75.80	190.83
		S^2_x	0.15	0.06	0.08	0.31	0.15	0.54
		C.V.%	2.10	3.01	3.57	17.24	8.59	17.85

Data revealed that, parental genotype Nubaria 1 recoded the highest number of branches(6.50), pods(13.70), as well as the highest estimates of seed yield (48.10 g/plant) and 100-seed weight (100.45 g)and possessed the shortest plants (101.1 cm). However, parentel genotype Giza 843 exhibited the lowest values of number of branches, (2.73/plant), seed yield(23.3 g/plant), and 100-seed weight (76.95g)with the tallest plants (116 cm) .These differences indicated wide variability for the different traits.

Estimates of heterosis percentage relative to mid parents (MP), potence ratio and inbreeding depression in the three crosses are presented in Table 3. Results suggested that highly significant heterosis % over mid parent was observed for number of pods/plant (96.86%), number of seeds/plant (50.52%), seed yield/ plant (37.58%),and 100-seed weight (9.21%) in Giza 716x Giza 843 cross. Meanwhile heterosis percentages were highly significant for plant height (16.21%), number of branches/ plant(33.57%), number of pods/plant (19.43%), number of seeds/plant (32.22%), seed yield/ plant (32.68%) in Nubaria 1 x Giza 843 cross. These results are in agreement with those reported by Abdalla, (1977); Abdalla and Fischbeck, (1983); Abdalla *et al.*, (2001); Attia *et al.*, (2001 and 2002) and El-Hady *et al.*, (2006, 2007 and 2008). The differences in heterosis percent might be due to genetic variability of the parents and for non-allelic interactions, which can either increase or decrease the expression of heterosis. Even in the absence of epistasis, multiple alleles at a locus could lead to either positive or negative heterosis (Cress, 1966). Regarding to inbreeding depression, significant positive values were found for all studied characters. These results indicated that both heterosis and inbreeding depression were associated in all traits. This may be logic since high heterosis in F_1 may be followed by considerable reduction in F_2 performance. Similar results were reported by; Abdalla *et al.*, (2001); Darwish *et al.*, (2005); Attia and Salem, (2006); Attia *et al.*, (2006); Attia, (2007) El-Hady *et al.*, (1997, 1998, 2007 and 2008).

Table 3: Mather's scaling test for average additiveness, Gamble's parameters for determining gene action and dominance relationships; heterosis (%) measured as deviation of F_1 hybrid from mid-parent, inbreeding depression (%) and potence ratio of the two crosses Giza 716 x Giza 843and Nubaria 1 x Giza 843.

	Plant height		N of branches/plant		N. of pods/plant		N. of seeds/plant		Seed yield/plant		100-seed weight	
	Giza 716 x Giza 843	Nubaria 1 x Giza 843	Giza 716 x Giza 843	Nubaria 1 x Giza 843	Giza 716 x Giza 843	Nubaria 1 x Giza 843	Giza 716 x Giza 843	Nubaria 1 x Giza 843	Giza 716 x Giza 843	Nubaria 1 x Giza 843	Giza 716 x Giza 843	Nubaria 1 x Giza 843
I-Dominance relationships:												
Heterosis	14.39	16.21**	1.01	33.57**	96.86**	19.43**	50.52**	32.22**	37.58**	32.68**	9.21**	3.82
Inbreeding depression	9.3	8.5*	9.9	47.0**	48.9**	31.8**	50.2**	41.4**	48.8**	47.2**	6.9*	7.5*
Potence ratio	-0.75	0.59	0.01	-0.21	3.35	0.30	2.52	0.52	0.86	-0.24	-0.39	-0.05
II- Scaling test:												
A	-34.00**	-4.40**	-0.07	-4.73**	-0.90	-4.37**	-9.37**	-10.13**	-10.97**	-25.27**	-6.88**	-36.51**
B	1.67	-9.20**	1.80**	-0.43**	-1.50**	7.93**	-11.03**	12.53**	-8.83**	38.00**	-10.01**	65.08**
C	-51.33**	-7.87**	-1.27**	-8.50**	-20.27**	-13.30**	-64.20**	-55.33**	-51.93**	-66.13**	-9.68**	-22.90**
D	-9.50**	2.87**	-1.50**	-1.67**	-8.93**	-8.43**	-21.90**	-28.87**	-16.07**	-39.43**	3.60	-25.73**
III- Gamble's parameters												
m	105.83**	115.400**	3.000**	3.267**	10.667**	9.567**	23.867**	27.733**	18.100**	25.000**	83.133**	92.800**
Additive effects (a)	-23.167**	-5.067**	-0.367**	-0.267**	1.067**	-4.233**	2.433**	-5.800**	1.800**	-19.233**	6.400**	-31.067**
Dominance effect (d)	34.933**	11.867**	3.033**	4.883**	28.133**	19.150**	59.900**	69.267**	41.967**	90.533**	0.331	55.467**
Additive x additive (aa)	19.000**	-5.733**	3.000**	3.333**	17.867**	16.867**	43.800**	57.733**	32.133**	78.867**	-7.200*	51.467
Additive x dominance (ad)	-17.833**	2.400**	-0.933**	-2.150**	0.300	-6.150**	0.833	-11.333**	-1.067*	-31.633**	1.565	-50.792**
Dominance x dominance (dd)	13.333*	19.333**	-4.733**	1.833**	-15.467**	-20.433**	-23.400**	-60.133**	-12.333**	-91.600**	24.083**	-80.036**

In addition, the conflicting estimates of heterosis and inbreeding depression were associated in all traits genes in the parental genotypes. Potence ratios exceeding unity for number of pods/plant and number of seeds/plant in the first cross (Giza 716 x Giza 843) indicting over dominance. On the other hand, the values of potence ratios were less than unity in other cases, indicating partial dominance. Similar trends were reported by Attia, (2007) and El-Hady *et al.*, (2007).

Scaling tests in Table 3 indicate "A" and "B" to provide evidence on additive x additive, additive x dominance and dominance x dominance type of gene interaction; "C" indicates dominance x dominance type of gene interaction and "D" provides information regarding additive type of gene interaction. The test of adequacy of scales is important because in most of the cases the estimation of additive and dominance components of the variance were calculated assuming the absence of gene interaction. The values of A, B, C and D should be equal to zero within the limits of their standard error. The significance of any one of these scales is taken to indicate the presence of non-allelic interaction. In all characters, the estimated mean effects (m) which reflect the contribution due to the overall mean plus the locus effects and interaction of the fixed loci, was highly significant.

Highly significant positive estimates of additive gene effects (a) were detected in the first cross (Giza 716 x Giza 843) for number of pods/plant, number of seeds/plant, seed yield/plant and 100-seed weight. On the other hand, the estimated values of dominance type (d) were significantly positive for all studied characters in the second cross (Nubaria 1 x Giza 843) and higher in magnitude than that of additive type in both crosses .The three types of epistatic effect additive (a a) , additive x dominance (a d)and dominance x dominance (d d) were significant or highly significant with different magnitudes and directions. The estimated values of additive variance (1/2 D) were higher than dominance variance (1/4 H) in the two crosses for all studied characters and revealed that both additive and dominance gene effects were important in the performance of these traits. Generally, the dominance and epistatic effects were more important than (aa) with more additive gene effect in the expression of all studied characters in the two populations. These results are in line with those obtained by El-Hady *et al.*,(1997 ; (1998;2007 and 2008) Attia *et al.*, (2002 and 2006) Attia , (2007) .

Heritability values , genetic advance and genetic coefficient for studied characters are presented in Table 4: Narrow sense heritability percents were 48.57% for seed yield /plant(g) to 96.04% for 100 – seed weight (g) in the Giza 716 x Giza 843 cross and from 61% for plant height to 96.38% for100 – seed weight in Nubaria 1 x Giza 843 cross. With respect to heritability estimates in broad sense, results revealed that100–seed weight possessed high heritability values (81.04%) followed by number of branches/plant (69.99%) and number of pods/plant (59.92%) in Giza 716 x Giza 843 cross. Meanwhile, Nubaria 1 x Giza 843 cross recorded 59.51,32.97, 51.73, 67.49, 57.09 and 77.53% heritability values for plant height, number of branches, pods, seeds and seed yield/plant as well as 100 – seed weight respectively. Similar treads were reported by El-Hady *et al* (1997, 2006 , 2007, 2008); Abdalla *et al.*, (1999 and 2001); Mansour *et al.*, (2001); Darwish *et al.*, (2005); Attia and Salem, (2006) Attia, (2007).

Data in Table 4 show the genetic advance upon selection as a percentage of F_2 generation for all traits in the two crosses. Results indicated that the predicted genetic advance expressed as a percentage of the mean was moderate to high for most cases. Johanson *et al.* (1955) reported that heritability estimates along with genetic advance are usually more useful than the heritability values alone in predicting the results of selecting the best individuals. On the other hand, heritability is not always associated with high genetic advance but to make effective selection, high heritability should be associated with high genetic advance. In the present study, relatively high genetic advance was found to be associated with rather moderate to high heritability estimates for number of pods, seeds and seed yield/plant as well as 100-seed weight. Therefore, selection for these traits in these crosses should be effective and satisfactory for successful breeding purposes.

Table 4: Narrow (h2n) and broad (h2b) sense heritability, genetic advance (Gs %) as percentage of F_2 means, and genetic coefficients of variation (GCV %) of the two crosses for studied traits.

	Plant height		*N.* of Branches/plant		N. of pods/plant		N. of seeds/plant		Seed yield/plant		100-seed weight	
	Giza 716 x Giza 843	Nubari alx Giza 846	Giza 716 x Giza 843	Nubari alx Giza 846	Giza 716 x Giza 843	Nubari alx Giza 846	Giza 716 x Giza 843	Nubari alx Giza 846	Giza 716 x Giza 843	Nubari alx Giza 846	Giza 716 x Giza 843	Nubari alx Giza 846
Phenotypic variance components:												
Additive variance (1/2 D)	65.01	23.29	0.17	0.10	3.45	2.74	9.30	27.62	1.67	21.83	112.88	168.81
Dominance variance (1/4 H)	-8.03	-14.68	0.02	0.14	-1.56	1.45	5.58	0.64	-2.05	4.30	15.39	33.14
Environmental variance (E)	26.67	15.26	0.03	0.03	1.93	0.56	5.61	6.33	6.67	6.05	5.51	7.89
h2n	75.82	61.00	88.00	89.38	66.45	89.50	78.51	84.52	48.57	84.17	96.04	96.38
h2b	58.92	59.51	69.33	32.97	59.92	51.73	35.65	67.49	12.90	57.09	81.04	77.53
Gs %	13.17	5.79	25.67	26.37	26.17	37.70	29.41	34.12	16.91	36.43	23.86	26.82
GCV %	8.64	4.23	15.63	15.94	18.35	22.77	18.96	21.21	13.87	22.69	13.91	15.61

With respect to seed yield/plant, low genetic advance was associated with low heritability values in narrow sense in this trait. Therefore, it could be suggested that the selection for seed yield in subsequent generations will be relatively more effective than in the early F_2 generation

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قوة الهجين و التباين الوراثى للمحصول و مكوناته فى الفول البلدى باستخدام نموذج العشائر الستة

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أجريت هذه الدراسة بمحطة البحوث الزراعية بالجيزة خلال الثلاث مواسم 2005 / 2006 و 2006 / 2007 و 2007/ 2008 لدراسة طبيعة فعل الجين وقوة الهجين بالنسبة لمتوسط الابوين و التدهور فى الجيل الثانى لصفات المحصول وبعض مكوناته. وقد تم التهجين بين ثلاثة تراكيب من الفول البلدى لإنتاج الهجينان: (جيزة 716 x جيزة 843) و(نوبارية 1 x جيزة 843) وذلك باستخدام نموذج العشائر الستة وقد أظهرت النتائج قوة هجين فى الجيل الاول كانت عالية المعنوية لمعظم الصفات المدروسة وذلك فى الهجين الثانى (نوبارية 1 x جيزة 843) كانت قيم التدهور الناتج عن التربية الداخلية فى الجيل الثانى معنوية لكل الصفات المدروسة– كانت هناك سياده فائقة فى الهجين الأول (جيزة 716 x جيزة 843) لصفات عدد قرون و بذور النبات بينما كانت السياده جزئية لباقى الصفات . كان التباين المضيف اعلى من السيادى فى كلا الهجينان لكل الصفات المدروسة مما يدل على ان كلا من التأثير المضيف و السيادى لهما أهمية لهذه الصفات. كان هناك تحسن وراثى ملحوظ لصفات المحصول ومكوناته مما يشير الى أن الانتحاب لهذه الصفات قد يكون له أهمية فى أغراض التربية الناجحة.