JKAU: Met., Env. & Arid Land Agric. Sci., **Vol. 21,** No.1, pp: 35-50 (2010 A.D./1431 A.H.)
DOI: 10.4197/Met. 21-1.3

Heterosis, Combining Ability and Components of Genetic Variance in Faba Bean (*Vicia faba* L.)

Hossam M. Ibrahim

Crop Science, Dept., Faculty of Agriculture, Alexandria University, Egypt

Abstract. The present investigation was carried out at the Agricultural Research Station, Faculty of Agriculture, Alexandria University to evaluate seven faba bean varieties (four local and three introduced) in the diallele cross set. Twenty one crosses were constituted in the winter season of 2006/2007, whereas parents and crosses were evaluated in a yield trial, in winter season of 2007/2008, in a randomized complete block design of three replications. Results revealed highly significant variations within parents and F_1 genotypes indicating a wide genetic variability for the studied characters and the possibility of genetic improvement using such genetic pools of faba bean. Several crosses recorded significant positive heterosis percentages relative to mid parent and better parent for seed yield per plant and 100-seed weight ranging from 17.46-84.95%, 22.47-68.49%, 8.53-23.26% and 10.43-18.64% relative to MP and BP for each character, respectively. Both general (GCA) and specific (SCA) combining abilities were significant for all studied characters revealing the important role of both additive and dominant components in the inheritance of the studied characters. Giza Blanca proved to be a good combiner for all studied characters except number of pods per plant and maturity time. Several crosses exhibited significantly positive SCA effects for studied characters especially Giza 716 × ILB 450 and ILB 450 × Giza Blanca which exhibited highly significant and positive SCA effects for seed yield per plant and 100-seed weight. Heritability in narrow sense was high for 100-seed weight (0.54) and short plant height (-0.51) while it was low for seed yield per plant.

Keywords: Faba bean, heterosis, Combining ability, heritability.

Introduction

Faba bean (*Vicia faba* L.) is one of the main pulse crops grown for seed in Egypt. It is widely considered as a good source of protein, starch, cellulose and minerals for humans in developing countries and for animals in industrialized countries (Haciseferogullari *et al*., 2003). In addition, faba bean is one of the most efficient fixers of the atmospheric nitrogen and, hence, can contribute to sustain or enhance total soil nitrogen fertility through bidogical N_2-fixation (Lindemann and Glover, 2003).

Faba bean is a self-pollinating plant with significant levels of out-cross and inter-cross, ranging from 20 to 80% (Suso and Moreno, 1999) depending on genotype and environmental effects. The genetic improvement of crop desired traits depends on the nature and magnitude of genetic variability and interactions involved in the inheritance of these traits which can be estimated using diallele cross technique. This technique may also result in the production of new genetic combinations whose performance, negatively or positively, may exceed that of the parents, a phenomenon known as heterosis. Exploitation of heterosis could pay off improving yield potential and its components in faba beans, where superiority of hybrids over the mid and/ or better parents for seed yield is associated with manifestation of heterotic effects in important yield components, *i.e.,* number of branches per plant, number of pods per plant and seed index. These heterotic effects may range from significantly positive to significantly negative for different traits depending on genetic make up of parents (Duc, 1997, El-Hosary *et al.*, 1997, El-Hady *et al.*, 1998, Abdalla *et al.*, 1999, El-Keredy *et al.*, 1999, Attia *et al.*, 2001, Darwish *et al.*, 2005 and El-Hady *et al.*, 2006).

In addition, an inference can be made from diallele crosses about general combining ability of parents and specific combining ability of hybrids. Such information may be helpful for breeders to identify the best combiners which may be hybridized to build up favorable fixable genes. Several researchers have reported the significance of both general and specific combining ability effects on seed yield and other important traits in faba bean (Kaul and Vaid, 1996, EL-Refaey *et al.*, 1999 Attia and Morsy, 2001, Attia *et al.*, 2002 & Attia and Salem, 2006).

The present study was carried out to investigate the nature of gene action and specific combining abilities of seven faba bean diverse genotypes and their F_1 generation using diallele cross mating technique.

Materials and Methods

Seven varieties of faba bean were crossed in diallele cross set. The varieties were four local, *i.e.*, Giza 716 (P_1), Giza 461 (P_4) and Giza Blanca (P_5), Giza 843 (P_6) and three introduced from International Center for Agriculture Research in Dry Areas (ICARDA), Aleppo, Syria, *i.e.,* ILB 312 (P_2), ILB 450 (P_3) and ILB 648 (P_7).

In 2006/ 2007 season, 21 crosses were constituted at Agricultural Research Station, Faculty of Agriculture, Alexandria University, Alexandria, Egypt. A yield trial the seven for parents and their crosses was conducted in the winter season of 2007/ 2008. A randomized complete block design with three replications was used. Each plot consisted of one ridge of 4m length and 60cm width. Hills were spaced 20cm with two plants by hill. Cultural practices were adopted as recommended for field beans production in the area.

At harvest, ten guarded plants were randomly sampled from each plot to provide measurements for maturity date, plant height, number of branches/ plant, number of pods/ plant, seed yield per plant, and 100-seed weight. Data were statistically analyzed according Steel and Torrie (1980).

Data were subjected to regular analysis of RCBD on plot mean basis to test genotype variances following statistical model, considering cultivar as fixed effects:

$$Y_{ij} = \hat{I}\,{}^{1}\!/_{4} + g_i + b_j + e_{ijk} \qquad (1)$$

Where:

Y_{ij} = Observation of ith treatment in the jth block (i= 1, 2, …., g=6; j= 1, 2, …, b=10)

$\hat{I}\,{}^{1}\!/_{4}$ = General mean

g_i= effect of the ith cultivar

b_j = Effect of the jth cultivar

e_{ijk} = Experimental error

The heterotic effects of F1 crosses populations were estimated as percentage over mid and better parents using the following formula:

$$\text{Mid parent heterosis (Relative heterosis) (\%)} = \frac{F_1 \text{ - Mid parent}}{\text{Mid parent}} \times 100 \quad (2)$$

$$\text{Better parent heterosis (Heterobeltiosis) (\%)} = \frac{F_1 \text{ - Better parent}}{\text{Better parent}} \times 100 \quad (3)$$

Where:

$$\text{MP the mid parent is calculated from mid parent} = \frac{P_1 \text{ - } P_2}{2} \quad (4)$$

The LSD for heterosis was computed following the formulae by Bhatt (1971).

Combining ability effects and variances were calculated according to Griffing (1956), method 2, model 1 (all possible combinations excluding reciprocals) as follows:

$$M_{ij} = \hat{I}\,{}^{1}\!/_{4} + GCA_i + GCA_j + SCA_{ij} + e_{ijk} \quad (5)$$

Where:

M_{ij} = Observation of ith cultivar in the jth block

$\hat{I}\,{}^{1}\!/_{4}$ = General mean

GCA_i = effect of the ith cultivar

GCA_j = Effect of the jth cultivar

SCA_{ij} = Combined effect of two cultivars

e_{ijk} = Experimental error

The estimates of variance components of GCA and SCA were calculated as follows:

Sources of variation	d.f.	Mean of squares	Expected mean of squares
GCA	n – 1	Mg	$\sigma^2_e + \sigma^2_{sca} + (n + 2\sigma^2_{sca})$
SCA	n (n -1)/2	Ms	$\sigma^2_e + \sigma^2_{sca}$
Error	(r-1)(p-1)	Me	σ^2_e

Where:

Mg = Mean squares of GCA

Ms = Mean squares of SCA

Me = Mean squares of error

p = No. of populations

r = No. of replicates

n = No. of parental lines

The standard error (SE) of the estimated general and specific combining ability effects were calculated as follows:

$$SE\ (G_i - G_j) = \left[\frac{2\,\sigma_e^2}{(n+2)}\right]^{1/2} \qquad (6)$$

$$SE\ (S_j - S_{ik}) = \left[\frac{2\,(n-1)\,\sigma_e^2}{(n-2)}\right]^{1/2} \qquad (7)$$

Results and discussion

Variation and Mean Performance

Mean squares for the studied parents and their F_1 genotypes (Table 1) revealed highly significant variations for all characters. That may indicate a wide genetic variability for studied characters, which may facilitate genetic improvement using such genetic pools of faba bean.

Table 1. Mean Squares for genotypes and their general and specific combining abilities, and gca/sca ratio for the studied characters.

Characters	Genotypes	GCA	SCA	GCA/ SCA	Error
Plant height (cm)	467.28**	55.57**	195.84*	0.289	76.94
No. of branches/ plant	2.89**	1.28**	0.84**	1.519	0.093
Flower set	8.50**	0.51**	3.76**	0.136	0.163
Pod set	4.64**	0.30**	0.42**	0.699	0.029
No. of pods/ plant	64.64**	24.98**	20.17**	1.235	0.637
Maturity time (days)	113.93**	42.09**	36.33**	1.158	0.620
100-seed weight (g)	807.32**	628.42**	125.38**	5.012	0.797
Seed yield/ plant (g)	1190.94**	391.10**	399.33**	0.979	30.90

*, ** Significant at 0.05 and 0.01 levels of probability

Mean performance of parents and their F_1 hybrids are presented in (Table 2). Regarding plant height, the two parents Giza 716 (P_1) and ILB 312 (P_2) had the tallest plants (132 and 133 cm, respectively), whereas the shortest plants belonged to Giza Blanca (P_5) which recorded 104 cm. The two parental genotypes Giza Blanca and Giza 843 (P_6) exhibited the highest number of branches/ plant (6.0 and 6.3 respectively) and were highly significantly superior to the remaining five parents. Giza Blanca, also, recorded the highest percentage of flower set (89.97%), followed by Giza 843 (86.07%), whereas ILB 648 (P_7) recorded the lowest value for that character (67.09%).

However, Giza 843 had the highest percentage of pod set (93.69%) and the highest number of pods per plant (37), whereas ILB 648 and ILB 321 had the lowest percentage of pod set and Giza Blanca was significantly inferior in number of pods per plant (23). On the other hand, Giza Blanca had the significantly longest maturity period (165 days), 100-seed weight (119.8g) and highest seed yield per plant (89g) compared to the other six parents.

Comparison of performance of F_1 hybrids to the corresponding highest parents revealed that two ($P_1 \times P_3$ and $P_2 \times P_3$), one ($P_2 \times P_3$), seven ($P_1 \times P_2$, $P_1 \times P_3$, $P_1 \times P_4$, $P_1 \times P_5$, $P_1 \times P_7$, $P_2 \times P_5$ and $P_3 \times P_5$), four ($P_1 \times P_3$, $P_1 \times P_4$, $P_2 \times P_5$ and $P_5 \times P_7$), four ($P_1 \times P_4$, $P_2 \times P_3$, $P_3 \times P_4$ and $P_3 \times P_6$), six ($P_1 \times P_3$, $P_1 \times P_4$, $P_1 \times P_6$, $P_1 \times P_7$, $P_3 \times P_6$ and $P_3 \times P_7$) and ten ($P_1 \times P_3$, $P_1 \times P_4$,

$P_1 \times P_5$, $P_1 \times P_6$, $P_1 \times P_7$, $P_2 \times P_3$, $P_3 \times P_4$, $P_3 \times P_5$, $P_3 \times P_6$ and $P_3 \times P_7$) F_1 crosses significantly surpassed the highest parental genotype for number of branches per plant, flower set, pod set, number of pods per plant, maturity time, 100-seed weight and seed yield per plant.

Table 2. Means of parents and their F1 for the studied characters in 2007 season.

Genotypes	Plant height (cm)	No. of branches/ plant	Flower set	Pod set	No. of pods/ plant	Maturity time (days)	100-seed weight (g)	Seed yield/ plant (g)
(P_1) Giza 716	132	3.7	76.19	82.92	32	155	93	73
(P_2) ILB 312	133	4.0	77.46	78.54	35	152	89	75
(P_3) ILB 450	119	3.5	72.15	76.93	29	140	78.3	60
(P_4) Giza 461	116	4.0	81.97	89.23	35	152	71	66
(P_5) Giza Blanca	104	6.0	89.97	78.57	23	165	119.8	89
(P_6) Giza 843	110	6.3	86.07	93.69	37	144	74.6	73
(P_7) ILB 648	127	3.75	67.09	78.50	31	150	83.3	65
$P_1 \times P_2$	111	3.1	75.92	89.04	30.7	145	86.6	78
$P_1 \times P_3$	109	4.4	67.90	84.40	34.7	143	105.2	123
$P_1 \times P_4$	115	4.0	74.75	93.16	39.1	157	100.4	94
$P_1 \times P_5$	119	4.8	70.40	92.31	28.3	145	120.9	109
$P_1 \times P_6$	113	4.1	81.13	88.30	33.2	148	103.3	101
$P_1 \times P_7$	114	4.0	71.64	88.71	32.8	146	102.7	98
$P_2 \times P_3$	115	5.1	79.16	75.0	24	157	72.8	76
$P_2 \times P_4$	118	3.7	70.29	86.03	32	153	79.9	72
$P_2 \times P_5$	120	3.3	74.93	87.39	38.3	150	76.3	74
$P_2 \times P_6$	118	4.0	81.77	86.12	31.4	153	76.3	74
$P_2 \times P_7$	119	3.8	72.28	78.52	30.8	151	74.3	71
$P_3 \times P_4$	127	2.8	68.66	57.34	34.5	155	78.2	74
$P_3 \times P_5$	116	6.0	80.44	80.35	30.0	150	107.6	110
$P_3 \times P_6$	122	4.4	79.11	85.31	32.2	153	92.9	92
$P_3 \times P_7$	120	4.2	69.62	77.72	30.0	150	91.6	90
$P_4 \times P_5$	125	3.5	76.85	81.08	34.5	152	93.5	72
$P_4 \times P_6$	113	5.2	84.02	91.46	36	148	72.8	70
$P_4 \times P_7$	121	3.9	74.53	83.86	33	151	77	67
$P_5 \times P_6$	107	6.2	88.02	86.13	30	154	97	81
$P_5 \times P_7$	116	6.2	78.53	78.535	34	155	97	81
$P_6 \times P_7$	118	5.0	86.58	86.095	34	147	79	69
$L.S.D._{0.05}$	14.32	0.50	0.66	0.28	1.30	1.29	1.46	9.07
$L.S.D._{0.01}$	19.04	0.66	0.877	0.370	1.73	1.71	1.94	12.07

These findings may suggest that the above mentioned parents and F_1 crosses may be of value for improving seed yield of faba bean through improvement of yield components.

Heterosis Compared to Mid (MP) and Better (BP) Parents

Values of heterosis percentages relative to mid parents (MP) were significantly, or highly significantly, positive in four, six, one, six, six, four, eight and nine crosses with a range of 6.55-53.07, 15.86- 37.86, 13.05, 8.22- 14.32, 13.77- 32.06, 5.53- 7.74, 8.53- 23.26 and 17.46- 84.95% for plant height, number of branches per plant, flower set, pod set (Table 3), number of pods per plant, maturity time, 100-seed weight and seed yield per plant, respectively (Table 4).

Table 3. Percentage of heterotic relative to mid (M.P) and better (B.P) parents for plant height, No of branches/plant, flower set and pod set in faba bean F_1.

Crosses	Plant height (cm)		No. of branches/ plant		Flower set		Pod set	
	MP	BP	MP	BP	MP	BP	MP	BP
$P_1 \times P_2$	-16.00**	-16.50**	-19.48*	-22.5*	-1.17	-1.31	10.29**	7.38
$P_1 \times P_3$	-13.14**	-17.42**	22.22*	18.91	-8.45**	-10.88*	5.59	1.78
$P_1 \times P_4$	-7.25**	-12.87**	3.89	0.00	-5.47	-8.80	8.22*	12.34**
$P_1 \times P_5$	0.84	-9.84**	-1.03	-20.00*	-15.26**	-21.75**	14.32**	11.32**
$P_1 \times P_6$	-6.61*	-14.39**	-18.00	-34.92**	0.00	-5.73	0.00	-5.75
$P_1 \times P_7$	-11.96**	-13.63**	7.38	6.66	0.00	-5.97	9.91*	6.98
$P_2 \times P_3$	-8.73**	-13.53**	36.00**	27.50**	5.82	2.15	10.79**	-4.5
$P_2 \times P_4$	-5.22	-11.27**	-7.50	-7.50	-11.82**	-14.24*	2.55	-3.58
$P_2 \times P_5$	1.02	-9.77**	-21.22*	-45.00**	-10.49**	-13.38*	11.29**	11.22**
$P_2 \times P_6$	-2.88	-11.27**	-22.33*	-63.50**	-1.21	-4.99	0.00	-8.07
$P_2 \times P_7$	53.07**	10.52**	-1.93	-5.00	0.00	-6.68	0.00	-0.02
$P_3 \times P_4$	8.85**	6.72**	-25.33**	-30.00**	-10.90**	-16.23**	-30.98**	-35.73**
$P_3 \times P_5$	4.30	-2.52	26.31**	0.00	-0.76	-1.86	3.34	2.26
$P_3 \times P_6$	6.55*	2.52	-10.20	-30.15**	0.00	-8.08*	0.00	-8.94
$P_3 \times P_7$	-2.43	-5.51	15.86	12.00	0.00	-3.50	0.00	0.99
$P_4 \times P_5$	13.63**	7.75*	30.00**	-41.66**	-10.6**	-14.58**	-1.60	-9.13*
$P_4 \times P_6$	0.00	-2.58	37.86**	17.46	-42.84**	-2.38	1.66	-2.38
$P_4 \times P_7$	-0.41	-4.72	0.64	-2.50	0.00	-9.07	1.81	-6.01
$P_5 \times P_6$	0.00	-2.72	0.81	-1.58	1.73	-2.16	0.00	-8.60
$P_5 \times P_7$	0.43	-8.66*	27.17**	3.33	0.00	-12.71*	0.00	-0.04
$P_6 \times P_7$	-0.42	-7.08	-0.49	-20.63*	13.05**	0.59	0.00	-8.10
Mean	0.64	-3.28	3.86	-11.38	-4.68	-13.86	2.24	-3.38

*, ** Significance of the effect from zero at 0.05 and 0.01 levels of probability.

Moreover, heterosis percentages relative to the better parent (BP) were significantly, or highly significantly, positive for three, one, three, one, one, four and eight crosses with percentages ranging 6.72- 10.52, 27.5, 11.22- 12.34, 11.71, 6.25, 10.43-18.64 and 22.47- 68.49% for plant height, number of branches per plant, pod set, number of pods per plant, maturity time, 100-seed weight and seed yield per plant, respectively. Based on the two estimates of heterosis percentages, three crosses (P_2×P_7, P_3×P_4 and P_4×P_5), one cross (P_2×P_3), three crosses (P_1×P_4, P_1×P_5 and P_2×P_5), one cross (P_1×P_4), one cross (P_3×P_6), four crosses (P_1×P_3, P_1×P_6, P_1×P_7 and P_3×P_6) and eight crosses (P_1×P_3, P_1×P_4, P_1×P_5, P_1×P_6,

$P_1 \times P_7$, $P_3 \times P_5$, $P_3 \times P_6$ and $P_3 \times P_7$) exhibited significantly positive heterotic effects over both mid and better parents for plant height, number of branches per plant, pod set, number of pods per plant, maturity time, 100-seed weight and seed yield per plant, respectively. None of the tested crosses expressed significantly positive heterotic effects compared to the better parent, for flower set. With respect to maturity time, four crosses ($P_1 \times P_2$, $P_1 \times P_5$, $P_1 \times P_7$ and $P_2 \times P_5$) exhibited significantly negative heterosis compared to their respective mid parents with a range of -4.26 to -9.37%.

Table 4. Percentage of heterotic relative to mid (M.P) and better (B.P) parents for No of pods/plant, maturity time, 100-seed weight in faba bean F_1.

Crosses	No. of pods/ plant		Maturity time (days)		100-seed weight (g)		Seed yield/ plant (g)	
	MP	BP	MP	BP	MP	BP	MP	BP
$P_1 \times P_2$	-8.35*	-12.28*	-5.53*	-6.45**	-4.83	-6.88	5.40	4.00
$P_1 \times P_3$	13.77*	8.43	-3.05	-7.74**	16.69**	13.11*	84.95**	68.49**
$P_1 \times P_4$	16.71**	11.71*	5.53*	1.29	22.43**	7.95	35.25**	28.76*
$P_1 \times P_5$	2.90	-11.56*	-9.73**	-12.12**	12.78**	0.91	34.56**	22.47*
$P_1 \times P_6$	-3.76	-10.27*	-1.00	-4.51	23.26**	11.07*	38.35**	38.35**
$P_1 \times P_7$	4.12	2.50	-4.26*	-5.80*	15.71**	10.43*	43.05**	34.24**
$P_2 \times P_3$	-25**	-31.42**	7.53**	3.28	-12.97**	-18.20**	12.59	1.33
$P_2 \times P_4$	-8.57*	-8.57	0.56	0.56	-0.12	-10.22*	2.12	-4.00
$P_2 \times P_5$	32.06**	0.85	-5.36*	-9.09**	-25.85**	-36.31**	9.75	-16.85*
$P_2 \times P_6$	-12.70*	-15.13**	3.37	0.65	-6.72	-14.26*	0.00	-1.33
$P_2 \times P_7$	-6.66	-12.00	0.00	-0.65	-12.22*	-16.51*	1.42	-5.33
$P_3 \times P_4$	7.81	-1.42	6.16**	1.97	4.75	-0.12	17.46*	12.12
$P_3 \times P_5$	15.38**	3.44	-1.63	-9.10**	8.53*	-10.18*	47.65**	23.59**
$P_3 \times P_6$	2.42	-12.97*	7.74**	6.25**	21.51**	18.64**	38.34**	26.03**
$P_3 \times P_7$	0.00	-3.22	3.44	0.00	13.36**	9.96	44.00**	38.46**
$P_4 \times P_5$	18.96**	-1.42	-4.1	-7.87**	-1.99	-21.95**	-5.26	-19.10*
$P_4 \times P_6$	0.00	-2.70	0.00	-2.63	0.00	1.60	0.71	-4.10
$P_4 \times P_7$	0.00	-5.71	0.00	-0.65	-0.19	-7.56	2.29	1.50
$P_5 \times P_6$	0.00	-18.91**	-0.30	-6.66**	-0.20	-19.03**	0.00	-8.98
$P_5 \times P_7$	22.92**	9.76	-1.58	-6.06**	-8.41*	-19.3**	5.19	-8.98
$P_6 \times P_7$	0.00	-8.10	0.00	-2.00	-22.20	-5.16	0.00	-5.47
Mean	3.42	-5.67	0.61	-3.20	2.06	-5.33	19.89	10.71

*, ** Significance of the effect from zero at 0.05 and 0.01 levels of probability.

These data suggest that heterotic effects for seed yield per plant were associated with other yield components, in several crosses, such as 100-seed weight and number of pods per plant. Moreover, various cross combinations exhibited different degrees of crosses superiority in some traits based on the genes in parental combinations that may contribute directly, or indirectly, to the expression of these traits. In addition, the heterosis estimates, compared to either MP or BP, for seed yield per plant and its major yield components indicated that there was sufficient genetic variability among the assessed parents to favor efficient breeding for these characters. Positive and significant heterosis percentages over MP or BP were reported by several researchers for faba bean characters which varied according to the cross combinations and traits (Duc, 1997, Stelling, 1997, Abdalla *et al*., 2001, Attia *et al*., 2001 and 2002, Darwish *et al.*, 2005, Attia and Salem, 2006, and El-Hady *et al.*, 1998 and 2006).

General and Specific Combining Abilities

Mean squares for both general combining ability (GCA) and specific combining ability (SCA) were highly significant, or significant, for all studied characters (Table 1). This may indicate the important role of both additive and dominance components in the inheritance of the studied characters, although the contribution of each component may vary according to character. The variance due to GCA, hence additive gene action, was more pronounced for number of branches per plant, number of pods per plant, maturity time and 100-seed weight. Meanwhile, variance due to SCA, as an indicator of non-additive gene action, was greater for plant height, flower set, pod set and seed yield per plant. These findings are in agreement with those reported by Kaul and Vaid (1996), El-Keredy, *et al*. (1999), El-Refaey, *et al.* (1999), Attia and Morsy (2001) and Salama and Salem (2001).

Comparison between GCA effects associated with each parent (Table 5) revealed that Giza 716 (P_1) showed positive and highly significant, or significant, effects for number of pods per plant, 100-seed weight and seed yield per plant, while it showed highly significant negative effect for maturity time. That may indicate the possibility of using that parent as a source for earliness and higher seed yield and yield components. Similarly, Giza Blanca (P_5) proved to be a good combiner for all studied characters except number of pods per plant and earliness. Giza 461 (P_4), Giza 843 (P_6) and ILB 648 (P_7) revealed good combining ability for number of pods per plant. On the other hand, both ILB 312 (P_2) and ILB 450 (P_3) were either of significant negative or insignificant effects for most of the studied characters indicating their inferiority as sources for yield improvement in breeding programs.

Table 5. General combining ability effects of the five parents for the studied faba bean characters.

Parents	Plant height (cm)	No. of branches/ plant	Flower set	Pod set	No. of pods/ plant	Maturity time (days)	100-seed weight (g)	Seed yield/ plant (g)
Giza 716 (P_1)	-2.06	-0.166	0.194	-0.155	0.676*	-0.896**	7.40**	8.78**
ILB 312 (P_2)	4.63	-0.220*	-0.122	-0.031	0.426	-0.144	-7.90**	-5.70**
ILB 450 (P_3)	1.06	0.074	0.311	-0.234	-1.546**	-3.66**	-4.80**	2.07
Giza 461 (P_4)	2.19	-0.418**	-0.005	0.195	2.583**	1.65**	-7.90**	-9.90**
Giza Blanca (P_5)	1.57	0.712**	-0.377	0.226*	-2.139**	2.98**	13.00**	3.54*
Giza 843 (P_6)	1.44	0.370**	-0.37	0.430**	2.95**	-2.22**	-5.50**	-3.00
ILB 648 (P_7)	1.40	0.370**	-0.369	0.400**	2.5**	-1.88**	-4.86**	-2.77
S.E. gi	3.00	0.11	0.27	0.10	0.28	0.27	0.32	1.89
S.E. gi-gj	4.70	0.17	0.42	0.16	0.45	0.42	0.50	2.98

*, ** Significance of the effect from zero at 0.05 and 0.01 levels of probability.

Four crosses ($P_3\times P_4$, $P_4\times P_5$, $P_5\times P_6$ and $P_5\times P_7$) had significant positive SCA effects for plant height (Table 6), while eleven crosses showed significant positive SCA effects for number of branches per plant ($P_1\times P_2$, $P_1\times P_4$, $P_1\times P_6$, $P_1\times P_7$, $P_2\times P_3$, $P_3\times P_5$, $P_4\times P_6$, $P_4\times P_7$, $P_5\times P_6$, $P_5\times P_7$ and $P_6\times P_7$). Regarding flower set, eight crosses exhibited significant and positive SCA effects ($P_1\times P_5$, $P_1\times P_6$, $P_1\times P_7$, $P_2\times P_3$, $P_2\times P_4$, $P_2\times P_6$, $P_2\times P_7$ and $P_5\times P_6$) whereas five crosses showed significant and positive SCA effects for pod set ($P_1\times P_6$, $P_1\times P_7$, $P_2\times P_6$, $P_2\times P_7$ and $P_4\times P_5$). Nine F_1's showed positive and significant SCA effects number of pods per plant ($P_1\times P_3$, $P_1\times P_4$, $P_2\times P_5$, $P_2\times P_6$, $P_2\times P_7$, $P_3\times P_4$, $P_3\times P_5$, $P_4\times P_5$ and $P_4\times P_6$) while nine F_1's exhibited significant and negative SCA effects for maturity time indicating their tendency to early maturity ($P_1\times P_2$, $P_1\times P_3$, $P_1\times P_5$, $P_1\times P_7$, $P_2\times P_5$, $P_2\times P_6$, $P_3\times P_6$, $P_4\times P_5$ and $P_4\times P_7$). Concerning 100-seed weight, twelve crosses revealed highly significant and positive SCA effects ($P_1\times P_3$, $P_1\times P_4$, $P_1\times P_5$, $P_2\times P_4$, $P_2\times P_6$, $P_2\times P_7$, $P_3\times P_5$, $P_4\times P_6$, $P_4\times P_7$, $P_5\times P_6$, $P_5\times P_7$ and $P_6\times P_7$), while eight of these crosses exhibited highly significant, or significant, positive SCA effects for seed yield per plant ($P_1\times P_3$, $P_1\times P_4$, $P_1\times P_5$, $P_2\times P_6$, $P_3\times P_5$, $P_4\times P_6$, $P_4\times P_7$ and $P_5\times P_6$) in addition to ($P_4\times P_5$). These findings indicate that SCA for seed yield per plant may be influenced by SCA for yield components.

GCA effects provide appropriate criterion for detecting the validity of a genotype in hybrid combination, while SCA effects may be related to heterosis. The results revealed that GCA effects, for some traits, were related to several SCA values of their corresponding crosses, where the two parents P_1 and P_5, which exhibited significant and positive GCA effects for 100-seed weight and seed yield per plant, produced crosses enjoying positive and highly significant SCA effects for both traits. This may indicate, in such combinations, that additive and non-additive genetic systems present in the crosses are acting in the same direction to maximize the characters in view (Abdalla, *et al*., 1999). These findings are in agreement with Darwish, *et al*. (2005), Attia and Salem (2006) & El-Hady, *et al*. (2006 and 2007).

Table 6. Specific combining ability effects of the different crosses for the studied characters.

Parents	Plant height (cm)	No. of branches/ plant	Flower set	Pod set	No. of pods/ plant	Maturity time (days)	100-seed weight (g)	Seed yield/ plant (g)
Giza 716×ILB312	-7.97	0.662**	-1.90**	-0.039	-2.41**	-5.64**	-4.26**	-6.62
× ILB 450	-6.40	-0.362	-0.762	-0.003	3.57**	-3.92**	11.21**	30.81**
× Giza 461	-30.68**	0.433*	-2.56**	-0.465*	3.84**	4.94**	9.47**	13.38**
× Giza Blanca	6.03	-0.124	2.27**	-0.630**	-2.29**	-5.64**	9.44**	14.24**
× Giza 843	7.00	0.550*	3.00**	0.940**	-2.40**	5.40**	-8.80**	-10.05**
× ILB 648	6.30	0.490*	1.90**	0.660**	-1.90**	-6.66**	-6.70**	-8.50*
ILB312×ILB450	6.87	1.129**	1.74**	-0.127	-6.88**	8.98**	-6.24**	-1.91
× Giza 461	-0.83	-0.200	2.20**	-0.456*	-3.02**	-0.159	4.14**	5.67
× Giza Blanca	0.56	-1.276**	-1.75**	-0.013	8.01**	-4.40**	-20.08**	-6.48
× Giza 843	-1.20	-0.330	2.90**	0.440*	3.00**	-3.90**	5.80**	8.80**
× ILB 648	-1.80	-0.350	2.10**	0.500*	4.10**	2.20**	6.00**	5.70
ILB450×Giza461	11.75*	-1.110**	-0.317	0.097	1.46*	5.22**	-0.786	0.095
× Giza Blanca	0.13	1.114**	-2.19**	0.283	1.68**	-1.02	7.29**	21.95**
× Giza 843	-1.80	-0.390	-2.80**	-0.390	-1.70**	-1.10*	-8.16**	-3.00
× ILB 648	-2.20	-0.360	-1.20*	-0.360	-1.20	0.99	-6.20**	-2.800
Giza461×Giza Blanca	12.18*	-0.914**	-1.49**	1.587**	2.05**	-4.16**	-2.96**	26.48**
× Giza 843	3.00	0.660*	-1.00	-0.460*	2.4**	2.90**	1.90**	10.10**
× ILB 648	-2.40	0.560*	-2.80**	-0.360	-2.01**	-1.80**	4.05**	9.20*
Giza Blanca × Giza843	12.50*	1.100**	3.40**	-0.290	-2.040**	2.00**	3.00**	13.13**
× ILB 648	11.00*	0.880**	-1.00	-0.300	-1.10*	1.10*	4.20**	6.70
Giza843×ILB648	-12.46*	0.842**	-0.246	-1.080**	-3.15**	5.70**	3.00**	4.00
S.E.Sij	5.05	0.21	0.54	0.21	0.55	0.54	0.62	3.84
S.E.Sij-Sik	11.48	0.04	1.03	0.04	1.04	1.03	1.17	7.27
S.E.Sij-Skl	10.48	0.36	0.94	0.36	0.95	0.94	1.07	6.64

*, ** Significance of the effect from zero at 0.05 and 0.01 levels of probability.

Heritability in narrow sense (Table 7) was high for 100-seed weight (0.54) and short plant height (-0.51), while it was low for the remaining characters. These values may indicate the possibility of increasing seed yield through selection for 100-seed weight which is an important yield component. Similar findings were reported by Salama and Salem (2001) and Toker (2004).

Table 7. Estimates of additive and non-additive genetic variances and heritability of the studied traits.

Characters	Estimates		
	Additive variance	Non-additive variance	Heritability in narrow sense.
Plant height (Cm.)	-40.08	118.89	-0.51
Number of branches/ Plant	0.12	0.75	0.14
Flower set	-0.93	3.60	-0.35
Pod set	-0.04	0.39	-0.11
Number of pods/ Plant	1.37	19.54	0.07
Maturity Time (day)	1.64	35.71	0.04
100-seed Weight (g.)	143.73	124.58	0.54
Seed yield/ Plant (g.)	2.35	368.44	0.01

In conclusion, the present results reveal that several crosses are highly promising to breed faba bean cultivars possessing genetic factors for earliness and high yield potential.

References

Abdalla, M.M.F, Darwish, D.S., El-Hady, M.M. and **El-Harty, E.H.** (1999) Investigations on faba bean (*Vicia faba* L.) 12- Diallele crossed materials grown under cages, *Egypt. J. Plant Breed.,* **3**: 213-229.

Abdalla, M.M.F, Darwish, D.S., El-Hady, M.M. and **El-Harty, E.H.** (2001) Investigations on faba bean (*Vicia faba* L.) 16- F_1 and F_2 diallele hybrids with reciprocals among five parents, *Egypt. J. Plant Breed.,* **5**: 155-179.

Attia, S.M. and **Salem, M.M.** (2006) Analysis of yield and its components using diallele matings among five parents of faba bean, *Egypt. J. Plant Breed.,* **10**: 1-12.

Attia, S.M. and **Morsy, S.M.** (2001) Diallele analysis of some yield and technological characters among four faba bean genotypes with their crosses. *Annals of Agriculture Science, Moshtohor, Faculty of Agriculture, Zagazig University,* **39**(1): 65-75.

Attia, S.M., Zakia, M.S., Ezzat, M., Rizk, A.M.A. and **Aly, K.A.** (2002) Heterosis, combining ability and gene action in crosses among six faba bean genotypes, *Egypt. J. Plant Breed.,* **6**: 191-210.

Attia, S.M., Shalaby, F.H., El-Sayed, Z.S. and **El-Hady, M.M.** (2001) Heterosis, inbreeding depression and combining ability in a diallel cross of five faba bean genotypes, *Annals of Agriculture Science, Moshtohor. Faculty of Agriculture, Zagazig University,* **39(**1): 53-64.

Bhatt, G.M. (1971) Heterosis performance and combining ability in a diallele cross among spring wheat (*T. aestivum* L.), *Aust. J. Agric. Res.,* **22**: 359-360.

Darwish, D.S., Abdalla, M.M.F., El-Hady, M.M. and **El-Emam, E.A.A.** (2005) Investigations on faba beans (*Vicia faba* L.) 19- diallele and triallele mating using five parents, *Egypt. J. Plant Breed,* **9:** 197- 208.

Duc, G. (1997) Faba bean (*Vicia faba* L.), *Field Crops Res.,* **53**: 99- 109.

El-Hady, M.M., Omar, M.A., Nasr, S.M., Mahmoud, S.A. and **El-Waraky, M.K.** (1998) Performance of some faba bean genotypes along with F_1 and F_2 generations, *Annals of Agriculture Science, Moshtohor. Faculty of Agriculture, Zagazig University,* **36(**2): 729-743.

El-Hady, M.M., Olaa, S.M.A., El-Galaly, A.M. and **Salem, M.M.** (2006) Heterosis and combining ability analysis of some faba bean genotypes, *J. Agric. Res. Tanta Univ*., **32**: 134-148.

El-Hady, M.M., Rizk, A.M., Omran, M.M. and **Regheb, S.B.** (2007) Genetic behaviour of some faba bean (*Vicia faba* L.) genotypes and its crosses, *Ann. Agric. Moshtohor,* **45**: 49-60.

El-Hosary, A.A., Shokr, S., El-Halim, A.A.A., Nasr, S.M. and **El-Aziz, A.M.A.** (1997) Heterosis and combining ability in faba bean (*Vicia faba* L.), *Egyptian Journal of Agricultural Research,* **75**: 811-826.

El-Keredy, M.S., El-Refaey, R.A., El-Hity, M.A. and **Zied, G.G.A.** (1999) Estimation of heterosis and combining ability in faba bean under two plant population densities. I-Earliness attributed. *Annals of Agriculture Science, Moshtohor, Faculty of Agriculture, Zagazig University,* **37**: 897-916.

El-Rafaey, R.A., El-Keredy, M.S., El-Hity, M.A. and **Zied, G.G.A.** (1999) Estimation of heterosis and combining ability in faba bean under two plant population densities, II-Yield and some of its components, *Annals of Agriculture Science, Moshtohor. Faculty of Agriculture, Zagazig University,* **37**: 917-939.

Griffing, B. (1956) Concept of general and specific combining ability in relation to diallele crossing systems, *Aust. J. Biol. Sci*., **9**: 463-493.

Haciseferogullari, H., Geaer, I., Bahtiyarca, Y. and **Menges, H.O. (**2003) Determination of some chemical and physical properties of Sakiz faba bean (*Vicia faba* L. Var major), *J. Food Eng.,* **60**: 476- 479.

Kaul, D.K. and **Vaid, K.L.** (1996) Combining ability in Faba bean, *FABIS Newsletter,* **38/ 39**: 12-17.

Lindemann, C. and **Glover, R.** (2003) *Nitrogen Fixation by Legumes*, New Mexico State University, Mexico. Available at: www.cahe.nmus.edu/pubs/_a/a-129.pdf.

Salama, S.M. and **Salem, M.M.** (2001) Genetic analysis and combining ability over sowing dates for yield and its components in faba bean (*Vicia faba* L.), *Agric. Sci., Mansora University,* **26**: 3621-3629.

Steel, R.G. and **Torrie, J.M.** (1984) *Principles and Procedures of Statistics*, McGraw-Hill Co. Inc., New York.

Stelling, D. (1997) Heterosis and hybrid performance in topless faba beans (*Vicia faba* L.). *Euphytica,* **97**: 73-79.

Suso, M.J. and **Moreno, M.T.** (1999) Variation in outcrossing rate and genetic structure on six cultivars of *Vicia faba* L. as affected by geographic location and year, *Plant Breed,* **118**: 347-350.

Toker, G. (2009) Estimates of broad-sense heritability for seed yield and yield criteria in faba bean (*Vicia faba* L.), *Hereditas*, **140** (3): 222-225.

قوة الهجين والقدرة على الائتلاف ومكونات التباين الوراثي في الفول البلدي

حسام الدين إبراهيم

قسم المحاصيل، كلية الزراعة، جامعة الأسكندرية، مصر

المستخلص. تم قياس ثمانية صفات فى سبعة آباء من الفول البلدي وهجن الجيل الأول الناتجة من إجراء كل التهجينات الممكنة بين هؤلاء الآباء فى اتجاه واحد، وذلك بمزرعة محطة البحوث الزراعية التابعة لكلية الزراعة- جامعة الإسكندرية خلال موسم ٢٠٠٦/٢٠٠٧م. تم تقييم السبعة آباء بالإضافة إلى ٢١ هجين في تجربة مقارنة محصول الفول في تصميم قطاعات عشوائية كاملة بثلاث مكررات فى موسم ٢٠٠٧/٢٠٠٨م. أوضحت النتائج المسجلة على نباتات الجيل الأول، أن هناك اختلافات معنوية بين الآباء وهجن الجيل الأول، مما يشير إلى اختلافات وراثية لكل الصفات المدروسة ويعطى إمكانية للتحسين الوراثى من خلال الاختلافات الوراثية لتراكيب الفول البلدي. سجلت بعض الهجن قيماً معنوية لقوة الهجين سواء المحسوبة على أساس متوسط الأبوين أو الأب الأعلى محصولاً لصفة محصول البذور للنبات، ووزن المائة بذرة، وتراوحت القيم من ١٧,٤٦-٨٤,٩٥٪، و٤٧,٢٢-٦٨,٤٩٪، و٨,٥٣-٢٣,٢٦٪، و١٠,٤٣-١٨,٦٤٪ بالنسبة إلى متوسط الأبوين، والأب الأعلى محصولاً لكل صفة على التوالي.

وكانت كلاً من القدرة العامة والقدرة الخاصة على الائتلاف معنوية فى جميع الصفات المدروسة، مما يشير إلى أهمية كلٍّ من

مكوني التباين فى جميع الصفات المدروسة فى توارث هذه الصفات.

أعطى الصنف جيزة بلانكا قيماً معنوية لكل الصفات المدروسة، ماعدا صفة عدد القرون للنبات، وميعاد النضج، مما يؤكد أهمية استخدام الصنفين جيزة بلانكا و ILB450 في برامج التربية للعمل على زيادة وزن ١٠٠ بذرة، وكذلك محصول النبات الفردي. أما بالنسبة للقدرة الخاصة على الائتلاف، فقد أعطى العديد من الهجن قدرة خاصة معنوية لعديد من الصفات وخاصة الهجن Giza 716× ILB 450 and ILB 450 × Giza Blanca الذى أعطى معنوية موجبة لكل من محصول البذرة للنبات، وصفة الـ ١٠٠ بذرة، وتراوحت نسبة تقديرات درجة التوريث بالمعنى الضيق، وكانت (٠,٥٤) بالنسبة لوزن الـ ١٠٠ بذرة، وأعطى قيماً منخفضة لارتفاع النبات المنخفض، بينما كانت منخفضة لصفة المحصول البذري للنبات الفردي.