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Full Length Research Paper

Assessment of heterosis and features of gene activity for yield and its components in faba bean (*Vicia faba* L.)

***Saad Ebeid, Hussein Zaghloul and Atef Pasha Sirri**

Department of Horticulture, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.

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Five Egyptian parental genotypes of Faba bean were used for carrying out half diallel design to study heterosis and nature of gene action for earliness, vegetative, yield and yield components traits. Mean squares of genotypes were found to be highly significant for all studied traits. The results showed that the majority of crosses exhibited significant heterosis estimates for better parent for all studied traits. General combining ability (GCA) and specific combining ability (SCA) mean squares were highly significant for all studied traits. The results indicated that the magnitude of additive genetic variance (σ^2A) were positive and lower than those of non additive (σ^2D) one for all the studied traits, indicating that non additive gene action played a major role in the inheritance of different traits under study. The broad sense heritability estimates (H^2_b %) were more than their corresponding narrow sense heritability (H^2_n %) for all studied traits. However, estimates of narrow sense heritability were 34.2 and 14.8% for earliness traits and ranged from 15.2 to 29.8% for number of branches per plant and plant height, respectively. Respecting to yield components, the estimates of narrow sense heritability ranged from 8.8 to 70.9% for number of pod per plant and weight of 100 seed (g), respectively. The results showed that the two cultivar, Giza 843 (P_4) and Misr 2 (P1) was good general combiner for earliness, yield and yield components, respectively. The cross (P_1xP_5) showed desirable SCA effects and significant heterosis values for earliness, and yield components. While, the two crosses, (P_1xP_3) and (P_3xP_4) exhibited desirable SCA effects for vegetative traits. These promising crosses could be used for breeding programs to produce pure lines.

Key words: Faba bean, general combining ability (GCA), specific combining ability (SCA), heterosis, gene action.

INRODUCTION

Faba bean (*Vicia faba* L.) is one of the most important pulse crops in Egypt; it is plays an important role in world agriculture due to the high protein content, its ability to fix atmospheric nitrogen and its capacity to grow and yield well on marginal lands (Alghamdi, 2007; Farag and Afia, 2012). Great efforts have been directed to improve yield level and quality properties in faba bean. In this trend, heterosis and combining ability provide important information for improving seed yield and other economic traits in faba bean. Superiority of hybrids over the better parent for seed yield and its attributes are associated with the magnitude of heterotic effects in important yield attributes, that is, number of branches per plant, pod setting percentage, number of pods per plant, 100-seed weight, shellout percentage and pod filling percentage. These heterotic effects may range from significantly positive to significantly negative for various traits according to genetic makeup of the parents (El-Keredy et al., 1999; Darwish et al., 2005; El-Hady et al., 2006; Farag and Afia, 2012).

*Corresponding author. E-mail: Saad 2012@alazhar.org

In this respect, different sizes of heterotic effects were obtained by many authors for economic traits in faba bean and desirable heterotic values over better parent for earliness, vegetable and yield components traits (Bond, 1964; Waly, 1982; Mitkees and Hassan, 1983; Kitiki and Demir, 1984; Mahmoud et al., 1984; Waly and Abdel-Aal, 1986; Mahmoud and Al-Ayobi, 1987; Ebmyer, 1988; El-Morsy, 1990; Kaul and Vaid, 1996; Melchinger, 1996; El Hosary et al., 1997; Stelling, 1997; El-Hady et al., 1998; Schill et al., 1998; Yamani, 1998; Abdelmula et al., 1999; Suso and Moreno, 1999; Bashoot, 2000; Abdalla et al., 2001; Attia et al., 2002; Zeid, 2003; Ahmed and Kambal, 2005; Darwish et al., 2005; Attia and Salem, 2006; El-Hady et al., 2006, 2007; Kunkaew et al., 2006; Tantawy et al., 2007; Alghamdi, 2009; Ibrahim, 2010).

Furthermore the roles of general combining ability (GCA) and specific combining ability (SCA) in the inheritance of faba bean were studied by several authors (Kaul and Vaid, 1996; El-Keredy et al., 1999; El-Refaey et al., 1999; Attia and Morsy, 2001; Salama and Salem, 2001; Attia et al., 2002; Attia and Salem, 2006; Ibrahim, 2010). GCA values were obtained for number of branches per plant, number of pods per plant, maturity time and 100-seed weight. While, significant SCA value was only noted for yield components. Alghamdi (2009) noticed that the estimates of GCA were larger than those of SCA for all the studied traits except for seed yield per plant, reflecting the importance of additive gene action in the expression of these traits. Moreover, Tantawy et al. (2007) found that the estimates of GCA and SCA were significant for earliness and yield components, suggesting the importance of additive and non-additive gene action in the inheritance of these traits.

The objective of the present study was to study heterosis and the types of gene action controlling the inheritance of earliness and economical traits of faba bean.

MATERIALS AND METHODS

This study was carried out during the two growing seasons of 2009/2010 and 2010/2011 in the Research Farm of the Faculty of Agriculture, Sohag University. Where, the soil is reclaimed with top layer (25 cm) of clay-loam. Five different local faba bean cultivars, Misr 2 (P_1), Giza 429 (P_2), Misr 1 (P_3), Giza 843 (P_4) and Giza 40 (P_5) (*V. faba* L.) representing a wide range of variability in their agronomic traits, were used in this study. In the winter season of 2009/2010, the seeds of all parents were sawn on 15 October under greenhouse Cage and crossed in a half diallel mating design to produce 10 F_1 hybrids.

In 2010/2011 season, the five parental genotypes and their crosses (10 F_1 hybrids) were sawn in a randomized complete block design with three replicates. Each experimental plot consisted of three ridges of 4 m length and 60 cm width. Hills were spaced 20 cm with two plants per hill.

At harvest, ten guarded plants were randomly sampled from each plot to measure the following traits: earliness, days to the 50% flowering (D50% F) and days to the 50% maturity (D50% M), vegetative traits, Plant height cm (PH), number of branches per plant (No. B/P) and pod setting percentage (PS%) which were estimated as number of pods that set/number of flowers that anthesized and yield traits, number of pods per plant (No. p/p), 100-seed weight (100SW). While the two traits, shellout percentage (Sh%) which were estimated as weight of dry seeds per plant/weight of dry pods per plant × 100, pod filling percentage (PF%) estimated as number of seeds per pod/pod length × 100, and total dry seed yield kg/ha (TDSY) and protein content percentage (PC%). Data were subjected to analysis of variance in order to test the significance of the differences according to Cochran and Cox (1957).

Statistical analysis

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

$$Y_{ij} = \mu + g_i + g_j + e_{ijk}$$

Where: Y_{ij} = Observation of ith treatment in the jth block (i,j= 1, 2, …., p); μ = general mean; g_i = effect of the ith cultivar as one parent; g_j = effect of the jth cultivar as second parent; e_{ijk} = experimental error.

The heterotic effects of F_1 crosses were estimated (as better parent) according to Singh and Khanna (1975).

Estimates of heritability in both broad and narrow sense were calculated according to the following equations:

$$h^2 = [(\sigma^2_A + \sigma^2_D) / (\sigma^2_A + \sigma^2_D + \sigma^2_e)] \times 100$$
$$h^2 = [(\sigma^2_A) / (\sigma^2_A + \sigma^2_D + \sigma^2_e)] \times 100$$

Sums of squares for genotypes was partitioned according to Griffing`s (1956) as method 2 model 1 (all possible combinations excluding reciprocals) into sources of variation due to GCA and SCA. The variances of GCA (σ^2_g) and SCA (σ^2_s) were obtained on the basis of the expected mean squares for all studied straits. Additive (σ^2_A) and non-additive (σ^2_D) genetic variances were estimated according to Matzinger and Kempthorne (1956).

RESULTS AND DISCUSSION

Genotypic variations

The analyses of variance for all studied traits showed that highly significant differences among faba bean genotypes for all studied traits (Table 1). This provides evidence for the presence of considerable amount of genetic variation among the studied genotypes. These results are in harmony with those obtained by Waly (1982), Waly and Abdel-Aal (1986), Mahmoud and Al-Ayobi. (1987), El-Hady et al. (1998), Attia et al. (2002), Darwish et al. (2005), El-Hady et al. (2006, 2007), Kunkaew et al. (2006), Tantawy et al. (2007), Alghamdi (2009) and Ibrahim (2010).

Heterotic effects

Estimates of heterosis better parent for all studied traits are presented in Table 2. In this direction, six crosses significantly flowered and/or matured earlier than their better parent with negative heterosis values ranging from

Table 1. Mean squares of variance of faba been genotypes for different studied traits.

S.V	DF	PH (cm)	No.B/P	No.D50% F	No.D50% M	PS%	TDSY	100S W	No. P/P	Shellout (%)	PF%	Protein (%)
Reps.	2	4.466	0.0287	0.156	0.0889	1.910	79.442	0.0441	0.0467	0.999	0.0002	0.586
Geno	14	51.086**	0.468**	10.356**	12.794**	40.651**	341588.418**	25.671**	94.377**	118.878**	0.0210**	8.228**
Error	28	0.752	0.0106	0.632	0.589	3.336	1738.163	0.0758	0.0718	0.218	0.0002	0.782

*, ** Significant different at 0.05 and 0.01 levels of probability, respectively No.D50% F, days to the 50% flowering; No.D50% M, days to the 50% maturity; PH, Plant height, no. B/P, number of branches per plan; PS%, pod setting percentage; TDSY, total dry seed yield kg/ha; No. P/P, number of pods per plant; PF%: pod filling percentage, 100S W: 100-seed weight.

Table 2. Estimates of heterosis over better parents for all studied traits.

Crosses		No. D50% F	No. D50% M	PH (cm)	No.B/P	PS%	TDSY	No. P/P	Shellout (%)	PF%	100S W	Protein (%)
P_1xP_2		7.55**	0.72	-7.30**	24.40**	19.02**	113.80**	53.10**	9.69**	23.58**	-2.70**	-4.38**
P_1xP_3		-1.74*	-2.47**	2.10**	8.90**	11.61**	86.58**	32.51**	0.99*	-14.23**	0.12	-4.17**
P_1xP_4		0.94	1.81**	-8.30**	13.80**	5.87**	77.67**	3.97**	-6.12**	7.84**	-3.95**	-5.79**
P_1xP_5		-11.76**	-7.61**	-2.80**	15.40**	17.33**	67.87**	25.07**	3.83**	2.69**	-3.59**	-15.66**
P_2xP_3		-8.70**	-3.89**	-6.20**	14.70**	25.85**	20.54**	18.93**	-10.94**	-3.46**	-7.52**	-7.62**
P_2xP_4		3.74**	0.37	7.70**	17.10**	8.69**	56.73**	24.28**	12.58**	8.58**	-6.31**	-4.70**
P_2xP_5		-3.36**	-2.77**	-4.50**	-11.80**	15.29**	32.33**	37.36**	-5.20**	-4.23**	-7.12**	-16.09**
P_3xP_4		-2.61**	-1.06	0.90	33.00**	-5.82**	15.21**	46.42**	0.98*	-6.54**	-5.45**	-11.61**
P_3xP_5		3.36**	-2.08**	-1.20	-2.60**	21.21**	27.94**	23.21**	-0.92*	-10.38**	-6.87**	-11.63**
P_4xP_5		-10.08**	-6.92**	1.60*	-9.80**	-3.18**	24.52**	27.98**	12.23**	-1.49**	-5.73**	-21.19**
LSD	0.05	1.329	1.283	1.450	0.175	1.223	6.987	0.449	0.781	0.017	0.467	1.480
	0.01	1.793	1.731	1.956	0.237	1.650	9.427	0.605	1.053	0.023	0.630	1.996

*; ** Significantly different at 0.05 and 0.01 probabilities level; No.D50% F, days to the 50% flowering; No.D50% M, days to the 50% maturity; PH, Plant height; no. B/P, number of branches per plan; PS%, pod setting percentage; TDSY, total dry seed yield kg/ha; No. P/P, number of pods per plant; PF%, pod filling percentage; 100S W, 100-seed weight.

-11.76 to -1.74% for days to 50% flowering and from -7.61 to 1.81% for days to 50% maturity. In respect to vegetative traits, three, seven and eight crosses exhibited significant positive heterotic effects relative to better parent for plant height (ranged from 1.6 to 7.7%), number of branches per plant (ranged from 8.9 to 33.0%) and pod setting percentage (ranged from 5.87 to 25.85%), respectively. Regarding yield traits, all crosses exhibited significant positive heterosis values for total dry seed yield kg/ha (15.21 to 113.80%) and number of pod per plant (3.97 to 53.10). While, Out of 10 crosses, only six crosses exhibited significant positive heterosis values relative to better parent for shellout percentage (0.99 to 12.58) and pod filling percentage (2.69 to 23.58). For weight of 100-seeds and protein content percentage all crosses exhibited significant negative heterosis values relative to better parent. In general, these results indicate that most crosses were significantly earlier and higher yielding than their better parent, suggesting the important role of non-additive gene action in the inheritance of studied traits. Pronounced and favorable heterosis values relative to better parents have been obtained by several investigators for faba bean traits which varied according to the cross combinations and traits (Duc, 1997; Stelling, 1997; Schill et al., 1998; Abdelmula et al., 1999; Bond and Crofton, 1999; Filippetti et al., 1999; Abdalla et al., 2001; Attia et al., 2002; Zeid, 2003; Ahmed and Kambal 2005; Darwish et al.,

Table 3. Half diallel analysis of variance of general combining ability (GCA) and specific combining ability (SCA) for all studied traits.

S.V	DF	No. D50% F	No. D50% M	PH (cm)	No.B/P	PS	TDSY	No. P/P	Shellout (%)	PF	W100S	Protein (%)
GCA.	4	16.752**	12.881**	68.109**	0.444**	20.891**	199512.815**	28.445**	146.826**	0.0276**	60.641**	6.128**
SCA	10	7.797**	12.759**	44.276**	0.478**	48.554**	398418.659**	120.750**	107.699**	0.0184**	11.683**	9.0678**
Error	28	0.632	0.589	0.752	0.0106	3.336	1738.163	0.0718	0.218	0.0002	0.0758	0.782

*; ** Significant different at 0.05 and 0.01 levels of probability; respectively; No.D50% F, days to the 50% flowering; No.D50% M, days to the 50% maturity; PH, Plant height; no. B/P, number of branches per plan; PS%, pod setting percentage; TDSY, total dry seed yield kg/ha; No. P/P, number of pods per plant; PF%, pod filling percentage; 100S W, 100-seed weight.

Table 4. Estimates of general combining ability effects (g_i) of each parent for all studied traits.

Genotypes	No. D50% F	No. D50% M	PH	No.B/P	PS	TDSY	No. P/P	Shellout (%)	PF	W100S	Protein (%)
P1 Misr 2	-0.695*	-0.286	1.495**	-0.097	0.884	143.459**	1.978**	-2.512**	-0.047**	0.805**	-0.375
P2 Giza 429	-0.314	-0.571*	-2.267**	0.027	0.610	-22.351	-0.393**	-2.759**	-0.020**	-0.667**	-0.576
P3 Misr 1	0.829**	0.810**	1.924**	-0.183	-0.704	17.812	0.011	1.723**	0.022**	2.552**	0.143
P4 Giza 843	-0.886**	-0.810**	-1.362**	0.060	0.610	-10.487	-0.993**	3.321**	0.046**	-0.943**	-0.014
P5 Giza 40	1.067**	0.857**	0.210	0.193	-1.399*	-128.433**	-0.603**	0.226	-0.001	-1.748**	0.821*
SE (gi)	0.269	0.259	0.293	0.035	0.617	14.094	0.091	0.158	0.005	0.093	0.299

*; ** Significant different at 0.05 and 0.01 levels of probability; respectively; No.D50% F, days to the 50% flowering; No.D50% M, days to the 50% maturity; PH, Plant height; no. B/P, number of branches per plan; PS%, pod setting percentage; TDSY, total dry seed yield kg/ha; No. P/P, number of pods per plant; PF%, pod filling percentage; 100S W, 100-seed weight.

2005; Attia and Salem, 2006; El-Hady et al., 2006; Kunkaew et al., 2006; El-Hady et al., 2007; Gasim and Link, 2007; Tantawy et al., 2007; Ghaouti and Link, 2008; Link et al., 2008; Alghamdi, 2009; Ibrahim, 2010).

Combining ability analysis

Mean squares of general and specific combining ability for all studied traits are presented in Table 3. The results showed that mean squares of general combining ability (GCA) and specific combining ability (SCA) were highly significant for all studied traits. These results indicated that both GCA and SCA were important in the inheritance of these traits. However, the variance due to GCA was more pronounced for days to 50% flowering, days to 50% maturity, plant height, shellout percentage, pod filling percentage and weight of 100 seeds consider as a result of additive gene action. Meanwhile, variance due to SCA as an indicator of non-additive gene action, was greater for number of branches per plant, pod setting percentage, total dry seed yield, number of pod per plant and protein content percentage These findings is in agreement with those reported by Kaul and Vaid (1996), El-Keredy et al. (1999), El-Refaey et al. (1999), Attia and Morsy (2001), Salama and Salem (2001), Algamdi (2009) and Ibrhim (2010).

GCA effects (gi)

Estimate of general combining ability effects (gi) of each parent for all studied traits were presented in Table 4. Results showed that Misr 2 (P_1) was the best general combiner for plant height, total dry seed yield, number of pods per plant and 100-seed weight. While, Giza 429 (P_2) was the best general combiner for maturity time and Misr 1 (P_3) was good general combiner for plant height, shellout percentage, pod filling percentage and 100-seed weight. Meanwhile, Giza 843 (P_4) was good general combiner for days to 50 % flowering, days to 50 % maturity, shellout percentage and pod filling percentage. However, Giza 40 (P_5) was good general combiner for protein content percentage. Consequently, Misr 2 (P_1) and Giza 843 (P_4) which exhibited useful general combining ability effects could be utilized in breeding programs to improve earliness and yield components and Giza 40 (P_5) for protein content percentage

Table 5. Estimates of specific combining ability effects (S_{ij}) of each cross for all studied traits.

Genotypes	No. D50% F	No. D50% M	PH (cm)	No. B/P	PS	TDSY	No. P/P	Shellout (%)	PF	W100S	Protein (%)
P1xP2	2.032**	1.302	-2.429*	0.524**	2.585	427.579**	7.006	6.822**	0.101**	-0.038	-0.048
P1xP3	0.556	-0.746	3.714**	0.300**	1.253	452.273**	1.868**	1.884**	-0.070**	-0.924**	-0.251
P1xP4	0.270	2.540**	1.667*	0.124	1.135	279.334**	-1.794**	-0.484	0.052**	-0.795**	0.393
P1xP5	-2.349**	-3.794**	-6.571**	-0.243*	3.991*	161.470**	5.249**	-4.340**	0.039**	0.310	-1.822**
P2xP3	-2.492**	-1.794*	-3.857**	-0.024	4.513**	-18.111	0.006	-1.266**	0.122**	-1.886**	-0.240
P2xP4	1.222	0.159	-0.238	0.200*	2.502	257.048**	1.311**	-8.990**	-0.029*	-2.924**	0.724
P2xP5	0.603	1.159	5.857**	0.100	1.611	20.040	4.854**	3.621**	-0.008	-1.552**	-2.655**
P3xP4	0.413	1.111	2.905**	0.510**	-1.810	-81.305*	9.173**	8.041**	0.063**	0.190	-0.518
P3xP5	2.127**	0.444	-0.667	0.310**	3.829*	159.304**	1.549**	-2.378**	-0.083**	-0.238	0.386
P4xP5	-1.492*	-2.603**	2.619**	-0.300**	-0.092	73.796	2.421**	9.251**	-0.008	-1.376**	-2.339**
SE (Sij)	0.694	0.670	0.757	0.090	1.594	36.391	0.234	0.408	0.012	0.240	0.772

*; ** Significant different at 0.05 and 0.01 levels of probability; respectively; No.D50% F, days to the 50% flowering; No.D50% M, days to the 50% maturity; PH, Plant height; no. B/P, number of branches per plan; PS%, pod setting percentage; TDSY, total dry seed yield kg/ha; No. P/P, number of pods per plant; PF%, pod filling percentage; 100S W, 100-seed weight.

SCA effects (S_{ij})

Estimated specific combining ability effects (S_{ij}) shown in Table 5 revealed that the cross combination (P_1xP_5), resulting from poor x poor general combiners, showed desirable negative significant SCA effects for earliness. As well as cross combination (P_2xP_3) and (P_4xP_5), resulting from crossing (good x poor) general combiners, showed desirable negative significant SCA effects for earliness. While for vegetative traits, five crosses exhibited positive SCA effects for plant height and number of branches per plant and only three crosses for pod sitting percentage. Concerning yield and yield components six, seven and five out of the ten hybrids were the best yielding crosses for total dry seed yield, number of pod per plant, shellout percentage and pod filling percentage, respectively.It could be noted that the promising crosses which showed desirable SCA effects exhibited high heterosis values for studied traits. These promising crosses could be used for faba bean hybrids. The results also revealed that GCA effects, for some traits, were related to several SCA values of their corresponding crosses, where the two parents P_3 and P_4, which exhibited significant and positive GCA effects for shellout percentage and pod filling percentage, produced crosses had 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 results are in agreement with Abdalla et al. (2001), Attia et al. (2002), Zeid (3003), Darwish et al. (2005), Attia and Salem (2006), El-Hady et al. (2006, 2007), Algamdi (2009) and Ibrhim (2010). They found that the best combinations as judged from SCA effects involved high x low combiners and the combinations involving the two best combiners did not exhibit SCA effects.

Gene action

Estimates of all types of gene action for all studied traits are presented in Table 6. The results indicated that the magnitude of additive genetic variance (σ^2_A) were positive and lower than those of non additive (σ^2_D) one for all of studied traits.

This finding could be verified by the ratio $(\sigma^2_D/\sigma^2_A)^{1/2}$ which was higher than one, indicating that non additive gene action played a major role in the inheritance of these studied traits. Similar findings were reported by El-Hady et al. (1998), Salama and Salem (2001), Toker (2009) and Ibrahim (2010). The additive and dominance components of genetic variance is very important in evaluating the potential of any heterotic response inbreeding depression not only reduces auto fertility and hence yield in the absence of

Table 6. Estimates of genetic parameters and heritability in broad (H^2_b%) and narrow (H^2_n%) sense for all studied traits.

Genetic parameter	No. D50% F	No. D50% M	PH (cm)	No.B/P	PS	TDSY	No. P/P	Shellout (%)	PF	W100S	Protein (%)
σ^2A	4.096	6.756	21.070	0.254	16.595	8436.456	5.777	16.120	0.010	9.767	3.914
σ^2D	9.969	17.472	61.186	0.564	59.717	413807.100	113.123	133.406	0.025	12.273	10.613
σ^2e	0.215	0.189	0.230	0.004	0.172	540.955	0.024	0.092	0.001	0.022	0.227
$(\sigma^2D/\sigma^2A)^{1/2}$	1.560	1.608	1.704	1.491	1.897	7.004	4.425	2.877	1.576	1.121	1.647
H^2b%	94.6	95.9	98.8	97.4	98.9	99.6	99.9	99.8	99.3	99.8	91.2
H^2n%	34.2	14.8	29.8	15.2	18.4	27.9	8.8	33.6	30.7	70.9	11.1

No.D50% F, Days to the 50% flowering; No.D50% M, days to the 50% maturity; PH, Plant height; no. B/P, number of branches per plan; PS%, pod setting percentage; TDSY, total dry seed yield kg/ha; No. P/P, number of pods per plant; PF%, pod filling percentage; 100S W, 100-seed weight.

pollinators, but also reduces yield through the loss of heterosis.

Estimates of heritability

The results in Table 6 showed that broad sense heritability estimates (H^2_b %) were higher than their corresponding of narrow sense heritability (H^2_n %). The estimates of narrow sense heritability were 34.20 and 14.8% for earliness traits. For vegetative traits, the estimates of narrow sense heritability ranged from 15.2 to 29.8% for number of branches per plant and plant height, respec-tively. Respecting to yield and yield components, the estimates of narrow sense heritability ranged from 8.8 to 70.9% for number of pod per plant and 100-seed weight, respectively. These findings may indicated that the possibility of increasing seed yield through selection for 100-seed weight and considered as one of important yield component. Heterosis, expressed as increase in vigor of the F1 hybrid over the better parent results from the combined action and interaction of allelic and interallelic genes. Similar findings were reported by Salama and Salem (2001), Toker (2009) and Ibrahim (2010).

Conclusion

From the data presented in this study, it could be concluded that the cross combination (P1xP5), (P2xP3), and (P4xP5) showed desirable SCA effects and significant heterosis values for most studied traits. This finding reflects the presence of considerable heterosis values, suggested that non additive gene effects played the major role in the inheritance of these traits. These promising crosses could be used for developing faba bean hybrids. The present study reveals that several combinations of crosses are highly promising to breeding faba bean cultivars for earliness and high yielding potential.

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