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Performance of Six Faba Bean Genotypes and Their F_2 Hybrids and Reciprocals

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Authors' contributions

This work was carried out in collaboration between all authors. All authors conceived and designed the study, participated in drafting and correcting the manuscript critically and gave the final approval of the version to be published.

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ABSTRACT

The present investigation was carried out at Giza and Sids Research Stations during 2011/2012 to 2013/14 growing seasons. A diallel cross including reciprocals among six faba bean genotypes (, Giza 843, Nubaria 1, Cairo 25, Cairo 5, Cairo 33 and Misr 3) was utilized to estimate different sources of genetic variability and other derived parameters, seed yield and its components: pods, seeds and 100-seed weight. Analysis of parent and F_2's indicated that Giza 843 and Nubaria 1 were good combiners for number of branches, seed yield/plant and 100-seed weight. The parent Cairo 25 was good combiner for pods/plant, seeds/plant and seed yield/plant. High GCA/SCA ratios revealed the predominance of additive gene action in most cases. Thus, selection could be favored for improving these traits. The additive genetic variance (D) was highly significant for pods/plant, seed yield/plant and 100-seed weight indicating that additive effect is important in the inheritance of these traits. Therefore selection would be expected to be effective. The component of variation due to dominance effects (H_1) was highly significant for all traits indicating the presence of dominance with asymmetrical gene distribution in the parental genotypes. All traits had high values of H_1 and H_2 than "D" except 100-seed weight indicating the important role of dominance genetic variance. Heritability estimates in narrow sense ranged from 0.01% in plant height to 42%

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for number of branches. Both additive and non-additive genetic variances played role in inheritance of different traits. Significant reciprocal-cross differences in F_2 should impose direction of crossing in favor of plasmon effects.

Keywords: Faba bean; combining ability; heritability; gene action; reciprocal-crosses.

1. INTRODUCTION

Faba bean is one of the oldest crops in the world. Globally, it is the third most important feed grain legume after soybean (*Glycine max*) and pea (*Pisum sativum* L). According to Food and Agriculture Organization (FAO), presently, it is grown in 58 countries.In Egypt; faba bean (*Vicia faba* L.) is one of the most important pulse crops. It 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 [1,2]. 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. 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 [3,4,5,2].

Combining ability analysis helps the breeders to identify the best combiners which may be hybridized either to exploit heterosis or to build up the favorable fixable genes. El-Hosary [6], found that the additive variance as well as non-aditive gene action might be controlling the inheritance of yield and its components in faba bean. Abdalla et al., Attia et al., El-Hady et al., Abdalla et al., [6-11] reported that both GCA and SCA variance were important for yield and its components.

The low heritability and consequent limited genetic improvement for yield in response to selection has led many scientists to search for characters which are associated with yield and are relatively highly heritable. Attia et al., Darwish et al., El-Hady et al., El-Hady et al. and Abdalla et al., [12,4,5,13,10] revealed that non- additive effects were more important for number of branches, pods, seeds and seed yield/plant than additive effects. On the other hand, the additive variance was important for 100-seed weight.

In systemic breeding program, the genetic variance components analysis in terms of type of gene action and breeding potentials of genetic entries involved in such program are obviously essential. The diallel analysis is a method for identifying parents that have superior combinations of the characters of interest.

The present study aimed to determine the magnetite of general and specific combining ability and nature of gene action of some faba bean hybrid combinations.

2. MATERIALS AND METHODS

The field experiments of the present study were carried out at Giza and Sids Research Stations, Agriculture Research Center (ARC), Egypt during 2011/2012, and 2012 / 2013 and 2013/2014 seasons. Six diverse faba bean (*Vicia faba* L.) varieties were used. The origin, pedigree and some features of these parental genotypes are presented in Table 1.

A diallel-mating including reciprocals was carried out among the six faba bean genotyps during 2011/2012 season and the $F_1$was raised in 2012/2013 to obtain F_2 in Giza. In 2013/14, at Sids an experiment was conducted in open field that included six parents and each of 30 F_2's. A randomized complete block design with five replications was used. Each ridge (plot) was 3 m long and 60 cm apart. aSeeds were sown individually at one side of ridge at 20 cm distance. Sowing date took place on mid-November 2013 at Giza and Sids Research Stations and harvested on end of April 2014. Ordinary cultural practices were applied to the faba bean fields.

The following data were recorded: days to flowering, plant height (cm), number of branches/plant, number of pods/plant, number of seeds/plant, seed yield/plant (g), and 100-seed weight (g).

Data were analyzed according to Griffing [14] Method 1, Model 1. In this approach, the combining ability variances and effects were estimated. Significant differences among genotypes were tested by regular analysis of variance of the RCBD according to Gomez and Gomez [15]. Genetic components of variation and genetic parameters were estimated according to Hayman and Jinks [16,17,18] using MSTAT-C Version 5.4 [19].

3. RESULTS AND DISCUSSION

Results of statistical analysis presented in Table 2, reveled highly significant differences among genotypes for all studied characters, indicating wide genetic variability for all variables. 100-seed weight recorded the highest mean square preceded by Number of seeds/plant.

The mean performance of parental genotypes and their F_2 crosses are presented in Tables 3 and 4. Cairo 33 and Misr 3 were the earliest parents (39.80). The parental genotype Nubaria 1 (P_2) exhibited the highest estimates of seed yield/plant (37.80) and the heaviest 100- seed weight (103.35). Cairo 25 (P_3) recorded the tallest plants (86.83) with the highest number of pods/plant (17.08) and number of seeds/plant (46.96).

With respect to the tested F_2crosses, results showed that six crosses ((P_1 x P_2), (P_1 x P_5), (P_2 x P_6), (P_4x P_1), (P_4x P_3) and (P_6x P_5); four crosses (P_1 x P_2), (P_2 x P_5), (P_3 x P_6) and (P_3x P_1); five crosses (P_2 x P_5), (P_2x P_1), (P_4 x P_1) (P_4 x P_2) and (P_6x P_3); four crosses (P_1 x P_2), (P_1 x P_3), (P_3 x P_4) and (P_4x P_1); four crosses (P_1 x P_2), (P_3 x P_4), (P_4 x P_1) and (P_3 x P_2); three crosses (P_2 x P_1), (P_2 x P_6) and (P_3 x P_2) and five crosses (P_2 x P_5), (P_2 x P_6), (P_3 x P_1) (P_4 x P_2) and (P_6x P_3) had higher values for days to flowering, plant height, number of branches/ plant, number of pods/plant, number of seeds/plant, seed yield /plant, and 100-seed weight, respectively. The cross (P_1 x P_2) had the highest mean values for all studied traits except for branches/plant and 100-seed weight.

Table 1. Origin, pedigree and some features of parental genotypes

Parent	Origin	Pedigree	Characters
Giza 843 (P_1)	FCRI*	Cross 461 x Cross 561	Early flowering and maturity, tolerant to *Orobanche* and resistant to foliar diseases
Nubaria1 (P_2)	FCRI	Selected from Giza Blanca	Large seeded type, with colorless hilum, resistant to foliar diseases and late flowering and maturity
Cairo 5 (P_3)	ADFACU**	Synthetic variety	Medium seeds, tolerant to *Orobanche*
Cairo 25 (P_4)	ADFACU	Synthetic variety	Medium seeds, tolerant to *Orobanche*
Cairo 33 (P_5)	ADFACU	Individual selection from program	Medium seeds, tolerant to *Orobanche, with colorless hilums*
Misr3 (P_6)	FCRI	L-667x (Cairo241x Giza 461)	Medium seeds, tolerant to *Orobanche*

**FCRI= Field Crops Research Institute, ARC, **ADFACU= Agron. Dept., Fac. Agric.., Cairo University*

Table 2. Significant of mean squares for faba bean parents and the F_2 diallel crosses

S V	d f	Days to flowering	Plant height	Branches/ plant	Pods/ plant	Seeds/ plant	Seed yield/ plant	100-seed weight
Genotypes	35	40.54**	192.23**	47.15**	26.12**	213.16**	178.54**	430.81**
G C A	5	14.82**	7.22	0.46**	4.84**	53.84**	61.92**	165.83**
S C A	15	10.72**	53.87**	0.15**	3.68**	44.98**	26.60**	75.74**
Reciprocals	15	3.26**	33.43**	0.32**	6.90**	36.54**	36.08**	70.03**
Error	70	0.65	8.59	0.05	0.76	9.37	7.64	17.97
GCA/SCA		1.38	0.13	2.99	1.32	1.20	2.33	2.19

*** indicates significant at 0.01 level of probability*

Table 3. Mean performance of faba bean parents and their F_2 crosses for studied traits

Genotypes	Days to flowering		Plant height (cm)		Branches/ plant	
Parents						
Giza 843 (P_1)	45.80		79.38		3.27	
Nubaria 1 (P_2)	50.00		83.07		3.57	
Cairo 25 (P_3)	41.40		86.83		3.14	
Cairo 5 (P_4)	45.20		80.17		3.31	
Cairo33 (P_5)	39.80		77.41		2.83	
Misr 3 (P_6)	39.80		76.72		2.89	
Crosses						
	F_2	**Reciprocals**	**F_2**	**Reciprocals**	**F_2**	**Reciprocals**
P_1xP_2	45.20	44.00	93.66	84.13	3.67	4.19
P_1xP_3	42.80	45.40	88.38	98.35	3.80	3.68
P_1xP_4	45.20	43.40	90.07	85.18	2.89	4.64
P_1xP_5	43.40	46.20	82.23	84.07	3.21	3.69
P_1xP_6	50.00	51.20	80.00	82.02	3.46	3.84
P_2xP_3	45.20	48.20	74.59	87.39	2.57	3.95
P_2xP_4	45.80	50.20	81.76	92.18	3.90	4.25
P_2xP_5	50.00	45.80	95.17	85.36	4.26	3.11
P_2xP_6	43.40	45.80	93.26	81.34	3.99	2.83
P_3xP_4	48.60	40.60	88.98	87.39	3.03	2.97
P_3xP_5	47.00	45.60	77.86	92.18	2.91	3.39
P_3xP_6	45.80	46.40	100.93	85.36	3.27	4.16
P_4xP_5	46.00	46.40	93.33	86.86	3.04	2.97
P_4xP_6	47.80	45.80	84.33	89.25	3.33	3.08
P_5xP_6	45.20	42.00	87.02	87.81	3.09	2.66
LSD 0.05	5.21		11.35		0.95	

Table 4. Mean performance of faba bean parents and their F_2crosses for studied traits

Genotypes	Pods/plant		Seeds/plant		Seed yield/plant		100-seed weight	
Parents								
Giza 843 (P_1)	12.20		33.21		26.47		79.35	
Nubaria 1 (P_2)	12.00		36.43		37.80		103.35	
Cairo 25 (P_3)	17.08		46.96		33.64		71.31	
Cairo 5 (P_4)	16.25		46.44		31.25		68.42	
Cairo33 (P_5)	13.57		36.41		28.82		79.19	
Misr 3 (P_6)	14.08		37.61		29.69		78.59	
Crosses								
	F_2	**Reciprocals**	**F_2**	**Reciprocals**	**F_2**	**Reciprocals**	**F_2**	**Reciprocals**
P_1xP_2	20.78	14.11	58.27	46.24	44.37	39.17	76.00	86.45
P_1xP_3	19.10	11.35	48.99	34.52	39.18	31.74	80.27	92.25
P_1xP_4	14.99	19.01	41.39	51.82	29.79	39.98	72.04	77.51
P_1xP_5	16.74	14.76	48.00	44.78	39.17	34.20	80.89	75.81
P_1xP_6	15.31	12.65	37.17	32.19	32.80	28.38	87.88	89.70
P_2xP_3	15.60	17.67	43.79	54.35	32.23	42.66	73.51	78.61
P_2xP_4	14.37	13.29	40.96	40.03	33.51	37.99	81.82	94.32
P_2xP_5	15.65	13.75	43.58	37.54	39.29	26.21	89.76	69.99
P_2xP_6	17.60	13.63	48.91	36.35	44.04	27.35	90.61	74.49
P_3xP_4	19.78	13.89	52.65	37.93	34.64	27.23	66.96	71.97
P_3xP_5	13.21	15.07	34.82	37.24	28.46	29.28	82.90	78.65
P_3xP_6	18.38	15.21	47.43	46.67	39.39	44.63	83.30	94.99
P_4xP_5	14.83	14.30	44.37	36.67	35.30	24.34	82.38	67.05
P_4xP_6	15.30	16.16	42.63	42.38	33.39	25.46	78.53	59.78
P_5xP_6	12.59	13.64	33.95	36.96	27.74	25.07	81.42	67.66
LSD 0.05	4.17		11.90		10.90		16.97	

3.1 Combining Ability

The dedication of general (GCA) and specific (SCA) combining ability of parental genotypes provides excellent information not only for selecting parents for crossing but also for applying the proper breeding scheme. The results shown in Table 5 suggested that the genotypes Cairo 25, Cairo 33 and Misr 3 were good combiner for days to flowering. The parental genotypes Giza 843 and Nubaria 1 were good combiners for number of branches, seed yield/plant and 100-seed weight. The parent Cairo 25 was good combiner for pods/plant, seeds/plant and seed yield/plant. Cairo 5 (P_4) had significant positive GCA effects (ĝi) for pods/plant and seeds/plant. The previous results are in harmony with the mean performance of parental genotypes indicating the efficiency of phenotypic performance for detecting the potentiality of parents for inclusion in cross breeding programs. These results are in accordance with those obtained by Abdalla et al., Abd El-Mohsen, Darwish et al., Abdalla et al. and Ashrei et al. [7,1,20,4,10,21,22,23].

The results of the specific combining ability (SCA) effects are presented in Table 6. Out of fifteen F_2crosses, five crosses (P_1 x P_2), (P_1x P_4), (P_2x P_6), (P_3 x P_4) and (P_5x P_6); seven crosses (P_1 x P_2), (P_1 x P_3), (P_1x P_4), (P_2 x P_5), (P_3 x P_6), (P_4 x P_5), and (P_5x P_6); five crosses (P_1x P_3) (P_1 x P_4), (P_2 x P_4), (P_2 x P_5), and (P_3x P_6);six (P_1x P_2) (P_1 x P_4), (P_1 x P_5), (P_2 x P_3), (P_2x P_6)and (P_3x P_6); five crosses (P_1 x P_2) (P_1 x P_4), (P_1 x P_5), (P_2 x P_3), and (P_3x P_6); four crosses (P_1 x P_2), (P_1 x P_4), (P_1 x P_5), and (P_3x P_6) and five crosses (P_1x P_3) (P_1 x P_6), (P_2 x P_4), (P_3 x P_5), and (P_3x P_6) possessed significant or highly significant positive SCA effects for days to flowering, plant height, number of branches/ plant, number of pods/plant, number of seeds/plant, seed yield /plant, and 100-seed weight, respectively.

Thus, SCA for seed yield seemed to be influenced by SCA for yield components. It is evident from the results that only some components of yield are more important for yield expression. The components may compete for metabolic substrates produced by the plant and conditions which favor the development of one component that could have an adverse effect on other components [24,12,25,26].

3.2 Reciprocal Differences

The estimates of significant differences in reciprocal crosses for significant cases are presented in Table 7. Reciprocal differences point to the presence of maternal and/or cytoplasmic components. Their presence necessitates need for including reciprocal crosses in biometrical analysis.

Seven crosses (P_2 x P_1), (P_4 x P_1), (P_5 x P_2), (P_6 x P_1), (P_4x P_3), (P_6 x P_3) and (P_5 x P_4); three reciprocals (P_5 x P_2), (P_6 x P_2) and (P_6 x P_5); eight crosses (P_2 x P_1), (P_3 x P_1), (P_5 x P_1),(P_6 x P_1), (P_5 x P_2), (P_6 x P_2), (P_4 x P_3)and(P_6 x P_3); eight crosses had (P_2 x P_1), (P_3 x P_1), (P_5 x P_1), (P_5 x P_2), (P_6 x P_2), (P_4 x P_3), (P_5 x P_4)and (P_6 x P_4) and four crosses (P_5 x P_2), (P_6 x P_2), (P_5 x P_4)and (P_6 x P_4) possessed significant or highly significant positive reciprocal effects for plant height, number of branches/plant, number of pods/plant, number of seeds/plant, seed yield /plant, and 100-seed weight, respectively.

Table 5. Estimates of the general combining ability effects (g_i) of parental faba bean lines for studied traits

Genotypes	Days to flowering	Plant height	Branches/ plant	Pods/ plant	Seeds/ plant	Seed yield/ plant	100-seed weight
				GCA effects			
Giza 843 (P_1)	-0.07	-0.44	0.22**	0.05	0.27	0.85*	1.80*
Nubaria 1 (P_2)	1.95**	0.23	0.24**	-0.18	1.36*	3.41**	5.53**
Cairo 25 (P_3)	-1.27**	1.28*	-0.07*	0.90**	2.15**	1.26*	-0.82
Cairo 5 (P_4)	0.42*	0.02	-0.02	0.48*	1.43*	-1.45*	-5.56**
Cairo33 (P_5)	-0.68**	-1.05*	-0.25**	-0.91**	-2.99**	-2.90**	-1.75*
Misr 3 (P_6)	-0.35*	-0.04	-0.12*	-0.33*	-2.22**	-1.16*	0.80
S.E. for							
g_i	0.21	0.77	0.06	0.23	0.81	0.73	1.12
g_i-g_j	0.33	1.20	0.09	0.36	1.25	1.13	1.73

** and ** indicate significant at 0.05 and 0.01 levels of probability, respectively*

Table 6. Estimates of specific combining ability effects (Sij) in the F_2 crosses of faba bean for studied traits

Genotypes	Days to flowering	Plant height	Branches/ plant	Pods/ plant	Seeds/ plant	Seed yield /plant	100-seed weight
P_1xP_2	-2.85**	3.09*	0.05	2.36**	8.41**	4.05**	-5.76*
P_1xP_3	-0.13	6.51**	0.18*	-0.94*	-2.88*	-0.12	5.63*
P_1xP_4	-2.52**	2.03*	0.15*	1.25**	2.69*	2.03*	-1.12
P_1xP_5	1.18**	-1.37	0.06	1.40**	6.89**	5.28**	-1.36
P_1xP_6	3.95**	-4.52**	0.14	-0.95*	-5.58**	-2.56*	6.53**
P_2xP_3	0.45	-6.54**	-0.32**	0.70*	3.35*	-0.69	-8.31**
P_2xP_4	2.17**	0.70	0.44**	-1.69**	-4.51**	0.33	8.44**
P_2xP_5	1.07*	5.07**	0.28*	0.58	-0.03	-1.21	-3.56*
P_2xP_6	-1.37**	1.10	-0.13	0.91*	1.28	-0.01	-3.44*
P_3xP_4	-1.82**	-2.75*	-0.31**	0.24	-0.50	-2.34*	-3.81*
P_3xP_5	0.88*	-4.81**	0.06	-1.07*	-5.34**	-2.95*	3.69*
P_3xP_6	2.25**	9.34**	0.50**	1.01*	4.91**	8.44**	9.51**
P_4xP_5	2.20**	5.11**	-0.14	-0.22	-0.14	0.71	2.37
P_4xP_6	1.17**	0.80	-0.07	0.36	1.09	-1.43	-5.75*
P_5xP_6	-0.93*	2.50*	-0.17*	-0.86*	-1.55	-3.00*	-4.17*
S.E.for							
S_{ii}	0.49	1.76	0.13	0.52	1.84	1.66	2.55
S_{ii}-S_{ik}	0.74	2.68	0.20	0.79	2.79	2.52	3.87
S_{ij}-S_{kl}	0.66	2.39	0.17	0.71	2.99	2.26	3.46

** and ** indicate significant at 0.05 and 0.01 levels of probability, respectively*

Table 7. Estimates of reciprocal effects (Rij) of diallel crosses for studied traits of F_2 generations of faba bean

Genotypes	Days to flowering	Plant height	Branches/ Plant	Pods/plant	Seeds/plant	Seed yield/ plant	100-seed weight
P_2xP_1	0.60	4.76**	-0.26*	3.33**	6.02	2.60*	-5.23*
P_3xP_1	-1.30**	-4.99**	0.06	3.87**	7.23	3.72*	-5.99*
P_4xP_1	0.00	2.45*	-0.88**	-2.01**	-5.21	-5.10**	-2.74
P_5xP_1	-0.20	-0.92	-0.24*	0.99*	1.61	2.48*	2.54
P_6xP_1	-2.10**	-1.01	-0.19*	1.33*	2.49	2.21	-0.91
P_3xP_2	-1.50**	-6.40**	-0.69**	-1.04*	-5.28	-5.21**	-2.55
P_4xP_2	-0.10	-5.21**	-0.17	0.54	0.46	-2.24*	-6.25*
P_5xP_2	2.10**	4.91**	0.57**	0.95*	3.02	6.54**	9.88**
P_6xP_2	0.00	5.96**	0.58**	1.99**	6.28	8.35**	8.06**
P_4xP_3	2.30**	4.40**	0.03	2.95**	7.36	3.71*	-2.51
P_5xP_3	-1.10*	-3.58*	-0.24*	-0.93*	-1.21	-0.41	2.13
P_6xP_3	-0.20	4.34*	-0.45**	1.58**	0.38	-2.62*	-5.85*
P_5xP_4	1.10*	3.23*	0.04	0.27	3.85	5.48**	7.67**
P_6xP_4	1.00*	-2.46*	0.13	-0.43	0.13	3.97*	9.37**
P_6xP_5	1.60**	-0.39	0.22*	-0.53	-1.50	1.33	6.88*
S.E. for							
Rij	0.57	2.07	0.15	0.61	2.16	1.95	2.99
Rij-Rki	0.81	2.93	0.21	0.87	3.06	2.76	4.24

** and ** indicate significant at 0.05 and 0.01 levels of probability, respectively*

Four F_2crosses (P_3 x P_1), (P_6 x P_1), (P_3 x P_2) and (P_5 x P_3) had negative reciprocal effect for days to flowering. Such reciprocal differences will impose direction of the crossing in favor of maternal and plasmon effects [27,25,26].

3.3 Genetic Parameters

Estimates of genetic and environmental component of variance and other derived parameters are given in Table 8.

The additive genetic variance (D) was highly significant (or significant) for all traits except for plant height indicating that additive effect seemed to be important in the inheritance of these traits. Therefore, selection for these traits in segregating generations would be effective.

The component of variation due to the dominance effects of genes (H_1) was highly significant for all traits indicating the presence of dominance with a symmetrical gene distribution in the parents for all studied traits. Also (H_2) components were highly significant for all traits indicating the importance of dominance effects controlling all studied traits. Since "D" was lower than "H_1" and "H_2" for all traits expect for plant height, suggesting that the dominance genetic variance was more important. However, the other traits showed higher values of H_1 and H_2 than "D" indicating the important role of dominance genetic variance. H_1 was greater than H_2 indicating that positive and negative alleles at the loci were not equal in proportion in the parents. Theoretically, H_2 should be equal to or less than H_1 [16]. These results are in accordance with those obtained by El-Hady et al. [28].

The (F) letter denotes the mean of covariance of additive and dominance effects over the array. Such estimate is significant or highly significant for days to flowering, number of pods/plant and 100-seed weight indicating the excess of dominant alleles controlling these traits.

All estimates of environmental variance (E) were highly insignificant for plant height, number of branches and seed yield/plant indicating that the rest of traits have been greatly affected by environmental factors except the three mentioned traits.

Dominance variance over all heterozygous loci (h_2) was highly significant for all studied traits except, number of seeds per plant, and 100-seed weight. Significant values of (h_2) indicates the prevalent of dominance effect over all loci in all crosses, while insignificant values indicates the absence of dominance effect over all loci in the heterozygotes and that could be due to the presence of considerable amount of canceling dominant effects in the parental lines.

Heritability in narrow senses in F_2's are shown in Table 8. It ranged from 0.01% in plant height to 42% for number of branches. This is indicator for the importance of non-additive genetic variance in the inheritance of these traits. Therefore, it could be concluded from Hayman [16] analysis and combining ability analysis that selection procedures which are known to be effective in shifting gene frequency when both additive and non-additive genetic variation are involved would be successful in improving most studied traits. It is worthy noting that the average degree of dominance $(H_1/D)^{1/2}$ was greater than unity for all studied traits indicating the presence of over dominance in the inheritance of these traits.

The average frequency of negative *vs.* positive alleles in the parental genotypes could be detected by computing the ratio ($H_2/4H_1$) which was slightly below the maximum value of 0.25 (which arises when U=V=0.5) over all traits. It ranged between 0.19 for number of pods/plant and 100-seed weight to 0.24 for plant height and number of branches per plant. The parents seemed to carry more dominant alleles than recessive as indicated by positive values of F_2 components. This agrees with findings of Kaul and Vaid and Attia et al. [29,9].

Table 8. Estimates of genetic parameters for studied traits in F_2 diallel crosses of faba bean

Parameter	Days to flowering	Plant height	Branches/ Plant	Pods/ plant	Seeds/ plant	Seed yield/ plant	100-seed weight
D	15.91**	8.05	0.04*	3.92**	28.02*	10.85**	141.72**
F	16.38**	10.21	-0.09*	4.54*	32.69	0.98	130.23**
H_1	25.67**	97.58**	0.23**	8.60**	100.54**	52.05**	172.25**
H_2	20.42**	95.12**	0.22**	6.52**	79.65**	42.98**	131.75**
h^2	14.16**	113.85**	0.21**	3.95**	26.30	16.26**	-4.91
E	0.50	6.31**	0.04**	0.42	5.16	5.11**	9.86
$(H1/D)^{1/2}$	1.27	3.48	2.56	1.48	1.89	2.19	1.10
$(H_2/4H_1)$	0.20	0.24	0.24	0.19	0.20	0.21	0.19
KD/Kr	2.36	1.45	0.33	2.28	1.89	1.04	2.43
h(n.s)	0.30	0.01	0.42	0.26	0.24	0.37	0.38
YD	24.42	63.77	3.05	13.63	35.11	12.58	-10.38
Yr	89.12	107.47	3.26	15.48	48.08	55.10	297.80
R	-0.57	-0.43	-0.24	-0.40	-0.48	-0.59	0.48
t^2	4.37	0.00	0.03	0.80	0.55	0.52	0.48
b	1.54	0.54	0.65	0.14	0.11	0.66	0.89

** and ** indicates significant at 0.05 and 0.01 level of probability, respectively*

The proportion of dominant and recessive alleles (K_D/K_R) in the parents was greater than unity in all traits except for number of branches /plant suggesting that dominant genes were more frequent than the recessive ones in the gene expression of the parental genotypes.

4. CONCLUSION

The studied parents proved to be useful to be utilized in improvement of faba bean. Reciprocal-crosses differences occurred frequently in F_2 generations. Such differences will impose direction of the crossing in favour of implying maternal and plasmon effects The inbreeding gain in seed yield and seed index indicated that selection could be practiced in F_2 generation to secure transgressive segregents with high yield and wherever needed with heaver seed index.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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