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DETERMINATION OF HETEROSIS AND GENETIC VARIANCES FOR YIELD, YIELD COMPONENTS AND *OROBANCHE* TOLERANCE IN FABA BEAN

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ABSTRACT

The present investigation was conducted during 2014/15 and 2015/16 seasons at Sakha Agricultural Research Station to estimate the type and relative amount of genetic variance components and combining ability for yield and its components in faba bean. For these aims, factorial mating design (4 lines x 4 tester) analysis was used. All genotypes (16 crosses and their 8 parents) were arranged in a field experiment under a naturally infested soil with Orobanche in a RCBD with three replications. Highly significantly mean squares of genotypes, parents and crosses were found for all traits of yield and its components. Results indicated that seed yield/plant was negative and highly significant correlated with number of Orobanche spikes. The additive gene effects were more important for all traits, except for number of branches and seed yield/plant. Therefore, it appeared that the inheritance of all the studied traits was controlled by a preponderance of additive gene effects. The higher heritability estimates for majority of the traits suggested that selection for such traits may be exercised in early filial generations. Contribution of (lines × testers) was greater than that of testers and lines for number of branches, pods/plant and seed yield /plant, suggesting the presence of large variation among parents and crosses for these traits. The best parental lines which revealed desirable GCA effects (a good general combiner) were Line 1 for number of Orobanche spikes, Line 2 for plant height, 100-seed weight and number of Orobanche spikes; and Line 4 for number of branches/plant and number of pods/plant. Whereas, tester T1 (Giza 843) and T4 (Nubaria 3) were the best ones for most studied traits. Most hybrids exhibited a positive significant mid-parent heterosis for seed yield, accompanied with negative heterosis for number of Orobanche spikes. The crosses (Line 3 x Misr 3) and (Line 4 x Misr 3) recorded best desirable SCA effects, which also recorded a significant heterosis over better parents for most yield components traits and number of Orobanche spikes. Then, these crosses were considered as good performing hybrids for these traits and could be used in the faba bean breeding program in future.

Key Words: ***Vicia faba, Variance Components, Combining ability, Orobanche.***

INTRODUCTION

Faba bean is one of the most important annual legume crops in Egypt. It is an important source for high quality and inexpensive protein in human diets and as a fodder for animals. Besides, faba bean plays an essential role in enhancing soil fertility (Duc *et al* 2010). In Egypt, The cultivated area was about 113.810 feddan (one feddan = 4200m^2) in the least five seasons with an average yield of 9.2 ardab/faddan (one ardab = 155 Kg). The total production in 2015/16 season was about 119.000 tons, while the total consumption was estimated to be about 420.000 tons. This means that, the percentage of self-sufficiency is only about 32.6%. So, to reduce the gap between production and consumption, the most effective is being developing new cultivars with high yielding potentiality and using the proper cultural practices.

The parasitic weed crenate broomrape (*Orobanche crenata* Forsk.) is a root parasite with devastating effects on many crop legumes, Rubiales *et al* (2012). It is a significant constraint to production of faba bean throughout the Mediterranean Basin, and the spread of broomrape has resulted in a reduction in the cultivated area of faba bean and other pulse crops. The parasite obtains nutrients and water through historian connected with the host vascular system, leading to up to 80% of yield losses in faba bean fields with high levels of infestation through the Mediterranean basin, North Africa and the Middle East Pérez-de-Luque *et al* (2010). Resistance or tolerance to broomrape is a major objective of breeding programs in these regions. Though breeding for broomrape resistance remains the most promising strategy. Traditional plant breeding has failed to produce stable resistance across time, location or parasite population. Sources of resistance to broomrape are scarce and of complex nature, (Cubero *et al* 1999). The genetic nature of broomrape resistance does not clear till now and requires more studies on Egyptian faba bean genotypes.

However, to breed high yielding varieties, breeders often face the problem of selecting parents and crosses. In this context, various breeding approaches have been suggested. The line by tester analysis developed by Kempthorne (1957) is one of the powerful tools available for evaluating the potential of new pure lines by crossing them to common testers and evaluating the performance of their testcrosses (Singh and Narayanan 2000). This scheme of evaluation allows progeny comparisons as well as their combining ability with testers. It is necessary to gather information on the nature of gene actions. General combining ability is attributed to additive type of gene effects, while specific combining ability is attributed to non-additive type of gene actions. In Egypt, several first studies concerning the role of general (GCA) and specific (SCA) combining abilities and some other breeding parameters in faba bean were done (Attia and Salem 2006, EL-Hady *et al* 2009, Ghareeb and El-Emam 2013, Ghareeb and Helal 2014 and Ibrahim *et al* 2018) and aids in selecting desirable parents and crosses for exploitation in pedigree breeding.

Heritability estimates provide information about genetic variation that is attributable to additive genes and is transferable to next generation (Baloch 2004). The success of any breeding venture, therefore, depends mainly on the presence of the abundant genetic variability for a trait which is amenable to selection. A lot of work on genetic variability and heritability estimates has already been carried out, yet the differences always existed due to either material and methodology used or environments in which the material is tested (Baloch 2004; Baloch and Bhutto 2003).

The present study aimed to evaluate the performance of some faba bean genotypes for *Orobanche* tolerance, to develop the *Orobanche* tolerance level with enhancing the high yielding potential , to estimate the heterosis, combining ability and determinate the genetic variability of faba bean genotypes.

MATERIALS AND METHODS

The present studies were carried out in the Farm of Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt during the growing winter seasons of 2014/15 and 2015/16. Four parental cultivars (male) namely; Giza 843 (T1) , Misr 3 (T2), Sakha 1 (T3) and Nubaria 3 (T4) were used as testers, while the four maternal genotypes (Female)namely; Line (L1) 'Misr 1 x Misr 2', Line (L2) 'Giza 716 x Misr 2', Line (L3) '(Giza 461 x Misr 2) (Misr 1 x Misr 2)' and Line (L4) '(Misr 1 x Misr 2) (Nubaria 1 x Misr 2)' used as lines and were crossed according to factorial mating system under insect free cages in the first season of (2014/15). In the second season (2015/16) the resulted F_1's along with their parental genotypes were sown in a randomized complete blocks design with three replications under *Orobanche* naturally infested soil. Each entry was represented by one ridge for parents and F_1's. Each ridge was 3m long and 60cm apart. Seeds were planted on one side of the ridge at 20cm hill spacing with one seed per hill. The choice of parents was based on: a) some newly developed lines of faba bean derived from food legumes breeding program and revealed had shown a certain resistance against the parasitic weed **O. crenata**, under field conditions at Sakha Agricultural Research Station, (b) differences in growth habit and *Orobanche* reactions and (c) differences in yielding ability. The pedigree, *Orobanche* reactions, foliar disease reaction of parental genotypes are presented in Table (1).

Table 1. Pedigree and reaction to foliar disease and *Orobanche* of eight faba bean genotypes under study.

Genotype		Pedigree	Reaction to *Orobanche*	Reaction to foliar disease
Testers (male)	Giza 843 (T1)	561/2076/85 X 461/845/83	Tolerant	Moderate
	Misr 3 (T_2)	L667 x (Cairo 241 x Giza 461)	Tolerant	Susceptible
	Sakha 1 (T_3)	Giza 716 x 620/283/85	Susceptible	Resistant
	Nubaria 3 (T_4)	Selected from Ahnacia line	Susceptible	Resistant
Lines (female) in F6	Line (L_1)	Misr 1 x Misr2	Tolerant	Susceptible
	Line (L_2)	Giza 716 x Misr 2	Tolerant	Moderate
	Line (L_3)	(Giza 461 x Misr 2) (Misr 1 x Misr 2)	Tolerant	Resistant
	Line (L_4)	(Misr 1 x Misr 2) (Nubaria 1 x Misr 2)	Tolerant	Resistant

Data were recorded as an average of 39 and 39 individual guarded plants chosen at random from each plot for the parents and F_1. The data were recorded on plant height (cm), number of pods/plant, number of seeds/plant, seed yield/plant (g), No. seeds/pod, 100 seed weight and number of *Orobanche* spikes/plant (total number of *Orobanche* spikes/plant was recorded at harvest time).

The statistical procedure was done according to the regular analysis of variance of randomized complete blocks design as outlines by Snedecor and Cochran (1994). The analysis of variance was done depending on the mean of the individual plant basis. Combining ability analysis was conducted based on the procedure developed by Kempthorne (1957).

The variances for general and specific combining ability were tested against their respective error variances, derived from the analysis of variance of the different traits as follows:

Covariance of half-sib of line = Cov.H.S. (line) = $\frac{Ml - Mlxt}{rxt}$

Covariance of half-sib of tester = Cov.H.S. (tester) = $\frac{Mt - Mlxt}{rxl}$

Covariance of full sib = Cov.F.S. =

$$\frac{(Ml - Me) + (Mt - Me) + (Mlxt - Me)}{3r} + \frac{6r\ Cov\ H.S. - r(1+t)Cov\ H.S.}{3r}$$

While Cov.H.S. (average) was calculated by the formula:

Cov.H.S. (average) = $\frac{1}{r(2lt-l-t)}\left[\frac{(l-1)(Ml)+(t-1)(Mt)}{1+t-2} - Mlxt\right]$

Assuming no epistasis, variance due to GCA (σ^2_{gca}) and variance due to SCA (σ^2_{sca}) were calculated as follows:

σ^2_{gca} = Cov.H.S. = ($\frac{(1-F)}{4}$) σ^2_A and σ^2_{sca} = = ($\frac{(1-F)}{2}$)^2 σ^2_D.

Additive and dominance genetic variances (σ^2_A and σ^2_D) were calculated. Significance test for general combining ability and specific combining ability effects were performed using *t*-test.

Heterotic effects were computed as the percentage deviation of mean performance from its better parent. It was estimated from mean values and its significance was performed using *t*-test (Steel *et al* 1997). Narrow sense heritability was estimated, after derivation of the variance components (Singh and Chaudhary 1985). (σ^2_A / σ^2_D) ratio was used to rate the relative weight of additive versus non-additive type of gene actions.

RESULTS AND DISCUSSION

Genetic variability among parents and hybrids

The analysis of variance of factorial mating design (females and males) for the studied traits in faba bean was presented in Table (2). Results revealed that highly significant differences for genotypes were observed for different traits under study.

Table 2. Analysis of variance of factorial mating design (females and males) for the studied traits in faba bean.

SOV	df	Plant height	No. of branches /plant	No. of pods /plant	No. of seeds/plant	Seed yield /plant	No. of seeds /pod	100- Seed weight	No. of *Orobanche* spikes
Replications	2	66.16**	0.02**	12.19	209.53	206.90	1.19	66.79	0.01
Genotypes	23	314.14**	1.09**	49.43**	548.27**	330.47**	1.33**	285.46**	30.01**
Parents	7	642.71**	0.57**	67.68**	625.41**	404.34**	1.21**	607.42**	63.33**
Crosses	15	181.38**	0.98**	17.17*	199.83**	101.54*	0.81**	76.63	15.73**
P. vs. C.	1	5.61	6.32**	405.57**	5234.81**	3247.42**	10.09**	1164.01**	11.06**
Lines	3	432.83**	0.38	28.20**	70.79	41.58	0.33	64.26	57.81**
Testers	3	202.82**	0.83**	27.44**	610.38**	178.68**	2.39**	215.40**	11.41**
Line x tester	9	90.41**	1.23**	10.07	106.00	95.81	0.45**	34.50	3.14**
Error	46	16.94	0.10	8.41	67.74	55.70	0.17	54.03	0.06

*** Refers to 0.05 significance probability level, ** Refers to 0.01 significance probability level**

Meanwhile, mean squares due to bean parents, revealed highly significant differences among the studied parents for all traits. The statistical analysis for crosses, revealed highly significant differences among the possible hybrids (F_1) for all traits except for hundred seed weight. These findings were providing evidence for the presence of high considerable amount of genetic variability among the studied faba bean F_1 crosses. Consequently, crosses variance was partitioned into lines (L), testers (T) and line x tester (L × T). Highly significant values were obtained for plant height, number of pods per plant and number of *Orobanche* spikes for lines. Furthermore, all the studied traits were significant for testers, revealing presence of genetic differences among lines (parental females) and testers (parental males). Obviously due to diverse nature of lines and testers, the crosses between them were also found to be significant for most traits. Lines x testers interaction was highly significant for plant height, number of branches per plant, number of seeds per pod and number of *Orobanche* spikes traits, indicating the predominance of gene action in controlling these traits and the weak effects of additive gene action and thus the importance of specific combining ability. Therefore, results suggested that faba bean lines may have different combining ability patterns and performed differently in crosses depending on the type of tester used. Similar results were reported earlier in faba bean by Radwan *et al* (2010), El-Hady *et al* (2008 and 2009), Attia (2007) and Ibrahim *et al* (2018).

Mean performance of parental cultivars and F_1 populations

Results of mean performances of the eight faba bean parents (females and males) along with their 16 F_1crosses for all the measured traits are presented in Table 3. The best grain yielding line was Line 2 which had the highest value for number of seeds/plant, seed yield/plant, number of seeds/pod and 100- seed weight with for the lowest value number of *Orobanche* spikes (55.40 seed, 43.00 g, 3.30 seed and 77.85 g with 2.80 spikes, respectively). Meanwhile, the best seed yielding tester was Tester 1 for number of pods/plant, number of seeds /plant, seed yield/plant and number of seeds/pod with for the lowest value number of *Orobanche* spikes (17.70 pods, 22.20 seeds, 35.60 g and 2.50 seeds with 2.80 spikes, respectively).

Table 3. Mean performance of parental faba bean genotypes and F1 crosses for all the studied traits.

Genotype code name	Plant height (cm)	No. of branches /plant	No. of pods /plant	No. of seeds /plant	Seed yield /plant (g)	No. of seeds/pod	100- Seed weight (g)	No. of *Orobanche* spikes/plant
Line 1	119.70	3.70	18.20	45.80	36.90	2.60	80.58	5.40
Line 2	110.10	3.60	17.00	55.40	43.00	3.30	77.85	2.80
Line 3	85.50	2.80	7.10	17.00	13.80	1.90	59.07	11.10
Line 4	79.70	4.20	6.30	13.50	10.60	1.20	48.32	15.40
Tester 1	110.10	3.30	17.70	44.20	35.60	2.50	80.03	3.10
Tester 2	114.50	3.60	12.90	30.40	26.50	1.70	60.46	4.40
Tester 3	115.80	3.40	16.90	41.00	35.50	2.30	82.04	3.10
Tester 4	107.10	4.00	14.80	35.90	33.80	2.40	88.83	4.10
Line 1xT1	107.90	3.30	19.80	66.40	52.10	4.40	75.70	3.10
Line 1xT2	106.90	4.00	18.20	50.00	40.80	2.80	80.02	2.50
Line 1xT3	104.20	4.10	17.10	44.70	35.80	2.60	78.32	4.80
Line 1xT4	94.80	5.00	19.00	56.10	51.20	2.80	92.39	2.90
Line 2 xT1	119.30	4.00	20.30	60.70	49.40	3.00	81.19	2.30
Line 2 xT2	119.20	4.40	18.60	55.80	47.60	3.10	84.32	4.50
Line 2 xT3	111.30	4.20	16.60	46.10	40.30	2.90	86.10	5.20
Line 2 xT4	110.10	4.20	17.80	44.40	37.80	2.70	84.61	5.50
Line 3 xT1	109.80	3.70	18.80	60.40	44.70	3.50	75.14	3.80
Line 3 xT2	95.90	3.80	19.20	57.20	47.30	2.90	79.07	5.70
Line 3 xT3	109.60	3.40	18.40	49.20	39.70	2.70	77.98	6.10
Line 3 xT4	106.00	5.00	13.50	41.40	34.00	3.60	80.93	5.30
Line 4 xT1	104.70	4.30	21.90	63.50	48.10	3.80	76.47	7.50
Line 4 xT2	106.90	4.90	22.20	57.10	44.50	2.60	77.21	6.80
Line 4 xT3	98.80	4.90	23.50	61.20	49.00	2.70	74.69	8.70
Line 4 xT4	91.40	3.50	16.70	44.00	40.20	2.60	89.10	10.60
LDS 0.05	6.79	0.52	4.79	13.58	12.32	0.68	12.13	0.40

The offspring which produced from genetically different hybrids may display a higher yielding potential compared to the grand mean yield. Most of the F_1 populations gave higher mean values against their parents (females and males) for all traits. From F_1 progenies, the top cross Line 3 x T1 gave the tallest plants (109.80 cm). However, the top crosses $L_1 \times T_4$ gave the highest and heaviest number of branches and 100- seed weight (5.00 branch and 92.39 g, respectively). While, Line 4 x T3 had the highest number of pods /plant (23.50 pods). Concerning number of seeds, seed yield per plant and number of pods per seed the highest and heaviest values were obtained by the top cross $L_1 \times T_1$ (66.40 seeds, 52.10 g and 4.40 seeds, respectively). Thus, they should possess the genetic factors for high yield potential. Therefore, these results could confirm the possibility of selection for these traits through hybridization of respective parents. Moreover, it allows breeders to build future breeding program for tolerance to *Orobanche* and high potential yield in faba bean crop. These findings were in agreement with those reported by Darwish *et al* (2005), El-Hady *et al* (2009), Ghareeb and Helal (2014) and Ibrahim *et al* (2018).

Results in Figure (1) showed relation of number of *Orobanche* spikes and seed yield /plant among parental faba bean genotypes and F_1 crosses. The highest values for seed yield, accompanied with lowest values for number of *Orobanche* spikes were the best genotypes (Abdalla and Darwish (2002), Abdalla *et al* 2014 and Bakheit *et al* 2016).

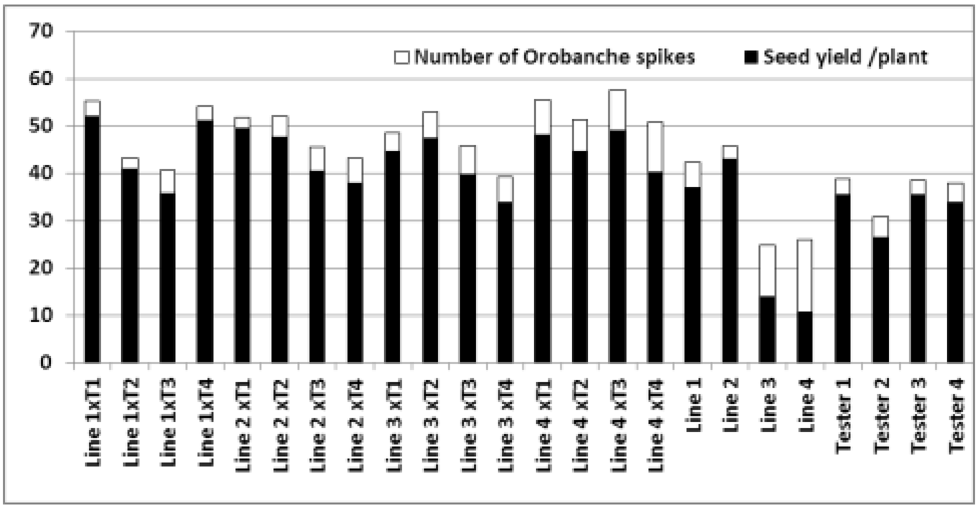

Fig. 1. Relation of number of *Orobanche* spikes and seed yield /plant among parental faba bean genotypes and F_1 crosses.

Results indicated that seed yield/plant was negatively and highly significant correlated with number of *Orobanche* spikes (-0.587^{**}). The histogram of Fig (1) revealed that the inbred line Line 2 and Line 1 had the best (desirable) values; meanwhile, Tester 1 and Tester 3 had the best ones for desired yield and tolerance traits. On the other hand, the top crosses Line 1 x T1, Line 1 x T4 and Line 2 x T1 recorded the best values for seed yield/plant and number of *Orobanche* spikes. The figure also indicated that seed yield/plant was related to number of *Orobanche* spikes. From the previous results, it is explained why selecting inbred lines with higher values for seed yield would have better chance to get a hybrid with higher seed yield.

Combining ability

The obtained information about general and specific combining ability for parents (females and males) and their hybrids may be helpful for breeders to identify the best combiners which may be hybridized to build up favorable genes.

General combining ability (GCA)

Estimates of both general ($\hat{g}_i$) combining ability effects of four lines and four testers for eight traits are presented in Table (4). As far as GCA effects of female lines is concerned, negative and significant maximum GCA effects (desirable for number of *Orobanche* spikes trait) were exhibited by inbred Line 1 toward lower spikes. On the other hand, positive and significant maximum GCA effects (desirable for some yield traits) were exhibited, by Line 2 for plant height, 100-seed weight and number of *Orobanche* spikes; and Line 4 for number of branches/plant and number of pods/plant. In general, results revealed that two inbred lines, i.e., Line 1 had negative and significant (favorable) GCA effects for number of *Orobanche* spikes; however Line 4 had positive and significant GCA effects for some seed yield traits.

Table 4. Estimation of general combining ability effects for various traits in parental lines and testers.

Genotype code name		Plant height	No. of branches /plant	No. of pods /plant	No. of seeds /plant	Seed yield /plant	No. of seeds/ pod	100- Seed weight	No. of *Orobanche* spikes
Females	gL1=	-2.45*	-0.09	-0.37	0.84	1.27	0.15	0.93	-2.01**
	gL2=	8.49**	0.07	-0.38	-2.43	-0.74	-0.18	2.78**	-0.96**
	gL3=	-0.59	-0.19*	-1.42	-1.42	-2.28	0.13	-2.40*	-0.11*
	gL4=	-5.45**	0.21*	2.18*	3.01	1.74	-0.10	-1.31	3.08**
Males	gT1=	4.52**	-0.37**	1.32	9.29**	4.84*	0.65**	-3.55**	-1.16**
	gT2=	1.33	0.11	0.64	1.57	1.36	-0.17	-0.52	-0.46**
	gT3=	-0.53	0.02	0.20	-3.87	-3.30	-0.37**	-2.00	0.87**
	gT4=	-5.31**	0.24*	-2.16*	-6.99**	-2.91	-0.10	6.08**	0.74**
S.E(gca)		1.19	0.09	0.84	2.00	1.89	0.11	1.02	0.04
S.E.(gi-gj)		1.68	0.13	0.91	2.83	2.68	0.15	1.45	0.06

*** Refers to 0.05 significance probability level, ** Refers to 0.01 significance probability level.**

Regarding testers, this investigation revealed that tester T1 was the best general combiner for plant height, number of seeds/plant, seed yield/plant and number of seeds/pod traits, in addition to number of *Orobanche* spikes. Meanwhile, tester T4 was the best one for branches /plant and 100- seed weight. The previous parental Line genotypes and tester T_1 can be used in faba bean breeding program to improve some studied traits, especially number of *Orobanche* spikes. The superiority of the heterozygous crosses as tester was reported by Radwan *et al* (2010), El-Hady *et al* (2009), Attia (2007), Abdalla *et al* 2017 and Ibrahim *et al* (2018).

Specific combining ability (SCA) effects

Estimates of specific combining ability (SCA) effects of the top crosses for all studied traits are presented in Table (5). The negative and significant SCA (desirable) effects were obtained by the cross Line 1 x T4, Line 4 x T2, Line 2 x T1, Line 3 xT4 and Line 4 xT3 for number of *Orobanche* spikes. Furthermore, the best top crosses that have positive and significant (desirable) SCA effects were; Line 3 xT4 and Line 4 xT2 for plant height; Line 3 xT4, Line 1xT4, Line 4 xT3 and Line 4 xT2 for number of branches/plant; Line 1xT4 for number of pods/plant, number of seeds/plant, seed yield/plant and 100- seed weight and Line 1xT1 and Line 3 xT4 for number of seeds/pod.

Table 5. Estimation of specific combining ability affects for some traits in the F1 hybrids.

Hybrids	Plant height	No. of branches /plant	No. of pods /plant	No. of seeds /plant	Seed yield /plant	No. of seeds /pod	100-Seed weight	No. of *Orobanche* spikes
Line 1xT1	-0.08	-0.46*	-0.03	2.82	2.25	0.58*	-2.35	0.96**
Line 1xT2	2.12	-0.16	-1.02	-5.86	-5.50	-0.18	-1.07	-0.37**
Line 1xT3	1.31	-0.01	-1.60	-5.77	-5.87	-0.17	-1.28	0.57**
Line 1xT4	-3.35	0.62**	2.65*	8.81*	9.12*	-0.23	4.70*	-1.17**
Line 2 xT1	0.42	0.09	0.47	0.38	1.56	-0.46*	1.28	-0.93**
Line 2 xT2	3.51	0.03	-0.52	3.19	3.32	0.39	1.39	0.57**
Line 2 xT3	-4.97*	0.14	-1.34	-3.92	-2.64	0.13	2.25	-0.02
Line 2 xT4	1.03	-0.27	1.39	0.35	-2.24	-0.05	-4.92*	0.37**
Line 3 xT1	-0.05	0.07	0.04	-0.94	-1.57	-0.34	0.41	-0.28**
Line 3 xT2	-10.74**	-0.28	1.05	3.59	4.50	-0.09	1.31	0.96**
Line 3 xT3	4.78	-0.61**	0.72	1.06	1.63	-0.07	1.70	0.01
Line 3 xT4	6.01*	0.82**	-1.81	-3.71	-4.55	0.50*	-3.43	-0.68**
Line 4 xT1	-0.30	0.29	-0.49	-2.26	-2.23	0.22	0.66	0.24**
Line 4 xT2	5.12*	0.41*	0.49	-0.92	-2.31	-0.12	-1.64	-1.16**
Line 4 xT3	-1.13	0.47*	2.23	8.63*	6.88	0.12	-2.68	-0.55**
Line 4 xT4	-3.69	-1.17**	-2.23	-5.45	-2.33	-0.22	3.65	1.47**
S.E(Sca effects)	2.38	0.18	1.29	4.00	3.79	0.22	2.05	0.08
S.E(Sij-Ski)	3.36	0.26	1.82	5.67	5.36	0.31	1.90	0.12

*** Refers to 0.05 significance probability level, ** Refers to 0.01 significance probability level.**

Generally, cross Line 3 xT4 recorded best values for plant height and number of branches/plant, while Line 1xT4 for number of pods/plant, number of seeds/plant, seed yield/plant and 100- seed weight. Then, these crosses were considered as good performing hybrids for seed yield and number of *Orobanche* spikes and they could be used in faba bean breeding programs to improve these traits. This is in agreement with the findings of several authors who estimated combining ability effects of line by tester analysis (El-Hady *et al* 2008 and 2009, Attia and Salem 2006, Abdalla *et al* 2017 and Ibrahim *et al* 2018).

Genetic components and proportional contribution

Results in Table (6) revealed the genetic component's estimates and proportional contribution (%) for the studied traits in faba bean. Regarding to variance due to specific combining ability (σ^2_{sca}) was higher than the general combining ability (σ^2_{gca}) for all the traits studied, suggesting the importance of dominant (non-additive) genes controlling them. The ratio of $\sigma^2_{gca}/\sigma^2_{sca}$ was less than unity which also confirmed the importance of dominant (non-additive) genes advocating the expression of traits. Similar results have been reported earlier in faba bean (El-Hady *et al* 2009, Attia and Salem 2006 and Ibrahim *et al* 2018).

The proportional contribution of lines, testers and their interactions from the total variances for different plant traits was shown in Table (6). The results revealed that the variance due to general combining ability values of lines ($\sigma^2_{gca\ L.}$) was higher than those of ($\sigma^2_{gca\ T.}$) for plant height, number of pods and number of *Orobanche* spikes, indicating that some of the total gca variances were due to the lines and contribution of lines (47.73, 32.85 and 73.51, respectively) was higher than the contribution of testers, thus, contributed reasonable amount of variance attributable to maternal effect. Similar to our findings, El-Hady *et al* (2009) and Ibrahim *et al* (2018) obtained some contribution to total variance by female parents.

Meanwhile, contribution of (females and males) was greater than that of testers and lines for number of branches, pods/plant and seed yield/plant. These results showed that interaction of females and males brought much variation in the expression of these traits. The results of the present study revealed large variation among parents and crosses for these traits. These results are in agreement with those obtained by Baloch *et al* (2016) and Ibrahim *et al* (2018).

Regarding to genetic component, additive (σ^2_A) values recorded higher than dominance (σ^2_D) variance for all traits except for number of branches/plant and seed yield /plant. Dominance genetic variance was lower than additive genetic variance for all traits except for number of branches and seed yield/plant. These results are supported by the ratio of (σ^2_A/σ^2_D) which takes values higher than unity (Table 6). Therefore, it appeared that the inheritance of most the studied traits was controlled by a preponderance of additive gene effects.

Table 6. Genetic component's estimates and proportional contribution (%) for the studied traits in faba bean.

Genetic parameters	Plant height	No. of branches /plant	No. of pods /plant	No. of seeds /plant	Seed yield /plant	No. of seeds /pod	100-Seed weight	No. of *Orobanche* spikes/ plant
$\sigma^2_{gca\ L.}$ = (Lines)	28.54	-0.07	1.51	-2.93	-4.52	-0.01	2.48	4.56
$\sigma^2_{gca\ T.}$ = (Testers)	9.37	-0.03	1.45	42.03	6.91	0.16	15.07	0.69
$\sigma^2_{gca\ Av.}$ =(Average)	3.16	-0.01	0.25	3.26	0.20	0.01	1.46	0.44
σ^2_{sca}	24.49	0.38	1.69	19.28	17.55	0.10	7.31	1.04
σ^2_A	75.81	-0.21	5.92	78.19	4.77	0.30	35.11	10.49
σ^2_D	24.49	0.38	1.69	19.28	17.55	0.10	7.31	1.04
σ^2_A / σ^2_D ratio	3.10	-0.55	3.49	4.06	0.27	3.01	4.81	10.09
Broad sense heritability(h^2_b)	85.55	62.36	60.42	66.92	34.10	73.84	77.12	99.83
Narrow sense heritability(h^2_n)	64.66	30.20	46.97	53.69	7.29	55.45	63.84	90.83
Lines Contribution%	47.73	7.80	32.85	7.09	8.19	8.07	16.77	73.51
Testers Contribution%	22.37	17.03	31.96	61.09	35.20	58.93	56.22	14.51
L × T Contribution%	29.91	75.17	35.19	31.83	56.61	33.00	27.01	11.97

Heritability estimates remained variable depending upon the genetic nature of genotypes and the studied traits. Generally, heritability estimates in broad sense are higher than narrow sense because narrow sense heritability uses only additive genetic variance as a numerator over the total phenotypic variance. The narrow sense heritability estimates varied from 30.20 to 90.83% (Table 6). The higher heritability estimates for some traits (number of *Orobanche* spikes/plant, plant height, 100- seed weight and number of seeds per pod and per plant) due to higher portion of additive variance and additive genes against the dominant variances and additive genes influencing quantitative traits. The higher heritability estimates for majority of the traits suggested that selection for such traits may be exercised in early filial generations for giving the opportunity of recombination between desirable genes to occur. Similar to our findings, Abd El-Aty *et al* (2017) and Ibrahim *et al* (2018) observed high narrow sense heritability for some traits.

Heterosis

Heterosis is the process by which the performance of an F_1 is superior to that of the mean of the crossed or better parents for some traits. Results in Table (7) revealed that eleven hybrids among 16 had negative significant mid-parent heterosis (favorable) and displayed highly tolerance above mid-parent value for number of *Orobanche* spikes. Line 3 xT1, Line 4 xT2, Line 1xT2, Line 3 xT4 and Line 4 xT1 -65.77**, -55.84**, -53.70**, -52.25** and -51.30**, respectively) recorded the highest significant and negative heterosis values for number of *Orobanche* spikes (tolerant crosses).

Table 7. Significant better parent heterosis (%) for the studied traits in faba bean.

Genotype code name	Plant height	No. of branches /plant	No. of pods /plant	No. of seeds /plant	Seed yield /plant	No. of seeds /pod	100-Seed weight	No. of *Orobanche* spikes
Line 1xT1	**-9.86****	**-10.81***	**8.79**	**44.98****	**41.19****	**69.23****	**-6.06**	**-42.59****
Line 1xT2	**-10.69****	**8.11**	**0.00**	**9.17**	**10.57**	**7.69**	**-0.69**	**-53.70****
Line 1xT3	**-12.95****	**10.81***	**-6.04**	**-2.40**	**-2.98**	**0.00**	**-4.53**	**-11.11****
Line 1xT4	**-20.80****	**25.00****	**4.40**	**22.49***	**38.75****	**7.69**	**4.01**	**-46.30****
Line 2 xT1	**8.36****	**11.11***	**14.69**	**9.57**	**14.88**	**-9.09**	**1.45**	**-25.81****
Line 2 xT2	**4.10**	**22.22****	**9.41**	**0.72**	**10.70**	**-6.06**	**8.31**	**2.27**
Line 2 xT3	**-3.89**	**16.67****	**-2.35**	**-16.79**	**-6.28**	**-12.12**	**4.95**	**67.74****
Line 2 xT4	**0.00**	**5.00**	**4.71**	**-19.86***	**-12.09**	**-18.18***	**-4.75**	**34.15****
Line 3 xT1	**-0.27**	**12.12***	**6.21**	**36.65****	**25.56**	**40.00****	**-6.11**	**-65.77****
Line 3 xT2	**-16.24****	**5.56**	**48.84****	**88.16****	**78.49****	**52.63****	**30.78****	**-48.65****
Line 3 xT3	**-5.35***	**0.00**	**8.88**	**20.00**	**11.83**	**17.39**	**-4.95**	**-45.05****
Line 3 xT4	**-1.03****	**25.00****	**-8.78**	**15.32**	**0.59**	**50.00****	**-8.89**	**-52.25****
Line 4 xT1	**-4.90***	**2.38**	**23.73***	**43.67****	**35.11****	**52.00****	**-4.45**	**-51.30****
Line 4 xT2	**-6.64****	**16.67****	**72.09****	**87.83****	**67.92****	**52.94****	**27.70****	**-55.84****
Line 4 xT3	**-14.68****	**16.67****	**39.05****	**49.27****	**38.03****	**17.39**	**-8.96**	**-43.51****
Line 4 xT4	**-14.66****	**-16.67****	**12.84**	**22.56**	**18.93**	**8.33**	**0.30**	**-31.17****

*** Refers to 0.05 significance probability level, ** Refers to 0.01 significance probability level**

The tallest cross was detected in Line 2 xT1 (8.36**) cross, meanwhile, Line 3 xT4 (25.00**), Line 1 xT4 (25.00**) and Line 2 xT2 (22.22**) crosses number of branches /plant. Whenever, Line 1 x T1 (69.23**), Line 4 xT2 (52.94**) and Line 4 xT1 (52.63**) crosses were detected for 100-seed weight. Six hybrids among 16 exhibited a positive significant better-parent heterosis for seed yield. Besides, positive significant heterosis for seed yield was shown by, Line 3 xT2, Line 4 xT2, Line 1xT1, Line 1xT4, Line 4 xT3 and Line 4 xT1. They expressed highly negative heterosis for number of *Orobanche* spikes. Line 3 xT2 and Line 4 xT2 presented the highest heterosis for seed yield, accompanied with negative heterosis for number of *Orobanche* spikes, and positive heterosis for the number of seeds/plant, number of pods/plant, number of seeds/pods and 100-seed weight. Several investigators reported high heterotic effect of faba bean (El-Hady *et al* 2009, Abdalla *et al* 2017 and Ibrahim *et al* 2018).

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تقدير قوة الهجين والتباين الوراثى للمحصول ومكوناته لتحمل الهالوك فى الفول البلدى

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أجري هذا البحث خلال موسمي ٢٠١٤/١٥ و ٢٠١٥/١٦ بمحطة البحوث الزراعية بسخا بغرض قياس نوع ومقدار مكونات التباين الوراثى والقدرة على التآلف لمحصول الفول البلدى ومكوناته. تم استخدام تحليل نموذج التزاوج العاملى (٤ سلالة x ٤ كشاف) لتحقيق هذه الاهداف. تم زراعة كل التراكيب (١٦ هجين و٨ آباء) تحت ظروف الاصابة الطبيعية بالهالوك بتصميم القطاعات الكاملة العشوائية فى ٣ مكررات. وقد سجل التباين الراجع الي التراكيب الوراثية، و الأباء، والهجن معنوية عالية لكل صفات المحصول ومكوناته. وأشارت النتائج لوجود ارتباط عكسى عالى المعنوية بين صفتى محصول البذرة /النبات وعدد شماريخ الهالوك. كان الفعل

الوراثى المضيف أكثر أهمية فى وراثة كل الصفات ما عدا عدد الافرع/النبات ومحصول البذرة/النبات. وبناء عليه فيرجح أهمية التاثير الاضافى للجينات فى توارث الصفات المدروسة. كما سجلت كفاءة التوريث بالمعنى الضيق قيما عالية لمعظم الصفات لذا يمكن اجراء الانتخاب فى الأجيال المبكرة لهذه الصفات. وكان توزيع (السلالة x الكشاف) اكبر منه فى السلالة أو الكشاف فى صفات عدد الافرع/النبات وعدد القرون/النبات ومحصول البذرة/النبات؛ مشيرا لوجود تباينا كبيرا لكل من الاباء والهجن فى هذه الصفات. وقد اوضحت النتائج أن السلالة ١ لصفة وعدد شماريخ الهالوك, السلالة ٢ لصفة ارتفاع النبات ووزن ١٠٠-بذرة وعدد شماريخ الهالوك, السلالة ٤ لصفة عدد الافرع/النبات وعدد القرون/النبات لكونها أفضل قدرة عامة على الائتلاف مرغوبة. بينما سجلا الكشاف جيزة ٨٤٣ ونوبارية ٣ افضل قدرة عامة لمعظم الصفات. وقد اظهرت معظم الهجن قيما عالية المعنوية موجبة لقوة الهجين بالنسبة للاب الأفضل لصفة محصول البذور/النبات مقترنة باخرى سالبة لصفة عدد شماريخ الهالوك.بينما أظهر كل من الهجين القمى السلالة ٣ x الكشاف مصر ٣ و السلالة ٤ x الكشاف مصر ٣ أفضل تأثيرات للقدرة الخاصة على الائتلاف؛ حيث سجل ايضا أعلى قوة هجين معنوية موجبة عن الأب الأفضل لمعظم صفات المحصول وصفة عدد شماريخ الهالوك. وعليه فيمكن اعتبار كلا الهجينين كافضل تراكيب وراثية لهذه الصفات للاستفادة منها فى برامج تربية الفول البلدى.

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