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Diallel crosses of genetic enhancement for seed yield components and resistance to leaf miner and aphid infestations of *Vici faba* L.

Mohamed Abd El-Hamid S. El-Bramawy[1], Mohamed Abd El-Naeim M. Osman[2]

[1]*Agronomy Department, Faculty of Agriculture, Suez Canal University, 41522 Ismailia, Egypt*

[2]*Plant Protection Department, Faculty of Agriculture, Suez Canal University, 41522 Ismailia, Egypt*

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Abstract

The genetic parameters for seed yield with its components and the resistance to infestations by some insect pests *viz., Liriomyza congesta* and *Aphis craccivora* were assessed in complete diallel crosses between six parents of faba bean. Highly significant differences among the six parents and their offspring F_1s were detected in all investigated characters. Positive general combining ability (GCA) effects for high potential of seed yield with certain components and high resistance to *L. congesta* and *A. craccivora* were found in BPL 710, Sakha 1 and Nubaria 1. The ratio of general and specific combining ability (GCA/SCA) indicated that there were great additive effects for the majority of the studied characters. Heritability values in bored sense were relatively high and passed 75% for maturity date, number of branches per plant, chlorophyll content, total shedding percentage, seed yield per plant, number of *L. congesta* mines and larvae/100 leaflets and number of *Aphis craccivora* individuals/100 leaflets, confirmed the importance of selection for these characters. The ratio of dominance (KD)/recessive (KR) alleles was less than one for all the studied characters, except the number of aphid individuals/100 leaflets. The correlation between parental performance (*Yr*) and parental order of dominance (*Wr+Vr*) was positive for number of pods per plant, 100-seed weight, chlorophyll content, total shedding percentage as well as the number of *L. congesta* mines and larvae/100 leaflets. This indicated that the faba bean parents possessed mostly negative genes in dominant form, while for the remaining characters, positive genes were mostly dominant.

*Corresponding Author: Mohamed Abd El-Hamid S. El-Bramawy ✉ el_bramawy1971@hotmail.com

Introduction

Faba bean (*Vicia faba* L.) is a valuable food legume crop in Egypt and many other Mediterranean countries, occupy nearly $2.5×10^6$ ha with 4.1 million tones of seed yield production worldwide (FAO, 2009). It is particularly important for human and animal nutrition, and generally considered as a rich source of low cost protein and carbohydrate, used as a meat extender or substitute and as a skim-milk substitute (Haciseferogullari *et al.,* 2003; Daur *et al.,* 2008). Furthermore, this crop can play a key role in sustainable production and management of agriculture hill and in enhancement total soil nitrogen fertility of nutrient poor soil through biological atmospheric nitrogen fixation (Lindemann and Glover, 2003).

However, the yield of faba beans may adversely affected by numerous biotic stresses including heavily attack by serious insect pests reducing its quality and quantity, lead to a steady reduction in the cultivated area in many countries (Ibrahim and Nassib, 1979; Hawtin and Hebbelthwaite, 1983). The major insect pests that destruct the green parts of beans in Egypt are the cowpea aphid, *Aphis craccivora* Koch (Homoptera*:* Aphidae), and the leaf miner, *Liriomyza congesta* Becker (Diptera: Agromyzidae) (El-Hosary *et al*., 1998 a, b; Awaad *et al*., 2005; Ebadah *et al*., 2006; El-Bramawy and Osman, 2010). *A. craccivora* causes direct damage to plant by piercing into phloem and feeding on soluble plant nutrients. This slows the rate of stem elongation, leaf production and decreases flower production, leading to wilt and collapse of the plant. Aphids also, caused indirect damage through transmission of plant viruses and stimulating formations of honeydew. In addition, aphids have a very high multiplication rate due to its parthenogenesis and viviparity (Weigand and Bishara, 1991). Leaf miner, *L. congesta* is the most widely distributed on faba bean fields in Egypt (Ebadah *et al.,* 2006). The larvae of *L. congesta* attack mainly the primary and secondary leaves of broad bean, where they feed on the leaf parenchyma, producing a characteristic form of mines. However, the high densities of leaf miners may severely reduce crop value or yield quantity and quality or may be kill the plants beans (Spencer, 1990).

Therefore, there is no doubt that faba bean cultivars uniform with high seed yield potential and resistances to insects are necessary for faba bean production in Egypt. Thus, breeding efforts in the crop considering should emphasize improvement of seed yield and its components as well as their resistance to insect infestations. By viewing of faba bean situation, it can notice that, despite its nutritional value, historic and cultural importance, the cultivated faba bean could not attain the substantial improvement in the yield potential due to partly the lack of resistance against biotic and abiotic stresses. However, the control of the main insects as biotic stresses that infested the faba bean in Egypt is problem complex and difficult to overcome completely. Hence, application of genetic improvement is consider being an alternative option proposed as the most effective strategies to management insect infestations with increasing the yield potential in the current faba bean genotypes.

On the other hand, faba bean is a self-pollinating plant with significant levels of outcross and inter-cross, ranging from 20 to 80% (Suso and Moreno, 1999) depending on genotype and surrounding 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. It can be estimate using diallel cross technique, which provide early information on the genetic behaviour of these traits in the first (F_1) generation (Chowdhry *et al.,* 1992). This technique may also result in the production of new genetic combinations performance, negatively or positively, may be exceeding over the parents. However, the superiority of parental may not depend so much on their actual performance as on their ability to combine well and through transgressive segregates (Zhang and Kang, 1997). The combining ability consider as an important criteria for plant breeders, where it is useful in connection with testing procedures to study and compare the performance of lines in hybrid combinations and the nature of gene action. So, the plant breeders are interesting with the gene effect estimates to apply the most effective breeding procedure for improvement the desired attributes. Moreover, the choice of the most efficient breeding methodology mainly depends upon the type of gene action controlling the genetic behaviour of most agronomic and economic characters. Nevertheless, for obtaining a clear picture of genetic mechanism of faba bean populations, the absolute value of variances must be partitioned into its genetic components. Hence, exploitation of the genetic components could encourage the improving yield potential and its components in faba bean plants. Whereas, the superiority of crosses/hybrids over parents for seed yield is associated with manifestation of gene effects in important yield components, *i.e.* number of branches per plant, number of pods per plant and seed index, in addition to the resistance of insect infestations. These effects may differ from significantly positive to significantly negative for different traits depending on genetic makeup of faba bean parents. On the other hand, heritability estimates provide values of relative importance of genetic components to phenotypic variation and useful for predicting the expected genetic advance under populations selection. These heritability estimates for different characters were calculated by several researchers using different materials and methods and reported that heritability values were high for 100-seed weight and resistance to insect infestations, but low to moderate for seed yield, number of branches per plant and number of pods per plant. The important of gene action and heritability were previously discussed by Duc (1997); El-Hady *et al.* (1997); El-Hady *et al.* (1998); El-Hosary *et al.* (1998 a, b); Abdalla *et al.* (1999); El-Keredy *et al.* (1999); Abdalla *et al.* (2001); Attia *et al.* (2001 and 2002); Awaad *et al.* (2005); Darwish *et al.* (2005); Attia and Salem (2006); El-Hady *et al.* (2006 and 2007); El-Harty *et al.* (2009) and Bayoumi and El-Bramawy (2010).

Therefore, the current work intended to estimate the combining abilities of faba bean genotypes with looking for new and durable forms of multiple insect resistances. In addition to determine the nature of gene action relative magnitude influencing of seed yield components and resistance to most dangerous insect pests, *Liriomyza congesta* and *Aphis craccivora* for faba bean plants.

Materials and methods

Experimental site and seasons

The present work was carried out at the Experimental Farm, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt during two successive growing seasons of faba bean, 2007/08 and 2008/09.

Analysis of soil structure

The soil texture of experimental site was sandy soil (94.5% Sand, 2.5% Silt and 3.0% Clay; PH = 7.54-7.60; Organic Matter = 0.048-0.056%). The available contents of N%, P% and K% in root zone in both seasons 2007/08, 2008/09 were 3.13, 3.43; 1.81, 1.85; 11.64, 11.93 ppm., respectively. These analysis were done at the soil and water Department, Fac. of Agric., Suez Canal Univ., according to Kilmer and Alexander (1949) method.

Faba bean materials and *cross model*

The genotype lines of *V. faba* used in this study were obtained from Food Legumes Research Department, Agriculture Research Center, Giza, Egypt. Six genotype parents of *V. faba* were selected on the basis of the presence of wide differences among them with respect to certain economically important traits, and their reaction with the most common insect pests (Table 1).

The selected parents were crossed in a diallel modeling to all possible combination, including reciprocals during the first season of 2007/08 to obtain a total of 30 F_1's seeds. The parents and their respective F_1 hybrids (complete diallel set) were planted out in an open field area at the experimental farm during the second growing season of 2008/09. The field trail of faba bean was implicated inside the sector of winter other crops planted and distributed around it, to screening them naturally for the insects infestations of *A. craccivora* and *L. congesta*. Moreover, the faba bean susceptible check cultivar (Giza 402) was planted surrounding each plot and around the experimental area as a belt to secure adequate source of insect infestations. The faba bean check cultivar (Giza 402) considered as a susceptible cultivar to both insect infestations (El-Hosary *et al.*, 1998 a; Awaad *et al.,* 2005; El-Bramawy and Osman, 2010).

Table 1. Name and pedigree history of fabe bean parents genotypes.

Name	Pedigree
Giza 643	Cross (249 I 84 / 80 x NA 83).
Giza 461	Cross (Giza3 x 1LB938).
Giza 716	Cross (461 1842183 x 5031 453/83 x I L B 938.
Nubaria 1	Individual plant selection from Giza Blanka.
BPL 710	NA, Introduce from Clombia.
Sakha l	Cross (716 I 924/ 88 x 620/283/81).

Experimental design

The experimental field was designed in a randomized complete block design (RCBD) with three replications for each entry of parents and their respective hybrids. Each plot was 4.0 m long and 1.8 m in width, four-rows in each plot. Spacing between rows = 60 cm, and spacing between hills in the same row =20 cm with one seed per hill. All agronomic practices were regularly conducted through different growing stages of faba bean plants when required without using any insecticides in both growing seasons of 2007/08 and 2008/09.

Estimation of seed yield and its components characters

The faba bean seed yield and its components characters were measured through the growing season of 2008/09. Maturity date was recorded by counting days from sowing to the harvest date in each plot per replication. The other yield characters represented as plant height (cm), number of branches per plant, number of pods per plant, 100-seed weight (g) and seed yield per plant (g) were recorded at the harvest time for ten guarded plants, randomly selected from each plot.

However, the following variables such as chlorophyll contents and total shedding percentage were also involved in this concern and measured as followed:-

Chlorophyll content

The leaf chlorophyll content was evaluated during flowering stage using chlorophyll meter which estimate value of SPAD [SPAD 502, Soil-Plant Analysis Development (SPAD value) section, Minolta Camera Co. Osaka, Japan] according to Castelli *et al.,* 1996.

Total shedding percentage

The total shedding percentage in the faba bean plant stems was recorded as follow:

Total shedding percentage (%) =

$$\frac{\text{Total number of flowers} - \text{Total number of mature pods} \times 100}{\text{Total number of flowers}}$$

Estimation of infestation rate and resistance to L. congesta and A. craccivora

Faba bean plants were weekly examined for the occurrence of *L. congesta* or *A. craccivora*. One hundred leaflets were randomly collected from each plot, separately at the lower, middle and upper parts of the plants at 7 days intervals during bud formation till harvest. The collected leaflets were putted in a polyethylene bags and transferred to the laboratory where they were examined under binocular microscope. Number of mines and larvae of leaf miner *L. congesta*, as well as the number of adults and nymphs of cowpea aphid *A. craccivora* were recorded. The first date of inspection was done after one month of plantation date.

Statistical analysis

Data were statistically analyzed using CoStat V. 6.311 (CoHort software, Berkeley, CA94701). The data for seed yield and its components characters, chlorophyll content and total shedding percentage as well as insect infestations by *L. congesta* and *A. craccivora* were subjected to statistical analysis using conventional two-way analysis of variance in a randomized complete block design with three replications according to Steel and Torrie (1997). The data were further subjected to the diallel analysis proposed by Griffing (1956) to determine the combining ability and Hayman (1954) to separate out the components of genetic variance and their ratios.

Results and discussion

The progress in the breeding program of a certain characters crop depends on the variability in populations and extend to which the desirable characters are heritable in this respect. Also depend on the nature and magnitude of gene controlling for the genetic behavior of most characters. However, the knowledge of the genetic architecture of yield and other characters including insect resistance help to formulate a meaningful breeding strategy for developing improved genotypes. Therefore, the obtained results and their discussion will present as they following,

Diallel analysis and its genetic components

The preliminary statistical analysis for faba bean parental and their hybrids, revealed highly significant differences among the parents and their possible hybrids (F_1) for all the studied characters (Table 2). These findings were providing evidence for the presence of high considerable amount genetic variability among the parental faba bean and their respective hybrids (F_1). These results were in harmony with those reported by El-Hosary *et al.* (1998 a, b), Awaad *et al.* (2005) and Bayoumi and El-Bramawy (2010).

In this concern, according to the above mentioned, the detailed analysis of combining ability and gene action was therefore appropriate for estimating the characters investigated through this work. ANOVA of the diallel data set with respect to faba bean seed yield and its components attributes as well as insect infestations incidence, revealed a highly significant general and specific combining ability (GCA and SCA) effects (Table 2). The GCA variance contains additive epistasis effect, while SCA variance contains dominance epistasis as outlined by Griffing (1956). Hence, the significant estimates of both GCA and SCA variances suggested that each of additive and non-additive in the nature of gene actions were involved in controlling these characters through all faba bean genotypes. These results confirmed those findings by El-Hady *et al.* (1991); Kaul and Vaid (1996); El-Hosary *et al.* (1998 a, b); Darwish *et al.* (2005); Attia and Salem (2006); El-Hady *et al.* (2007) and Ibrahim (2010) who reported the significant genetic variation among faba bean genotypes (parents and their hybrids) in respect to yield and its components attributes. Moreover, the plant resistance character against the insect infestations of *L. congesta* as the number of mines/100 leaflets, larvae/100 leaflets and *A. craccivora* as the number of aphid individuals/100 leaflets possessed a little bit significant difference compared to the above-mentioned characters *via* yield components.

Therefore, as noted above, highly significantly differences were noted among faba bean genotypes for all the studied characters, it were the same for the GCA and SCA variance effects, except only for plant height of SCA (Table 2). The GCA/SCA ratio of mean squares for all studied characters in 6 x 6 diallel in faba bean genotypes were higher than unity (1) except for maturity date (0.85) and number of pods per plant (0.78) in Table (2). Therefore, this means that greater considerable role with contribution of additive effects of genes in the genetic expressions, which controlling these characters. In contrast, non-additive (dominance) gene action was found to be more important for the exception characters, indicated that dominance gene effects mainly controlled in the inheritance of these characters and selection can be effective in their improvement through our faba bean materials. However, it could be emphasized that δ^2GCA/δ^2SCA ratio may not always project the true picture of the gene action for a particular characters. This state is due to the deferential of parental ability to combine well with each other. On the other hand, such combination depends considerably upon complex interaction among genes and genotype by environment (Mulusew *et al.,* 2008). In regarding to reciprocal maternal effects (RE's), they were not significant and had lower percentages for all characters investigated except for plant height (157.20), number of branches per plant (2.64) at $P<0.01$ and shedding rate % (67.0), Table (2). This probably due to these characters (plant height, number of branches per plant ($P<0.01$) and shedding rate % were not under strict nuclear control and have been influenced by cytoplasmic genomes. This was because primarily a function of mother plant's adaptability. This finding was supported by the results detected before by Sadeghian and Khodaii (1998) and Sundar *et al.* (2005), who obtained the same through a reciprocal mating in their experiments.

Performance of parents and their hybrids

The performance of faba bean parents and their respective crosses over seed yield and its components attributes, as well as the degree of insect infestations with *L. congesta* (number of mines/100 leaflets, larvae/100 leaflets) and *A. craccivora* (number aphid individuals/100 leaflets) were presented in Table (3). There is no doubt genetically, that the offspring which produced from different hybrids may be displays a higher yielding potential compared to the mean yield of its parents. Mean values of the six faba bean parental and their respective hybrids are obtainable in Table (3). The behavior of maturity date character was differed significantly from one genotype to another over all faba bean genotypes (parents and their hybrids). Whereas, the most hybrids were initiate flowering earlier and should be mature earlier than the parents. The required period to mature of faba bean parents plants ranged from 150 (P_4, Nubaria 1) to 159 (P_5, BPL 710) days, while, the average of period length from planting to mature date in the different hybrids ranged from 145 (Giza 716 x Nubaria 1) to 158 (BPL 710 x Giza 461) days. Therefore, it can note that the crosses P_3 x P_4 (Giza 716 x Nubaria 1) and P_6 x P_4 (Sakha 1 x Nubaria 1) were the earliest hybrids for maturity character. While, the crosses P_5 x P_2 (BPL 710 x Giza 461) and P_6 x P_2 (Sakha 1 x Giza 461) were the latest hybrids among all hybrids considering. The parent P_3 (Giza 716) possessed the lowest values for number of branches per plant, number of pods per plant, 100-seed weight (g), seed yield per plant, chlorophyll content and total shedding percentage, as well as the number of mines/100 leaflets, number of larvae/100 leaflets and number of aphid individuals/100 leaflets (Table 3). The parent P_6 (Sakha l) showed the lowest values for branches number pr plant, pod number per plant and seed yield per plant, while it had moderate values with degree of insect infestations as the number of mines/100 leaflets, number of larvae/100 leaflets and number of aphid individuals/100 leaflets (Table 3). The parent P_1 (Giza 643) gave the highest values for number of branches per plant (4.7), number of pods per plant (38.0) and 100-seed weight (82.0g). Moreover, it showed earlier flowering and lowest shedding rate parentage (49.0%), as well as the number of mines/100 leaflets (176), number of larvae/100 leaflets (125) and number of aphid individuals/100 leaflets (138). Although, the parent P_5 (BPL 710) possessed the highest period for maturity date (159 days) and lowest values for number of pods per plant (18.0), chlorophyll content (29.0, SPAD-value) and seed yield per plant (27.0g), it had lowest rate of the insect infestations as number of mines/100 leaflets (149), number of larvae/100 leaflets (119) and number of aphid individuals/100 leaflets (98) as noted in Table 3. The hybrids P_2 x P_6 (Giza 461 x Skha-1) and P_5 x P_2 (BPL 710 x Giza 461) revealed the highest values in the number of pods per plant, 100-seed weight and seed yield per plant, while it possessed the lowest values in each of shedding rate % and insect infestation as the number of mines/100 leaflets, larvae/100 leaflets and number of aphid individuals/100 leaflets. The mean values of seed yield per plant in the F_1's were ranged from 25.0g (Giza 643 x Nubaria 1) to 88.0g (BPL 710 x Giza 461). Also, Giza 716 x BPL 710 possessed high values for plant height (103.0cm), leaf chlorophyll content (48.0, SPAD-value), number of pods per plant (37.0), seed yield per plant (67.0g), while possessed low values in the shedding rate (37.0%), number of mines/100 leaflets (171.0), number of larvae/100 leaflets (124.0) and number of aphid individuals/100 leaflets (132.0). On the other hand, although the hybrid Giza 716 x Nubaria 1 revealed early mature (145 day), it possessed the lowest number of larvae/100 leaflets (118) among all hybrids with medium length in plant height (90cm) and intermediate number of branches per plant (4.0). On the other side, the hybrid, Giza 643 x Nubaria 1 was late in maturity date (156 days) and low number of pods per plant (11) with highest value in shedding rate (80%). While this hybrid scored the aggressive values in both insect infestations, where it were 251, 191 and 211 for the number of mines/100 leaflets, number of larvae/100 leaflets and number of aphid individuals/100 leaflets, respectively. These highest infestations may be due to the highest leaf chlorophyll contents that reached to 50 SPAD-value (Table 3).

Regarding to the mean performance of the parents and their hybrids, it could conclude that these hybrids had highly promising characters for breeding faba bean cultivars. Thus, it should possess the genetic factors for earliness mature, high yield potential, low percentage in shedding rate and high leaf chlorophyll content (48, SPAD-value), beside lowest rate of infestation with *L. congesta* as number of mines/100 leaflets, number of larvae/100 leaflets and *A. craccivora* as number of aphid individuals/100 leaflets. These results could be confirmed the possibility of selection for these characters through the hybrids and their respective parents. Moreover it allowed the gate open in the front of plant breeders to build future breeding program for high potential yield with high resistance to insect infestations in faba bean crop. These findings were in agreement with whose reported by El-Hosary *et al.* (1998 a, b); Salama and Salem (2001); Awaad *et al.* (2005); Darwish *et al.* (2005); El-Hady *et al.* (2007); Bayoumi and El-Bramawy (2010) and Ibrahim (2010).

Combining ability

In diallel hybrids, such information about general and specific combining ability for parents and their hybrids may be helpful breeders to identify the best combiners which may be hybridized to build up favorable fixable genes. The estimates of GCA effects "gi" listed in Table (4), where differed from one individual parent to another and from character to character. The parental variety Giza 461 (P_2) had highly significant positive GCA effects for the most studied characters including the resistance to insect infestations. Therefore, this parent could be good combiner for improving these studied characters, since the significant values positive or negative according to the desirable trend of these characters (Table 4). However, the parental variety Nubaria 1 (P_4) was good combiner for resistance to insect infestations as the number of mines/100 leaflets, number of larvae/100 leaflets and number of aphid individuals/100 leaflets. Also, the parent BPL 710 (P_5) showed positive and highly significant values for chlorophyll content (2.23) and seed yield per plant (3.11), while was negative and significant values with maturity date (-2.63), shedding rate parentage (-7.83), number of mines/100 leaflets (-0.25) and number of aphid individuals/100 leaflets (-1.42). Therefore, the hybrid BPL 710 (P_5) could be good source for improving these mentioned characters in faba bean crop. Consequently, it could be concluded that previously mentioned parental genotypes and hybrids would prospect in faba bean breeding and therefore may be valuable for improving seed yield and its components including resistance to insect infestations. Similar findings were earlier reported by El-Hosary *et al.* (1998 a, b); Salama and Salem (2001); Darwish *et al.* (2005); El-Hady *et al.* (2007) and Ibrahim (2010).

Table 2. Mean squares obtained from preliminary analysis and combining abilities in 6 x 6 diallel in faba bean genotypes for the studied characters.

S.O.V	D.F.	Maturity date (Days)	Plant height (cm)	No. of branches per plant	Leaf chlorophyll content (SPAD-value)	No. of pods per plant	Shedding rate %	100-seed weigh (g)	Seed yield per plant	Number of mines/ 100 leaflets	Number of larvae/ 100 leaflets	Number of aphid individuals/100 leaflets
Rep.	2	3.64	146.0	0.26	1.39	413.70	35.20	3546.50	186.80	0.07	0.61	0.31
Genotype	35	389.0**	720.4**	39.6**	142.36**	3179**	2972.2**	18413.5**	3585.3 **	8.87 **	4.38 **	455.0 **
Error (preliminary)	70	10.21	161.4	5.36	91.30	681.70	206.2	7013.01	280.30	0.10	0.29	0.43
G.C.A	5	32.1 **	835.9 **	1.99 **	26.31 **	635.8 **	803.1**	3682.7**	717.0 **	1.77 **	3.57 **	91.0**
S.C.A	9	37.91 **	80.0 ns	1.77 **	24.26 **	813.2 **	330.2**	2924.4**	712.3 **	0.43 **	1.95 **	21.6**
G.C.A/ S.C.A		0.85	10.45	1.12	1.08	0.78	2.43	1.26	1.01	1.12	1.83	4.21
Reciprocal	15	41.0 **	157.2 ns	2.64 ns	10.39 *	489.0 **	67.0 ns	3811.3	7616.3 **	0.58 **	2.64 **	7.41**
Error (C.A)	58	3.19	54.5	0.38	1.87	39.9	35.5	330.2	101.0	0.01	0.23	0.43

ns ,* & ** not significant, significant at the 0.05 & significant at the 0.01 probability levels, respectively.

Genetic components of variance

The separating of the total genetic variance to its parts *via* additive and dominance gene effects for the studied characters showed in Table (5). The results indicated that the additive (D) and dominance (H_1 and H_2) components were found to be at the significant level of 5% or 1% for all studied characters, which confirmed their importance in the expression of these characters (Table 5). However, D component was reached to the significant level only for the *A. craccivora* infestation as the number of aphid individuals/100 leaflets, but did not for *L. congesta* as the number of mines or larvae100 leaflets. These results were in agreement and/or disagreement with those reported by El-Hosary *et al.* (1998 a, b), Salama and Salem (2001), Attia *et al.* (2002), Attia and Salem (2006) and Ibrahim (2010).

The *F* component was significant and positive for chlorophyll content (267.60), shedding rate (401.3%), seed yield per plant (466.01) and number of aphid individuals/100 leaflets (4.59), while its effect on the other characters were not significant. This indicates that the presence of the excessive of dominant alleles compared to recessive alleles (Table 5).

Significant differences of environmental variance (E) components were recorded for number of pods per plant, 100-seed weight, seed yield per plant and number of larvae/100 leaflets (Table 5), indicating that the environmental variance could play a major role in their contribution to the total phenotypic variance. Hence, increasing years and locations are so necessary for obtaining reliable estimation. These results are more or less agreement with the results detected by Lithourgidis *et al.* (1991).

The estimator (h^2), which refers to the dominance effects over all heterozygous loci, was no significant for the majority of the studied characters except for the 100-seed weigh (14.70). This indicating that no direction for the dominance effect due to heterozygosity, which confirmed the H_1 and H_2 results. This finding was in harmony with the result detected by Lithourgidis *et al.* (2003).

Table 3. Mean performance in 6 x 6-diallel set of faba bean genotypes (parents and their hybrids) for the all studied characters.

Characters / Parents & crosses	Maturity date (Days)	Plant height (cm)	No. of branches per plant	Leaf chlorophyll content (SPAD-value	No. of Pods per plan	Shedding rate %	100-seed weigl (g)	Seed yiel per plan	Numbe of mine 100 leaflets	Numbe of larva 100 leaflets	Number of aph individuals/10 leaflets
P_1	156	79	4.7	43	38	49	82	53	176	125	138
P_2	151	79	2.3	45	22	32	67	58	179	131	150
P_3	153	91	2.3	32	18	76	63	31	255	195	181
P_4	150	96	3.0	49	25	66	81	72	161	120	139
P_5	159	87	3.2	29	18	75	70	27	149	119	98
P_6	155	87	2.6	25	10	83	87	15	264	204	223
P_1 x P_2	153	77	2.9	27	10	72	86	23	240	191	209
P_1 x P_3	148	73	4.9	44	28	57	77	58	177	131	148
P_1 x P_4	155	82	5.8	28	11	69	78	25	242	186	207
P_1 x P_5	154	83	2.6	30	15	78	76	28	234	171	210
P_1 x P_6	153	82	3.0	40	28	68	78	49	178	129	147
P_2 x P_1	155	80	4.3	38	28	68	75	47	184	123	141
P_2 x P_3	156	89	3.9	38	19	61	82	47	182	120	154
P_2 x P_4	157	95	4.4	47	30	57	77	62	179	137	148
P_2 x P_5	152	81	4.4	39	26	64	84	47	184	128	151
P_2 x P_6	156	86	2.4	47	36	36	87	63	176	121	140
P_3 x P_1	156	100	4.2	36	18	82	70	40	191	133	157
P_3 x P_2	154	98	3.2	34	14	75	83	33	217	145	194
P_3 x P_4	145	90	4.0	37	18	80	77	42	188	118	149
P_3 x P_5	155	101	5.3	36	16	75	87	37	194	122	169
P_3 x P_6	153	102	4.1	31	22	74	69	31	205	170	187
P_4 x P_1	156	80	3.7	50	11	80	80	16	251	191	211
P_4 x P_2	153	93	3.1	37	17	77	79	41	191	123	164
P_4 x P_3	149	97	3.7	38	31	52	84	40	188	121	158
P_4 x P_5	154	98	3.1	31	29	44	79	30	215	174	187
P_4 x P_6	153	96	3.6	41	16	69	87	49	181	119	162
P_5 x P_1	150	73	3.2	42	18	54	77	42	189	121	164
P_5 x P_2	158	99	3.7	50	35	23	88	84	134	89	101
P_5 x P_3	154	103	3.7	48	37	37	73	68	171	124	132
P_5 x P_4	148	93	4.8	38	31	63	80	39	198	139	162
P_5 x P_6	156	96	2.1	37	18	59	87	41	190	138	154
P_6 x P_1	149	81	4.4	38	22	71	78	45	194	139	161
P_6 x P_2	157	78	4.7	26	25	64	82	30	211	172	191
P_6 x P_3	152	91	2.8	23	23	71	72	20	245	189	201
P_6 x P_4	147	95	3.4	27	13	80	75	26	241	194	203
P_6 x P_5	154	92	3.3	24	15	79	78	25	237	169	191

P_1 = Giza 643, P_2 = Giza 461, P_3 = Giza 716, P_4 = Nubaria 1, P_5 = BPL 710 and P_6 =Sakha 1

The mean degree of dominance for all loci $[(H_1/D)^{½}]$ was more than unity (one) for all the characters studied, except number of mines/100 leaflets resistance (0.86) under *L. congesta* infestation (Table 5). These findings indicated the involvement of an over dominance expression for all characters, while the presence of partial or incomplete dominance of resistance to *L. congesta* (number of mines/100 leaflets). However, the over-dominance observed in such characters may not be an index of true over-dominance, since the degree of dominance could be biased due to linkage, epistasis or both together (Comstock and Robinson, 1952).

These results were in harmony with the results reported by El-Hosary *et al.* (1998 a).

The gene frequency among the faba bean parents, estimated by means of *U* and *V* ($H_2/4H_1$), indicated a symmetrical distribution of genes with positive and negative effects for maturity date, 100-seed weight and number of *L. congesta* mines/100 leaflets (Table 5). The distribution seemed to be nearly symmetrical for plant height, number of pods per plant, seed yield per plant and number of aphid individuals/100 leaflets.

Table 4. Estimates of general combining ability effects for yield, its components and insects infection.

Parents	Maturity date (Days)	Plant height (cm)	No. of branches per plant	Leaf chlorophyll content (SPAD-value)	No. of Pods per plant	Shedding rate %	100-seed weigh (g)	Seed yield per plant	Number of mines/ 100 leaflets	Number of larvae/ 100 leaflets	Number of aphid individuals/100 leaflets
Giza 643	2.17	1.25	-2.32	-3.15	-6.48	6.67	-10.68	-5.21	0.53	1.39	3.80
Giza 461	-0.66	5.21	0.67	1.91	7.14	-6.46	16.03	2.82	-0.10	-2.01	-0.09
Giza 716	-0.80	-0.94	0.95	-0.79	-1.86	2.63	15.69	-1.99	0.02	0.25	-0.11
Nubaria 1	0.79	-5.59	-1.69	-1.38	-3.65	2.96	-8.26	-1.11	-0.07	-0.70	-0.84
BPL 710	-2.36	2.30	1.36	2.23	0.10	-7.83	-6.26	3.11	-0.25	0.69	-1.42
Sakha l	0.88	-2.23	1.03	1.18	4.76	2.04	-6.51	2.38	0.13	0.38	-1.34
L.S.D. (gi-gj) 0.05	1.966	0.226	1.123	1.39	0.208	2.557	1.251	1.966	0.68	1.02	1.31
L.S.D. (gi-gj) 0.01	2.651	0.304	1.514	1.76	0.281	3.449	1.687	2.651	0.97	1.35	1.54

P_1 = Giza 643, P_2 = Giza 461, P_3 = Giza 716, P_4 = Nubaria 1, P_5 = BPL 710 and P_6 =Sakha

Recessive alleles were obtained in the majority of characters, with respect to number of aphid individuals/100 leaflets, since the ratio of dominance (KD)/recessive (KR) alleles was less than one for all the studied characters, except number of aphid individuals/100 leaflets (1.03). For the most remaining characters, nearly a symmetrical distribution of dominant and recessive alleles seems to be the case. This indicates a preponderance of dominant genes in the parents for number of aphid individuals/100 leaflets. On the other characters, it could notice that the excess of recessive genes was evident throughout these characters. These results confirmed with the finding reported by Lühs *et al.* (2002).

The value of K (h^2/H_2, which stands for the number of groups of genes that exhibit dominance for each character) was <1 for all the studied characters. This suggested that just one group of genes showed dominance governed all of them. While this parameter could be underestimated, when the dominance effects of all genes was not concerned with equivalent, size and distribution, where the distribution of genes was correlated (Jinks, 1954), or complementary gene interactions occur (Mather and Jinks, 1971).

Heritability values in bored sense (h^2b) were relatively high and passed 75% for the most of characters. These characters *via* maturity date, number of branches per plant, chlorophyll content, total shedding percentage, seed yield per plant, number of *L. congesta* mines/100 leaflets, number of *L. congesta* larvae/100 leaflets, number of *A. craccivora* individuals/100 leaflets, and possessed in the same order 0.93, 0.77, 0.89, 0.90, 0.80, 0.82, 0.89 and 0.97. However, heritability in narrow sense (h^2n) was low and scored values less than 50%, exception maturity date (0.76) and plant height (0.63). These results confirmed that the environmental effects constitute a major portion of the total phenotypic variation in these characters. The results were more or less in agreement with those reported by Toker (2009) and Ibrahim (2010).

Table 5. Estimates of genetic variance components and related statistics in F1s for the all studied characters after Hayman´s analysis of a diallel between six faba bean var.

Genetic parameters	Maturity date (Days)	Plant height (cm)	No. of branches per plant	Leaf chlorophyll content (SPAD-value)	No. of pods per plant	Shedding rate %	100- seed weigh (g)	Seed yield per plant	Number of mines/ 100 leaflets	Number of larvae/ 100 leaflets	Number of aphid individuals/100 leaflets
D	19.14 *	27.2	0.66	190.45**	70.44 **	328.2 **	98.17 *	290.50**	0.30	0.49	3.27 **
H_1	52.22 **	48.18 **	1.54 **	391.21**	241.8 **	476.8 **	135.1**	695.10**	0.94**	3.17 **	25.76 **
H_2	39.69	32.63	1.23 **	217.04	220.4**	299.4 **	63.5	470.01**	0.54	1.03	17.47
F	89.06	- 44.30	0.74	267.60	-38.9	401.3 **	-31.0	466.01**	0.62	2.98	4.59
E	0.69	17.09	0.12	23.47	111.8 **	13.43	58.34 **	34.42 **	0.04	0.95 *	0.26
h^2	-3.20	5.00	1.23	2.48	6.56	5.12	14.70 *	2.98	0.28	1.68	1.89
$(H_1/D)^{0.5}$	3.66	1.33	1.52	1.03	1.0	1.20	1.06	1.54	0.86	3.18	2.81
$UV(H_2/4H_1)$	0.25	0.24	0.18	0.11	0.23	0.17	0.25	0.24	0.25	0.19	0.23
Kd/(KD+KR)	0.80	0.19	0.68	0.74	0.10	0.75	0.16	0.76	0.79	0.49	1.03
K	0.61	0.52	0.49	0.81	0.91	0.41	-0.18	0.95	0.31	0.48	0.19
h^2b	0.93	0.74	0.77	0.89	0.39	0..90	0.58	0.80	0.82	0.89	0.97
h^2n	0.76	0.63	0.21	0.49	0.31	0.37	0.23	0.14	0.19	0.41	0.43
r (Yr, Wr+Vr)	-0.59	-0.43	-0.47	0.31	0.52	0.27	0.50	-0.32	0.32	0.41	-0.19

D: Component of variance due to additive effects; H_1: Component of variance due to dominance effects; H_2: dominance effects indicating the symmetry of positive and negative effects of (*U*) proportion of homozygous parents; *F*: Covariance of additive and dominance effects; *h*2: dominance effect, estimated as the algebraic sum over all loci in heterozygous phase in all crosses; *E*: environmental or non-heritable components of variance; H_1/D: average degree of dominance over all loci; *UV*: product of proportion of negative genes and positive genes in the parents; *KD/KR*: ratio of total number of dominant to recessive genes in all parents; *K*: Number of gene groups which control the trait and exhibit dominance; *r(Y*r*, W*r*+V*r*)*: correlation coefficient between parental means averaged over blocks (*Y*r) and the parental order of dominance (*W*r*+V*r) of each array averaged over blocks, gives an idea of the direction of the dominance, *i.e,* if the increasing or decreasing genes for the trait are the dominant ones.

The correlation between parental performance (*Yr*) and parental order of dominance (*Wr+Vr*) was positive for number of pods per plant, 100-seed weight, chlorophyll content, total shedding percentage, as well as the number of *L. congesta* mines/100 leaflets and larvae/100 leaflets. These findings indicated that the faba bean parents possessed mostly negative genes in dominance form for the above-mentioned characters. While, in concerning the remaining characters, the positive genes were mostly dominance (Table 5).

Conclusions

Faba bean genotypes uniform with high seed yield potential and resistances to insects are necessary to be considering as a main target faba bean production. Therefore, breeding efforts in the current work emphasized on enhancement of seed yield components and resistance to leaf miner and aphid infestations. Our genetic analysis confirmed that additive and dominance gene action was very important in controlling the behavior of most agronomic characters, including the resistance to both insect infestations. For achieving faba bean genotypes, BPL 710, Sakha 1, Nubaria 1 and Giza 461 as well as their respective crosses were the best genotypes for short time to mature and lowest total shedding percentage, high yield potential and adapted/tolerant to insect infestations. The results confirmed that the environmental effects constitute could be a major portion of the total phenotypic variation in the characters studied and the selection should be effective for certain of these characters.

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References

Abdalla MMF, Darwish DS, El-Hady MM, EL-Harty EH. 1999. Investigations on faba bean (*Vicia faba* L.) 12-Diallel crossed materials grown under cages. Egyptian Journal of Plant Breeding **3,** 213-229.

Abdalla MMF, Darwish DS, El-Hady MM, EL-Harty EH. 2001. Investigations on faba bean (*Vicia faba* L.) 16-Diallel hybrids with reciprocals among five parents. Egyptian Journal of Plant Breeding **5,** 155-179.

Attia Sabah M, Shalaby FH, El-Sayed ZS, El-Hady MM. 2001. Heterosis, inbreeding depression and combining ability in a diallel cross of five faba bean genotypes. Annals of Agriculture Science, Moshtohor, **39(1),** 53-64.

Attia Sabah M, Saied MSh, Ezzat Zakia M, Rizk AMA, Aly KhA. 2002. Heterosis, combining ability and gene action in crosses among six faba bean genotypes. Egyptian Journal of Plant Breeding **6(2),** 191- 210.

Attia Sabah M, Salem Manal M. 2006. Analysis of yield and its components using diallel mating among five parents of faba bean. Egyptian Journal of Plant Breeding **10(1),**1-12.

Awaad HA, Salem AH, Mohsen AMA, Atia MMM, Hassan EE, Amer MI, Moursi AM. 2005. Assessment of some genetic parameters for resistance to leaf miner, chocolate spot, rust and yield of faba bean in F2 and F4 generations. Egyptian Journal of Plant Breeding **9(1),**1-15.

Bayoumi TY, El-Bramawy MAS. 2010. Genetic behavior of seed yield components and resistance of some foliar diseases with its relation to yield in faba bean (*Vicia faba* L.). The International Conference of Agronomy, 20-22 September, ELArish, 290-315.

Castelli F, Contillo R., Miceli F. 1996. Non-destructive determination of leaf chlorophyll content in four crop species. Journal of Agronomy and Crop Science **177,** 275-283.

Chowdhry MA, Akhtar MS, Ahmad MT. 1992. Combining ability analysis for flag leaf area, yield and its components in spring wheat. Pakistan Journal of Agricultural Research **30,**17-23.

Comstock RE, Robinson F. 1952. Estimation of average dominance of genes. In: Heterosis. Iowa State College Press, Ames, Iowa, 491-516.

Darwish DS, Abdalla MMF, El-Hady MM El-Emam EAA. 2005. Investigations on faba bean (*Vicia faba* L.) 19-Diallel and triallel mating using five parents. Proceed. Fourth Pl. Breed. Conf. March 5 (Ismailia) Egyptian Journal of Plant Breeding **9(1),**197-208.

Daur I, Sepetoglu H, Marwarth KB, Hassan G, Khan IA. 2008. Effect of different levels of nitrogen on dry matter and grain yield of faba bean. Pakistan Journal of Botany **40(6),** 2453-2459.

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

Ebadah IMA, Mahmoud YA, Moawad SS. 2006. Susceptibility of some faba bean cultivars to field infestation with some insect pests. Research Journal of Agriculture and Biological Sciences **2(6),**537-540.

El-Bramawy MAS, Osman MAM. 2010. Influence of potassium fertilization on yield components and resistance to leaf miner and aphid infestations of *Vicia faba* L. Agriculture Research Journal, Suez Canal University, **9(3),** 93-104.

El-Hady MM, Omer MA, Khalil SA. 1991. Heterosis, combining ability and genetic components for yield and its variables in diallel crosses of faba bean. Egyptian Journal of Applied Sciences **6(10),** 1-13.

El-Hady MM, Omer MA, Nasr SM, Mahmoud Samia A, El-Waraky MK. 1998. Performance of some faba bean genotypes along with F1 and F2 generations. Annals Of Agricultural Science, Moshtohor, **36(2),** 729-743.

El-Hady MM, Attia Sabah M, El-Galaly Ola AM, Salem Manal M. 2006. Heterosis and combining ability analysis of some faba bean genotypes. Journal of Agriculture Research, Tanta University **32(1),** 134-148.

El-Hady MM, El-Karim Gh A Gad, MA Omer. 1997. Genetical studies in faba bean (*Vicia faba* L.). Journal of Agriculture Science, Mansoura University **22(11),** 3561-3571.

El-Hady MM, Rizk AMA, Omran MM, Ragheb SB. 2007. Genetic behavior of some faba bean (*Vicia faba* L.) genotypes and its crosses. Annals of Agriculture Science, Moshtoher **45(1),** 49-60.

El-Hosary AA, Sedhom SA, Bastawisy MH, El-Mahdy MH. 1998 a. Daillel analysis of some quanitive characters in faba bean (*Vicia fabea* L.). Proceeding of the 8th Conference on Agronomy, Suez Canal University, Ismailia, Egypt, 28-29, November, 256- 267.

El-Hosary AA, Bastawisy MH, Tageldin MH 1998 b. Heterosis and combining ability for yield and its components, earliness, total shedding and resistance to diseases and insects in faba bean (*Vicia fabea* L.). Proceeding of the 8th Conference on Agronomy, Suez Canal University, Ismailia, Egypt, 28-29, November, 268-279.

EL-Harty EH, Shaaban M, Omran MM, Ragheb SB. 2009. Heterosis and genetic analysis of yield and some characters in faba bean (*Vicia faba* L.). Minia Journal of Agriculture Research and Development **27(5),** 897-913.

El-Keredy MS, El-Refaey RA, El-Hity MA, Zied GGA. 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.

FAO 2009. FAOSTAT data, 2009 – last updated 20 December, 2008. Food and Agriculture Organization, Rome.

Griffing JB. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. Australian Journal of Biological Sciences **9,** 463- 493.

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

Hawtin GC, Hebblethwaite PD. 1983. Background and history of faba beans production. In: The Faba Beans (*Vicia faba*), a basis for Improvement. Hebblethwaite PD, ed. Butterworths, London, 3–22.

Hayman BI. 1954. The theory and analysis of diallel crosses. Genetics **39,** 789-809.

Ibrahim AA, Nassib AM. 1979. Screening for disease resistance in broad beans (*Vicia faba*) in Egypt. Fabis Newsletter **1,** 25.

Ibrahim HM. 2010. Heterosis, Combining Ability and Components of Genetic Variance in Faba Bean (*Vicia faba* L.). Journal of King Abdulaziz University, Faculty of Meteorology, Environment and Arid Land Agriculture Sciences **21,** 35-50.

Jinks JL. 1954. The analysis of continuous variation in a diallel cross of *Nicotiana rustica*. Genetics **39,** 767-788.

Kaul DK, Vaid KL. 1996. Combining ability in Faba bean, FABIS Newsletter **38/39,** 12-17.

Lithourgidis AS, Roupakias DG Tzavella-Klonari K. 1991. Factors affecting the differentiation of resistant faba bean plants after inoculation with *Sclerotinia trifoliorum*. Plant Breeding **107,** 258-261.

Lithourgidis AS, Tzavella-Klonari K, Roupakias DG. 2003. The causal fungus of stem rot disease of faba beans in Greece. Journal of Phytopathology **151,** 631-635.

Kilmer VG, Alexander LT. 1949. Methodes of Machanical analysis of soils. Soils Science **68,** 15.

Lühs WF, Seyis R, Snowdon R, Baetzel R, Friedt W. 2002. Genetic improvement of *Brassica napus* by wide hybridisation, GCIRC Bulletin **18**, 227–234.

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

Mather K., Jinks JL. 1971. Biometrical Genetics, 2nd ed. Chapman & Hall Ltd., London. 382.

Mulusew F, Tadesse T, Tetta T. 2008. Genotype-environment interactions and stability parameters for grain yield of faba bean (*Vacia faba* L.) genotypes grown in south eastern Ethiopia. International Journal of Sustainable Crop Production **3(6),** 80-87.

Sadeghian SY, Khodaii H. 1998. Diallel cross analysis of seed germination traits in sugar beet. Euphytica **103(2),** 259-263.

Salama SM, Salem MM. 2001. Genetic analysis and combining ability over sowing dates for yield and its components in faba bean (*Vicia faba* L.), Agriculture Science., Mansora University **26,** 3621-3629.

Spencer KA. 1990. Host specialization in the world Agromyzidae (Diptera). Series Entomologica, Kluwer Academic Publishers, Dordrecht, **45,** 1-444.

Steel RGD, Torrie JH. 1997. Principles and Procedures of Statistics, 3rd ed. McGraw-Hill, New York.

Suso MJ, Moreno MT. 1999. Variation in outcrossing rate and genetic structure on six cultivars of *Vicia faba* L. as affected by geographic location and year, Plant Breeding **118,** 347-350.

Sundar KS, Munk L., Mathur SB. 2005. Role of weather on *Alternaria* Leaf Blight Disease and its effect on Yield and Yield Components of Mustard. Nepal Agriculture Research Journal **6,** 62-72.

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.

Weigand S, Bishara SI. 1991. Status of insect pests of faba bean in the Mediterranean region and methods of control. CIHEAM - Options Méditerranéennes - Série Séminaires **10,** 67-74.

Zhang Y, Kang MS. 1997. DIALLEL-SAS: a SAS program for Griffing's diallel analyses. Agronomy Journal **89,** 176–182.