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INVESTIGATIONS ON FABA BEANS, *Vicia faba* L.
19- DIALLEL AND TRIALLEL MATINGS USING FIVE PARENTS

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ABSTRACT

Five diverse faba bean genotypes: Line 390, Cairo 375, Giza 40, Nubaria 1 and Minica were used as parents in a diallel and triallel mating designs to determine the nature of gene action and relative magnitude of heterosis and combining ability effects of single and three way crosses.

Significant mean squares were detected for genotypes, general and specific combining ability effects for all traits. The g^2/s^2_i ratios exceeded unity for flowering date, maturity date and 100-seed weight indicating that additive gene effects were more important than non-additive gene effects in the inheritance of these traits. Remaining traits exhibited less than unity ratio.

Results revealed highly significant differences among genotypes and their components: parents (P), single crosses (SC) and three way crosses (TWC) indicating a wide genetic variability among each category of genotypes for all studied traits. The magnitude of variance is higher of parents than both groups of crosses for flowering date, maturity date, number of branches and 100-seed weight. However, both groups of crosses recorded higher mean squares than parental genotypes for plant height, number of pods and number of seeds. For seed yield/plant the three way crosses recorded more than two folds as showed by either parents or single crosses. It is worth to note that the comparison of homozygous genotypes (parents vs. both of heterozygous ones) shown higher variance compared to SC vs. TWC for all traits. This means that considerable heterosis were obtained by both groups of crosses comparing to parental genotypes

Generally, the general, specific and three line specific combining ability effects of parental genotypes from diallel varied from those obtained from triallel's in signs and magnitudes and also among traits. This may be due to participating extra parents in triallel's, which complicated the trend that could be concluded.

Key words: ~~*Faba bean, Diallel*~~, *Triallel, Heterosis*, ~~*Combining ability effects.*~~

INTRODUCTION

The acreage's and seed yields of faba bean vary due to seasons and locations. The yield instability is attributed to various biotic and environmental stresses (Darwish and Abdalla 1997). The faba bean yield and stability could be improved by using heterozygous/heterogeneous varieties (Stelling *et al* 1994b and Darwish *et al* 2001). The utilization of synthetic varieties was proposed as a mid-way for exploiting the heterosis in addition to heterogeneity in modern faba bean varieties (Bond 1982, Darwish 1992 & 1996, Abdalla and Darwish 1992, Link *et al* 1994, Stelling *et al* 1994 a & b and Darwish *et al* 2001).

The selection of proper synthetic variety components, which possessed high combining ability and high heterosis, is important for producing reliable faba bean varietal performance. The assessment of component valuability could be achieved from employing systematic crosses or a utilization of polycross test for detecting the suitability of various genotypes in building up a synthetic faba bean variety (Darwish *et al* 2001). On the other hand, the genetic improvement of various traits depends on the nature and magnitude of genetic variability in addition to hybridization offers new recombinations and releases raw material for improvement.

Combining ability effects helps the breeder to identify the best combiners to be crossed either to exploit heterosis or to build up the favorable fixable genes. Several authors stated the significance of both general and specific combining ability effects for important agronomic traits, yield and yield components (El-Hady *et al* 1997, 1998, Abdalla *et al* 1999, 2001, El-Hosary 1983 a&b, Mansour *et al* 2001, and Abd El-Mohsen, 2004).

Diallel cross technique have been frequently used for analyzing the combining ability and gene action of faba bean breeding material (Bond 1966, 1967, El-Hady 1988, Attia 1998 and Attia *et al* 2002). However, diallel mating design provide unbiased estimates of different genetic components under the assumption of the absence of epistatic effects (Cockerham 1961). The triallel mating design was suggested as an alternative model for avoiding the bias and inferences of existing non-allelic interaction when utilizing of diallel (Rawlings and Cockerham 1962). On the other hand, the triallel mating design provides reliable information about the genetic components of variance i.e. additive, dominance, additive x additive, additive x dominance and dominance x dominance (Rawlings and Cockerham 1962). Triallel analysis giving additional information on magnitude of types of epistatic components and also on order of parents to be used in three-way crosses for obtaining superior transgressive segragants (Laxman *et al* 2003).

However, such technique was not published concerning the evaluation of faba bean parental genotypes.

This study aimed to understanding the nature of gene action and relative magnitude of heterosis and combining ability using both diallel and triallel mating designs of five faba bean diverse lines.

MATERIALS AND METHODS

The field trials of this investigation were carried out at the Research Station, Faculty of Agriculture, Cairo University, Giza during 2001/2002, 2002/2003 and 2003/2004 seasons. Five diverse faba bean lines developed via single seed descent for more than 5 generations under insect free cages were used as parents. The origin and some features of these lines are presented in Table (1).

Table 1. Origin, pedigree and features of the five parental genotypes.

Genotype	Origin	Pedigree	Features
Line 390 (P_1)	ADFACU	Egyptian local selection.	White hilum, *Orobanche* tolerant.
Cairo 375 (P_2)	ADFACU	Egyptian local selection.	High yielder, profuse flowering.
Giza 40 (P_3)	FCRI	Individual plant selection from Rebaya 40.	Small-seeded, early maturing.
Nubaria 1 (P_4)	Spain	Individual plant selection from Reina Blanca.	Large-seeded, foliar disease resistant, white hilum.
Minica (P_5)	Netherlands	Inst. of Agron. & Plant Breeding, Gottingen, Germany.	White hilum.

ADFACU = Agron. Dept. Fac. Agric. Cairo Univ FCRI = Field Crops Research Institute

All possible single crosses (SC) among the five parents excluding reciprocals were made in 2001/2002 season under insect free cages. In 2002/2003 season, rehybridization was made to increase seeds of F_1 and to produce all possible 30 three-way crosses (TWC) involving the five lines. A triallel denoted as (AB) C is defined as a cross between line C and the unrelated F_1 hybrid (AB). Lines A & B being called grand parental lines and line C as full or immediate parent

In 2003/2004 an evaluation trial was conducted involving five parents, their 10 SC and 30 TWC crosses in a randomized complete block design (RCBD) with three replications. Each genotype was represented in each replicate by one ridge 1.5 m long and 60 cm apart. Single-seed hill was planted at one side of the ridge distanced 20 cm. Normal recommendations of faba bean growing were done.

Data were recorded on all plants per plot for parents, F_1's diallel and F_1's triallel for 50 % flowering date, 95 % maturity date, plant height, number of branches/plant, number of pods, seeds and seed yield/plant as well as 100-seed weight on plot basis.

Estimates of combining ability (GCA and SCA) for diallel mating design were analyzed according to Griffing (1956) Method II Model I. For triallel, estimates of genetic components and various crossing combination's effects were analyzed according to Singh and Chaudhary (1985).

RESULTS AND DISCUSSION

Variation, mean performance and heterosis of single and three way crosses

Statistical analysis of variance are presented in Table (2) revealed highly significant differences among genotypes and their components: parents (P), single crosses (SC) and three way crosses (TWC) indicating a wide genetic variability among each category of genotypes for all studied traits.

Table 2. Significance of mean squares due different sources of variation for studied traits during 2003/2004.

S.O.V.	df	Flowering date	Maturity date	Plant height	No. of branches
Genotypes	44	85.2**	115.9**	317.0**	4.8**
Parents (P)	4	200.1**	207.2**	202.4**	8.7**
Single crosses (SC)	9	116.1**	60.7**	250.4**	3.2**
Three-way crosses (TWC)	29	58.8**	122.4**	248.4**	4.4**
SC vs TWC	1	21.9**	18.0**	334.9**	0.3
P vs Sc & TWC	1	177.0**	156.0**	3346.4**	18.6**
Error	58	2.8	3.1	10.9	0.3
S.O.V.	**df**	**No. of pods/plant**	**No. of seeds/ plant**	**Seed yield /plant**	**100-seed weight**
Genotypes	44	264.2**	1555.9**	684.7**	366.9**
Parents (P)	4	162.5**	670.5**	227.5**	812.2**
Single crosses (SC)	9	252.9**	1029.1**	248.8**	545.4**
Three-way crosses (TWC)	29	226.3**	1339.0**	602.6**	237.6**
SC vs TWC	1	9.8*	286.8**	83.8	72.6
P vs Sc & TWC	1	2127.6**	17399.0**	9419.1**	1023.4**
Error	58	43.3	244.6	136.0	47.4

The magnitude of variance of parents is higher both groups of crosses for flowering date, maturity date, number of branches and 100-seed weight. However, both groups of crosses recorded higher mean squares than parental genotypes for plant height, number of pods and number of seeds. For seed yield/plant the three way crosses recorded more than two folds as shown by either parents or single crosses. The two allowed orthogonal comparisons, i.e.

SC *vs.* TWC and P *vs.* SC & TWC showed highly significant mean squares for all studied traits except for the first comparison for number of branches/plant. It is worth to note that the comparison of genotypes (parents *vs.* both of heterozygous ones) showed higher variance compared to SC *vs.* TWC for all traits. This means that considerable heterosis was obtained by both groups of crosses comparing to parental genotypes.

The mean performance of parents and their crosses are presented in Table (3). Both groups of crosses possessed tallest plants with profused branching that beard more pods, seeds and seed yield/plant with heavier seed than their parents. However, for flowering and maturity dates single crosses were earlier than parents and three way crosses with delaying both dates due to three way crosses. On the other hand, the parental genotypes recorded lower limits of ranges for all studied traits except flowering and maturity and showed higher coefficient of variability for all traits than for both groups of crosses. Moreover, the mean performance of three way crosses was higher corresponded with wider ranges than single crosses for the most important yield traits (pods, seeds and seed yield). This means that the crossing of single crosses with unrelated parents gave extra heterosis than those obtained by single crosses comparing with parental performance. The superiority of single crosses over parental genotypes were 53.7, 54.6, 72.0 % for pods, seeds and seed yield/plant, respectively. Whereas, the corresponding superiority of three way crosses over parents were 62.3, 77.3 and 91.6 %, respectively.

The heterosis percentages of single crosses over mid parents and three way crosses over corresponding SC and line parents are presented in Table (4). Pronounced and favorable heterosis were obtained by several authors for faba bean traits which varied according to the crossed combinations and traits (Bond 1966, Abdalla and Fischbeck 1983, El-Hosary 1983 a & b, El-Hady *et al* 1997 & 1998, Abdalla *et al* 1999 & 2001, Abdel-Mohsen 2004 and others). The obtained three way crosses heterosis encourages the breeder for detecting proper components of synthetic varieties to be included in blends and allowing interpollination of better three way crosses for more heterozygosity and heterogeneity.

Table 3. Mean performance, ranges and C.V. % of faba bean parents, single crosses and three way crosses during 2003/2004.

	Flowering date	Maturity date	Plant height	No. of branches	No. of pods /plant	No. of seeds/ plant	Seed yield /plant	100-seed weight
Parents (P)								
Mean	51.1	151.9	96.1	4.5	20.5	47.1	29.6	63.9
Range	44.0-64.3	142.3-163.7	87.3-107.3	3.2-7.4	14.3-32.4	32.5-71.5	18.9-39.1	51.7-92.8
C.V. %	16.0	5.5	8.5	38.0	36.0	31.7	29.4	25.7
Single crosses (SC)								
Mean	49.3	150.9	111.8	5.8	31.5	72.8	50.9	73.8
Range	43.0-62.3	143.3-158.7	96.2-124.9	4.0-8.0	17.3-45.3	42.7-100.9	39.9-66.6	62.4-96.1
C.V. %	12.6	3.0	8.2	17.8	29.2	25.4	17.9	18.3
Three way crosses (TWC)								
Mean	52.3	153.6	100.3	5.5	33.4	83.5	56.7	68.4
Range	44.7-63.0	141.3-163.7	80.8-116.7	3.2-8.5	23.2-64.5	61.3-158.5	33.7-105.3	55.0-96.6
C.V. %	8.5	4.2	9.1	22.2	26.0	25.3	25.0	13.0

Combining ability of diallel and triallel analyses

The combining ability analysis of diallel cross performed in the existence of significant genotypic variance, showed that both additive and non-additive gene effects are operating in the heredity of all studied traits (Table 4). However, the relative importance of additive (g^2_i) versus non-additive (s^2_i) effects could be elucidated from calculating the ratio of both effects, respectively. The obtained g^2_i / s^2_i ratios (Table 4) proved that additive gene effects appear to be predominant only for flowering date, maturity date and 100-seed weight of diallel analysis. Thus, selection may be effective for improving these traits. The other traits could be improved by maintaining and encouraging the level of heterozygosity in growing varieties.

Table 4. Significance of mean squares due to genotypes, general (GCA), specific (SCA) combining ability and ratio of additive (g^2_i) to non-additive (s^2_i) gene effects for the studied characters.

Traits	df	Genotypes	GCA	SCA	g^2_i/s^2_i
		14	4	10	
Flowering date, days		134.1**	1281**	11.4**	1.8
Maturity date, days		99.0**	98.1**	6.8**	2.5
Plant height, cm		395.5**	133.8**	131.0**	0.1
Number of branches/plant		6.4**	3.3**	1.6**	0.3
Number of pods/plant		293.7**	151.6**	76.4**	0.3
Number of seeds/plant		1333.7**	554.6**	396.7**	0.2
Seed yield/plant, g		548.3**	117.9**	208.7**	0.1
100-seed weight, g		651.3**	638.8**	48.4**	2.4

** indicates significant at 1 % level of probability.

The triallel analysis showed that the mean squares due to TWC were highly significant for all traits (Table 5). The partition of TWC variance into different components of various cross combinations: general line, two line (both first and second kind) and three-line specific effects were performed to explore the nature of gene action controlling trait/s. The significance of such components of TWC variance showed that all of these components were significant for flowering date, plant height, number of pods and seeds/plant. This indicated that all three types of epistatic components, i.e additive x additive, additive x dominance, dominance x dominance along with additive and dominance gene actions are involved in expression of these traits (Table 5).

Table 5. Significance of mean squares due to different source of variation of triallel analysis.

S.O.V	df	Flowering date	Maturity date	Plant height	Branches	Pods	Seeds	SY/plant	100-seed weight
General line effect of the first kind (hi)	4	14.2**	249.5**	539.0**	5.7*	91.3**	1075.8**	477.8	182.3
General line effect of the second kind (gi)	4	102.2**	133.9**	206.2**	11. **	215.0**	2044.1**	1267.6*	199.9
Two line specific effects of the 1st kind (dij)	5	127.8**	298.6**	302.1**	1.9	472.6**	2929.9**	951.6*	402.5*
Two line specific effects of the 2nd kind (sij)	11	54.5**	58.8**	246.1**	4.6**	271.0**	1063.7**	521.3**	279.6**
Three-line specific effect (Tijk)	5	18.7**	0.000	106.0**	0.00	315.2**	1586.4**	700.7*	214.4*
Crosses	29	58.8**	126.7**	248.2**	4.4**	226.5**	1338.9**	602.6**	237.6**
Error	58	2.8	3.3	10.9	0.3	43.3	244.6	135.9	47.4

The remaining traits lacked of significance in one or two of the aforementioned components. Dominance (as two line specific effect of the first kind, d_{ij}) for branches and additive effect of genes (as general line effect of the first kind, h_i), for seed yield per plant and seed index were insignificant. The non-allelic interactions as dominant x dominant (three line specific effect, T_{ijk}) for maturity and branches in addition to additive x additive (as general line effect of the second kind gi) for seed index were also insignificant. Thus, the strategies for improving these traits should be take this information in consideration before planning or deciding the effective selection method in segregating generations. Moreover, the magnitude of each variance component vary from trait to another which affected the efficiency of selection method in improving various traits. The obtained results of existing epistatic effects greatly violate the assumption of the absent of epistatic effects in using diallel mating design for providing estimates of additive and dominance variances.

Generally, the general, specific and three line specific combining ability effects of parental genotypes from diallel varied from those obtained from triallel's in signs and magnitudes and also among traits. This may be due to participating extra parents in triallel's, which complicated the trend that could be concluded.

It's worth to note that parent order effects were clearly observed in all combinations for most traits. The obtained results had clearly elucidate the advantages of triallel analysis over diallel analysis by the additional information on the existence of epistatic gene action and also on order of parents to be crossed in three way crosses. Such information greatly assist the planning of breeding program either for detecting the components of synthetic variety or for obtaining superior transgressive segregants in selection program.

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دراسات على الفول البلدى

١٩ . نظام التهجين التبادلى والثلاثى لخمسة آباء من الفول البلدى

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أجريت التجارب الحقلية لهذا الدراسة فى محطة التجارب والبحوث الزراعيــة-كليــة الزراعــة-جامعة القاهرة بالجيزة خلال موسم ٢٠٠٢/٢٠٠١، ٢٠٠٣/٢٠٠٢، ٢٠٠٤/٢٠٠٣. استخدمت فــى هــذه الدراسة خمسة آباء من الفول البلدى (سلالة ٣٩٠، قاهرة ٣٧٥، جيزة ٤٠، نوبارية ١، مينيكــا) متباينــة وراثيا بالإضافة الى الهجن الفردية والثلاثية الناتجة منها لتحديد أهمية تأثير القدرة علــى التــالف لصفــات التبكير والمحصول ومكوناته.

أظهرت النتائج وجود اختلافات معنوية بالنسبة للتراكيب الوراثية وكذا قدرتها العامــة والخاصــة على الائتلاف بالنسبة للهجن الفردية لكل الصفات تحت الدراسة كما أوضحت النسب المتحصل عليها للقــدرة العامة الى الخاصة الى تجاوز ثلاث صفات للوحدة وهى تاريخ التزهير والنضج ووزن الــ ١٠٠ بذرة ممــا يشير الى أهمية دور الفعل الجينى المضيف بالمقارنة بالغير مضيف فى وراثة هذه الصفات. بينما أوضحــت بقية الصفات الى ان النسبة لم تتجاوز الوحدة مما يشير الى أهمية الفعل الجينى الغير مضيف بالنسبة للفعــل الجينى المضيف فى وراثة هذه الصفات.

أظهرت النتائج وجود اختلافات عالية المعنوية والتراكيب الوراثية ومكوناتها المختلفة وهى الآبــاء والهجن الفردية والثلاثية مما يشير الى وجود اختلافات وراثية كبيرة بين كل مكون للصفات تحت الدراســة. أظهرت النتائج ان تباين الآباء كان الأعلى بالمقارنة بالهجن الفردية والثلاثية لصفات التزهير وتاريخ النضــج وعدد الأفرع للنبات ووزن الــ ١٠٠ بذرة بينما كان التباين أعلى فى الهجن الفرديــة والثلاثيــة بمقارنتــها بالآباء لصفات ارتفاع النبات وعدد القرون والبذور للنبات. بالنسبة لصفة محصول البذور/نبات، سجلت الهجن الثلاثية قيم تباين أعلى من الضعف بالمقارنة بآبائها والهجن الفردية . ومن الجديــــر بــالذكر ان المقارنــات الفردية (بين الآباء وهجنها سواء الفردية والثلاثية) أظهرت قيم عالية للتباين مقارنة بالهجن الفرديـــة فــى مقابل الثلاثية لصفات تحت الدراسة وهذا يشير الى وجود تأثير لقوة الهجين للصفات تحت الدراسة.

وبصفة عامة أظهرت النتائج المتحصل عليها عدم وجود اتجاه واضح لتــأثيرات القــدرة العامــة والخاصة وكذا التأثير التناقى والثلاثى بين الهجن التبادلية والثلاثية. وهذا قد يرجع الى مشــــاركة أب آخــر الهجن الثلاثية مما يظهر تعقيدات تؤثر على الاتجاه الممكن الحصول عليه.

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