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Inheritance of Seed Yield and Some Yield Components of Faba Bean Using Six Populations

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Abstract

Six populations P_1, P_2, F_1, F_2, BC_1, and BC_2 of two faba bean crosses were established during winter 2013/2014 to 2014/2015 seasons and evaluated in 2015/2016 winter season at Experimental Farm, Faculty of Agriculture, Al-Azhar University at Assiut Branch. The mean values of F_1 surpassed the high parent in each cross for all the studied traits, indicating over dominance. Variance estimates of the segregating generations were greater than that of the F_1 and their parents. The magnitude of dominance was higher than additive effects for all studied traits in the two crosses, indicate the importance of dominance gene effects in the inheritance of all studied traits. High genetic gain was found to be associated with rather high and moderate heritability estimate for most studied traits, therefore selection for these traits in the two crosses under investigation should be effective and satisfactory.

Keywords: *Six population, heterosis, inbreeding depression, heritability*

Introduction

Faba bean (*Vicia faba* L.) is an important source of protein for human in developing countries and animal in industrialized countries (Haciseferogullari *et al* 2003). In addition, as other seed legumes, faba bean provides nitrogen fixation and has a major role in crop rotation in many regions of the world (Alan and Ceren 2007).

Faba bean breeders have used several biometrical techniques to formulate the most efficient breeding procedures for evaluation of genetic effects of genes controlling quantitative traits to bring about the maximum improvement of enhance yield potentials amongst a large array of them, generation mean analysis is an efficient procedure. Generation mean analysis uses six basic generations which included parents (P_1 and P_2), first and second generations (F_1 and F_2) and first two backcrosses (BC_1 and BC_2). An understanding of the mode of gene action, knowledge of genetic variances, levels of dominance, and the importance of genetic effects may help plant breeders to enhance yield potentials (Wolf and Hallauer 1977). The generation mean analysis is an important tool for the estimation of different genetic effects such as types of gene action, heritability and heterosis (Kearsey and Pooni 2004, Checa *et al* 2006, Rebetzke *et al* 2006 and Tiruneh-Mulugeta *et al* 2013). Heritability estimate is useful in predicting the expected genetic advance from selection in segregating populations. The estimates of genetic advance help in understanding the type of gene action involved in the expression of various polygenic characters. High values of genetic advance are indicative of additive gene action, whereas low values are indicative of non-additive gene action (Singh and narayanan 1993). Thus the heritability estimates will be reliable if an accompanied by a high genetic advance. Exploitation of heterosis could pay off improving yield potential and its components in faba bean, where superiority of hybrids over the mid and/or better parents for seed yield is associated with manifestation of heterotic effects in important yield components, i.e., number of branches/plant, number of pods/plant and 100-seed weight.

The aim of the present study was to perform genetic analysis of yield and yield components in two crosses of faba bean, using generation mean analysis. Furthermore, inheritance of traits under investigation was studied.

Materials and Methods

The present investigation was carried out at Experimental Farm, Faculty of Agriculture, Al-Azhar University at Assiut Branch during three successive winter seasons 2013/2014, 2014/2015 and 2015/ 2016.

The experimental materials in this study consisted of six populations P_1, P_2, F_1, F_2, BC_1, and BC_2 of four faba bean parental genotypes i.e., Giza 2, Giza 3, Giza 40 and Giza 716. Where, two crosses were formed the first (Giza 2 (P_1) x Giza 40 (P_2)) and the second (Giza 3 (P_3) x Giza 716 (P_4)). The origin and maturity of these faba bean genotypes are presented in Table 1.

Table 1. The name, origin and maturity of four faba bean parental genotypes.

Parents	Origin	Maturity
Giza 2	Egypt	Early
Giza 3	Egypt	Early
Giza 40	Egypt	Early
Giza 716	Egypt	Moderate

Experimental layout

In 2013/2014 season, the following two crosses were formed to obtain F_1:

The first cross: Giza 2 x Giza 40

The second cross: Giza 3 x Giza 716

In 2014/2015 season, the F_1 seeds of the two crosses with their parents were sown and the F_1 plants were self pollinated to obtain F_2 and backcrossed to both parents to obtain BC_1 and BC_2 for each cross.

In 2015/2016 season, the six populations P_1, P_2, F_1, F_2, BC_1 and BC_2 from each cross were sown in a randomized complete block design (R.C.B.D) with three replications Experimental Farm, Faculty of Agriculture, Al-Azhar University at Assiut Branch. Each parent was represented by two ridges, each F_1 by one ridge, each F_2 by 5 ridges and each BC by 3 ridges in each replicate. The ridge was 3 m in long with 60 cm between ridges. Planting was done in hills spaced 20 cm apart on one side of the ridge. The recommended cultural of faba bean production were applied at the proper time.

Data were collected for plant height (cm), number of branches/plant, number of pods/plant, 100-seed weight (g) and seed yield/plant (g).

Statistical analysis:

Various biometrical parameters used in this investigation would only be computed if the F_2 genetic variance was found to be significant. Heterosis (H%) was expressed as percent increase of the F_1 performance above the better parent value. Inbreeding depression (I.d%) was estimated as the average percent decrease of the F_2 from the F_1. F_2 deviation (E_1) and backcross deviation (E_2) were measured as suggested by Mather and Jinks 1971. Potence ratio (P) was also calculated according Peter and Frey 1966.

Genetic analysis of generation means to give estimates of mean effect parameter (m), additive (a), dominance (d), additive x additive (aa), additive x dominance (ad) and dominance x dominance (dd) were calculated using the methods illustrated by Gamble (1962). Heritability was calculated in both brad and narrow sense according to Mather 1949. The predicted genetic advance under selection (Δ g%) was obtained following Miller *et al* 1958.

Results and Discussion

Varietals differences in response to their genetic background were found to be significant in the all studied traits. The genetic variance within F_2 populations was found to be significant for all the studied traits in both two crosses. Consequently, the various biometrical parameters used in this investigation were estimated. Mean performance and variance of the six populations P_1, P_2, F_1, F_2, BC_1 and BC_2 from each cross for all the studied traits are presented in Table 2. The obtained results exhibited that mean values of P_2 in both crosses were higher than P_1 for all the studied traits, except plant height in both crosses, while in crosses the means of parents gave different values from one to another. The mean values of F_1 surpassed the high parent in each cross for all the studied traits, indicating over dominance. Variance estimates of the segregating generations were greater than that of the F_1 and their parents. These results are supported with the findings of Hendawy 1994 and Akhshi *et al* 2014.

Table 2. Mean performance and variance for the six populations of the two crosses (Giza 2 x Giza 40) and (Giza 3 x Giza 716) of faba bean.

Traits	Crosses	Mean and variance	Parameters					
			P_1	P_2	F_1	F_2	BC_1	BC_2
Plant height	Cross 1	Mean	127.65	117.38	151.24	139.22	143.35	139.46
		Variance	108.12	122.48	144.85	422.55	265.33	305.43
	Cross 2	Mean	117.74	99.55	135.65	125.95	132.12	124.55
		Variance	111.56	123.78	166.12	588.33	422.58	395.32
No. of branches/ plant	Cross 1	Mean	1.97	5.17	6.04	4.08	4.94	516
		Variance	1.44	2.16	2.22	4.22	3.44	3.25
	Cross 2	Mean	2.03	5.15	5.99	4.01	4.85	5.13
		Variance	2.22	1.96	2.95	5.22	4.12	4.06
No. of pods/plant	Cross 1	Mean	19.77	29.33	39.80	26.38	24.56	29.11
		Variance	44.23	21.55	70.77	159.44	118.25	105.12
	Cross 2	Mean	26.53	36.22	39.32	28.23	30.62	35.13
		Variance	36.56	41.44	45.16	90.33	61.98	74.24
100-seed weight	Cross 1	Mean	46.23	60.46	66.23	61.77	50.35	56.23
		Variance	59.66	66.27	99.22	222.94	175.24	155.67
	Cross 2	Mean	50.55	65.11	75.46	66.12	58.33	72.78
		Variance	45.15	66.65	85.44	312.25	285.55	145.22
Seed yield/plant	Cross 1	Mean	22.32	31.46	41.35	36.33	26.66	31.00
		Variance	55.22	66.34	100.23	285.33	275.22	165.12
	Cross 2	Mean	26.68	35.78	39.95	35.29	30.82	35.57
		Variance	122.04	141.73	158.59	406.15	261.17	302.81

Useful heterosis, inbreeding depression (I.d%), the F_2 deviation from the average of the F_1 and mid-parent value (E_1), the backcross deviation E_2 and potence ratio (P) of the two crosses for all the studied traits are presented in Table 3. The obtained results exhibited that significant or highly significant positive useful heterosis was found for all the studied traits in both crosses, indicating that heterotic effects for seed yield/ plant were associated with other yield components. In addition, there was sufficient genetic variability among the assessed parents to favor efficient breeding for these traits. Significant hybrid vigour was previously reported in faba bean by Hendawy 1994, Attia *et al* 2001, Darwish *et al* 2005, El-Hady *et al* 2006 and Obiadalla-Ali *et al* 2013.

Inbreeding depression estimates were significant or highly significant for all the studied traits of both crosses. Heterosis in the F_1 generation should be followed by appreciable reduction in the F_2 generation, since the two parameters are similar in their causes. Present results were found to agree with this expectation in all the studied traits.

The F_2 mean performance was high significant deviated from the average of the F_1 and mid-parent value E_1 for all the studied traits in both crosses. Backcross deviation E_2 was also found to be significant for all the studied traits, except number of branches/pod of both crosses. The F_2 deviation was accompanied by backcross deviation in most traits in both crosses and that would ascertained the pronounced contribution of epistatic effect in the inheritance of nearly all the studied traits under investigation.

The potence ratio values indicated the existence of over dominance towards the better parent for all the studied traits. Generally, potence ratio estimates were found to follow the same pattern of the heterosis in all the studied traits of both crosses.

Table 3. Heterosis, inbreeding depression (I.d%), E_1, E_2 and potence ratio (P) of the two crosses (Giza 2 x Giza 40) and (Giza 3 x Giza 716) of faba bean.

Traits	Crosses	Heterosis	Inbreeding depression %	E_1	E_2	Potence ratio
Plant height	Cross 1	28.84**	7.94*	186.12**	9.05**	- 5.59
	Cross 2	36.26**	7.15*	166.77**	12.38**	- 2.97
No. of branches/plant	Cross 1	16.83**	32.45**	4.63**	0.49	1.54
	Cross 2	16.31**	33.06**	4.61**	0.40	1.54
No. of pods/plant	Cross 1	36.15**	33.72**	30.98**	- 10.60**	3.23
	Cross 2	8.54*	28.20**	39.95**	- 4.95**	1.64
100-seed weight	Cross 1	9.56*	6.74*	82.00**	- 13.00**	1.81
	Cross 2	15.89**	12.37**	86.22**	- 2.18**	2.42
Seed yield/plant	Cross 1	31.44**	31.44**	42.55**	- 10.58**	3.17
	Cross 2	11.62**	26.26**	46.55**	- 10.58**	1.91

*,** significant at 0.05 and 0.01 probability levels, respectively.

Genetic analysis of generation means to give estimates of mean effect parameter (m), additive (a), dominance (d), additive x additive (aa), additive x dominance (ad) and dominance x dominance (dd) are presented in Table 4. The obtained results exhibited highly significant for the mean effects (m) of all the studied traits in the two crosses, indicated that all the studied traits were quantitatively inherited. Additive gene effects (a) were found to be highly significant for all the studied traits in the two crosses, except number of branches/plant in the two crosses, suggesting the potential for obtaining further improvement of these traits. Dominance gene effects (d) were found to be highly significant for all the studied traits in the two crosses. The magnitude of dominance was higher than additive effects for all the studied traits in the two crosses, indicate that the importance of dominance gene effects in the inheritance of all studied traits. The values of additive x additive (aa) and dominance x dominance (dd) were highly significant for all the studied traits of the two crosses. On the other hand, the values of additive x dominance were non significant for all the studied traits in the two crosses, except 100-seed weight in the second crosses. In most cases, the magnitude of additive x additive gene effects appeared to be higher than dominance x dominance and additive x dominance types of gene effects, indicating that epistasis in the basic mechanism control the inheritance of the studied traits. These results are supported with the findings of El-Hady *et al* 1998, Salama and Salem (2001), Attia *et al* 2002, Bakheit *et al* 2002, Salama and Mohamed 2004, Attia and Salem 2006, Obiadalla-Ali *et al* 2013, Tiruneh-Mulugeta *et al* (2013) and Akhshi *et al* 2014.

Table 4. Gene action of the two crosses (Giza 2 x Giza 40) and (Giza 3 x Giza 716) of faba bean for all the studied traits during 2015/2016 winter season.

Traits	Crosses	Gene action parameters					
		M	A	D	Aa	Dd	Ad
Plant height	Cross 1	139.22**	3.89**	37.44**	8.72**	- 26.82**	- 1.25
	Cross 2	125.95**	7.57**	36.55**	9.54**	- 34.29**	- 1.53
No. of branches/plant	Cross 1	4.08**	- 0.22	6.35**	3.88**	- 4.86**	1.38
	Cross 2	4.01**	- 0.28	6.32**	3.92**	- 4.72**	1.28
No. of pods/plant	Cross 1	26.38**	- 4.56**	17.12**	1.82**	19.45**	0.18
	Cross 2	28.23**	- 4.51**	26.51**	18.57**	- 8.67**	0.34
100-seed weight	Cross 1	61.77**	- 5.89**	- 21.03**	- 33.91**	59.91**	1.22
	Cross 2	66.12**	- 14.45**	15.36**	- 2.27**	6.62**	- 7.16**
Seed yield/plant	Cross 1	28.35**	- 4.33**	16.38**	1.92**	19.23**	0.24
	Cross 2	29.46**	- 4.75**	23.66**	14.95**	- 5.36**	- 0.20

*,** significant at 0.05 and 0.01 probability levels, respectively.

Heritability in both broad and narrow sense and genetic advance as percentage of F_2 mean were calculated and the obtained results are presented in Table 5. Relatively high heritability estimates in broad sense were detected for all the studied traits, except number of branches/plant in the two crosses and number of pods/plant in the second cross, where moderate estimate were obtained. The estimated values of narrow sense heritability were found to be rather high for plant height in the two crosses, number of pods/plant in the first cross, 100-seed weight and seed yield/plant in the second cross. Moderate narrow sense heritability estimates were obtained for number of pods/plant in the second cross, 100-seed weight in the first cross. Relatively low narrow sense heritability estimates were detected for number of branches/plant in the two crosses and seed yield/plant in the first cross. The differences in magnitude of both broad and narrow sense heritability estimates for nearly all studied traits would ascertained the presence of both additive and non-additive gene action in the inheritance of all the studied traits as previously obtained from gene action parameters (Table 4).

Genetic advance under selection (Δ g %) was found to be relatively high in magnitude for all the studied traits in the two crosses, except plant height in the two crosses, where moderate estimates of Δ g % were obtained. Dixit *et al* 1970 pointed out that high heritability is not always associated with high genetic gain. In this study high genetic gain was found to be associated with rather high and moderate heritability estimate for most studied traits, therefore selection for these traits in the two crosses under investigation should be effective and satisfactory. However, for number of branches/plant in the two crosses and seed yield/plant in the first cross which had low narrow sense heritability and high genetic advance, may be due to a relatively wide range of variability in these populations and selection may be effective but of less success than in the former traits. These results are supported with the findings of Hendawy 1994, Obiadalla-Ali *et al* 2013 and Abdel Aziz and Mohamed 2015.

Table 5. Heritability estimate, genetic advance (Δ g) and genetic advance of the two crosses (Giza 2 x Giza 40) and (Giza 3 x Giza 716) of faba bean for all the studied traits during 2015/2016 winter season.

Traits	Crosses	Heritability %		Genetic advance	
		Broad sense	Narrow sense	Δ g	Δ g %
Plant height	Cross 1	70.38	64.92	33.49	24.06
	Cross 2	77.25	60.98	29.87	23.72
No. of branches/plant	Cross 1	54.03	41.47	1.22	29.90
	Cross 2	54.47	43.30	1.55	38.65
No. of pods/plant	Cross 1	71.45	59.90	13.45	50.99
	Cross 2	54.55	49.12	10.77	38.15
100-seed weight	Cross 1	66.34	51.57	17.65	28.58
	Cross 2	78.94	62.04	25.88	39.14
Seed yield/plant	Cross 1	74.09	45.67	14.34	39.47
	Cross 2	65.34	61.14	20.22	57.30

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توريث صفه المحصول وبعض مكوناته باستخدام العشائر السته فى هجينين فى الفول البلدى

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الملخص

أجريت هذه الدراسه خلال الثلاث مواسم ٢٠١٤/٢٠١٣ - ٢٠١٥/٢٠١٤ - ٢٠١٦/٢٠١٥ بمزرعه كليه الزراعه بجامعه الأزهر بأسيوط باستخدام اربعه اباء من الفول البلدى (جيزه ٢ - جيزه ٣ - جيزه ٤٠ - جيزه ٧١٦) حيث تم تكوين هجينين الاول جيزه ٢ x جيزه ٤٠ والثانى جيزه ٣ x جيزه ٧١٦ وقد اشتملت الدراسه على الابوين والجيلين الاول والثانى والجيلين الرجعيين مع الاب الاول والثانى. وقد دونت البيانات على صفات ارتفاع النبات ، عدد افرع النبات ، عدد قرون النبات ، وزن الـ ١٠٠ بذره ومحصول بذور النبات.

اظهرت النتائج ان قيم متوسط الجيل الاول كانت اعلى من افضل الاباء لكل الصفات المدروسه فى كلا الهجينين مشيرا الى السياده الفائقه. كانت قوه الهجين على اساس افضل الاباء معنويه وموجبه لكل الصفات المدروسه. كان تاثير التربيه الداخليه معنويا فى جميع الصفات المدروسه مما يؤكد دور التباين التفوقى فى وراثتها. ان توارث كل الصفات المدروسه كان محكوما بالفعل الجينى من النوع المضيف وغير المضيف مع تاثير اعلى لجينات السياده عن جينات الاضافه. كانت قيمه درجه التوريث العاليه والمتوسطه مرتبطه بالتحسين الوراثى لمعظم الصفات المدروسه فى كلا الهجينين.