EVALUATION OF SOME BREEDING METHODOLOGIES IN FABA BEAN (*Vicia faba* L.)

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ABSTRACT

The present study was carried out during the five years 1995/96, 1996/97, 1997/98,, 1998/99 and 1999/2000 at Sids Research Station, Beni-Suef governorate, Egypt. The study aimed at evaluating the effectiveness of pedigree, bulk (natural selection), single pod descent (SPD) and mass selection breeding method. Two F_2 populations derived from two crosses were used. Eighteen families derived from each of the four breeding methods in each cross were tested for seed yield (t/ha), seed yield per plant (g) and 100-seed weight (g) in F_6. A randomized complete block design with three replications was used. Significant seed yield differences existed within F_6 families of each cross by applying either of the four methods. The widest ranges in seed yield were obtained by the bulk method. The bulk breeding method produced consistently more superior families in either and over the two crosses with 19, 18, 15 and 14 families for bulk, SPD, pedigree and bulk methods, respectively. The genotypic (δ^2_G) and phenotypic (δ^2_{Ph}) variances estimated from bulk method were the highest compared with other breeding methods over the two crosses. Heritability estimates and expected genetic advance indicated that the bulk method recorded higher values compared with the other three methods. Based on the results obtained it seems that the bulk breeding method was the most effective compared to the other three breeding methods. Considering the partial allogamous nature of the crop, it could be concluded that the bulk method was more efficient and could be less costly in breeding for high seed yield.

INTRODUCTION

Faba bean (*Vicia faba* L.) is the most important nutritive popular food crop in Egypt. It plays a major role in the Egyptian diet as a source of protein. The crop is partially allogamous species having an intermediate level of out-crossing (in the 20-25 % range). Increasing seed yield and improving the stability of yield are the main objectives of most breeding programs.

Breeding methods employed in faba beans ranged from single seed descent as proposed by Brim (1966), through pedigree or bulk pedigree approaches to mass selection. Mass selection is the most widely used breeding method in faba bean improvement especially in upgrading local population following hybridization (Nassib and Khalil, 1981).

Faba beans are thus a unique crop which has been handled in breeding programs in a number of ways, some of which have emphasized the self-pollinated nature of the crop while others have emphasized the cross pollinated nature of the crop.

The main objective of this investigation was to compare the effectiveness of pedigree, bulk, single pod descent (SPD) and mass selection breeding methods in increasing seed yield in faba bean.

MATERIALS AND METHODS

This study was carried out during the five years 1995/96, 1996/97, 1997/98, 1998/99 and 1999/2000 at Sids Research Station, Beni Suef governorate, Egypt.

The parental material consisted of 3 faba bean genotypes as follows:

1- Giza 2: Developed by single plant selection from local land races, performed well in Middle Egypt, medium seeded type (100-seed is 65 gms), light brown seeds and early maturing variety.
2- BPL 3876: An introduction from ICARDA, medium seeded type (100-seed weight is 80 gms), brown colored seed coat and early maturing genotype.
3- BPL 4068: An introduction from ICARDA, medium seeded type (100-seed weight is 90 gms), light brown seeded and early maturing genotype.

The study aimed to evaluate the effectiveness of four breeding methods in faba bean namely: Pedigree, Bulk, Mass selection and Single Pod Descent (SPD).

Two F_2 populations of the following two crosses were used:

1- Giza 2 x BPL 3876.
2- Giza 2 x BPL 4068.

In 1995/96 growing season, approximately 500 plants per F_2 population were spaced planted in the field, in ridges 60 cm apart with plants 20 cm apart within rows. Throughout the growing season, plants were weeded and monitored for pests. The plants were sprayed three times with primor insecticide during the growing season to control virus-bearing aphid populations. From each F_2 population three groups of random plants were taken, each group consisted of 100 plant. The first group of random plants was handled by taking single pod from each plant to produce SPD, then plants were harvested in mass to produce bulk population. The second group of random plants was threshed each plant separately and weighted for seed yield, the top 20 % of plants were composited and used as mass selection. The third group of random plants was threshed each plant separately to use in pedigree method.

The F_3 seeds from pedigree, bulk, SPD and mass selection populations were grown in 1996/97growing season. At maturity, the SPD populations were obtained by composting a single pod taken from each plant. A random sample of 500-seeds was taken from all bulk population plants after threshing. In mass selection populations, all plants were threshed and weighted individually and a random sample of 500-seeds was obtained from top composited 20 % plants. In pedigree method, a random sample of 100 plants was taken for generation advance.

In 1997/98 season, the F_4 populations for pedigree, bulk, SPD and mass selection were grown at Sids Research Station. At maturity, a sample of 80 plants from each population was taken at random for generation advance.

In 1998/99 season, the F_5 random plants were grown and at harvest, a random group of 18 families from each population was taken and threshed each family separately.

In 1999/2000 season, eighteen F_6 families derived from each of the four breeding methods over the two crosses were tested in the field for seed yield and other agronomic traits. A randomized complete block design with three replications was used for each breeding method. Each replicate had 18 plots randomly assigned to the 18 families. Each plot consisted of 5 ridges three meters length with 60 cm between ridges. Planting took place on two rows per ridge, in double seeded hill, 20 cm apart. At harvest, the mid three ridges per plot were harvested and accordingly the harvested plot was 5.4 m^2. The following characters were recorded:

1- Seed yield (t/ha).
2- Seed yield per plant (g).
3- 100-seed weight (g).

The pattern of generation advance for pedigree, bulk, SPD and mass selection breeding methods is presented in Fig.1.

Statistical analysis:

The evaluation of pedigree, bulk, SPD and mass selection breeding methods was determined by planting the F_6 families for each method in a trial of randomized complete block design. The four trials of each cross were subjected to combined analysis according to the procedure outlined by Snedecor and Cochran (1982).

The efficiency of the four breeding methods were compared based on the following:

1-The different measured statistics; i.e. ranges, means and number of superior families.
2- The different genetic parameters; i.e. variances (genotypic δ^2_G and phenotypic δ^2_{Ph}), heritability (h^2), expected genetic advance (Δ_G) and coefficient of variability.

RESULTS AND DISCUSSION

The average seed yield (t/ha) and other agronomic traits of 18 F_6 families of each of the two crosses derived through the four breeding methods are presented in Tables 1 and 2. Significant differences existed within the F_6 families of each cross by applying either of the four methods. The combined analysis of variance (Table 3) revealed that the difference in seed yield between the two crosses-on the average of the four methods was highly significant with Giza 2 x PBL 3876 outyielding the other cross by 15.3 %. Also were the differences between the four methods-on the average of the two crosses (Table 4).

Table 3: Mean squares of combined analysis of variances of F_6 for seed yield, seed yield/ plant and 100 - seed weight produced by applying four breeding methods in the two crosses.

S.O.V	df	Traits		
		Seed yield (t/ha)	Seed yield/plant (g)	100-Seed weight (g)
Reps.	2	0.539	7.071	79.400
Crosses (A)	1	13.817**	3784.301**	1354.664**
Error (a)	2	0.125	3.22	10.316
Breeding method (B)	3	6.811**	366.480**	161.218
AxB	3	0.496	90.538*	1105.592**
Error (b)	12	0.216	27.445	65.693
Families (C)	17	0.700**	82.070**	161.446**
AC	17	0.372**	69.537**	156.263**
BC	51	0.432**	63.800**	176.321**
ABC	51	0.402**	98.622**	194.967**
Error (c)	272	0.085	23.253	20.432

The bulk method produced the highest seed yield (t/ha) which exceeded pedigree, mass selection and SPD by 8.1, 8.1 and 7.3 %, respectively. The same trend was obtained for seed yield/plant and 100-seed weight through bulk method breeding.

Table 5 presents the range, population mean ($\bar{X}$) and number and percent of superior families derived through the four breeding methods. The range of the bulk method was consistently higher than the other breeding methods.

The efficiency of the breeding methods in the present study was evaluated based on the number of superior families having higher values than the population means ($\bar{X}$). Data presented in Table 5 show that the bulk breeding method produced consistently more superior families in each and over the crosses with 19, 18, 15 and 14 families for bulk, SPD, pedigree and mass selection methods, respectively. These values represent 53, 50, 41.5 and 38.5 % of the total number of the families in the two crosses in the same order. The same results were obtained for the other economic traits in which bulk breeding method produced consistently superior families with heaviest 100-seed weight in each of and over the two crosses with 19, 16, 16 and 15 families for bulk, SPD, pedigree and mass selection methods, respectively. These values represent 56, 44, 44 and 41.5 % of the total number of families in the two crosses. For seed yield/plant the advantage was for mass selection compared to the other breeding methods. The mass selection produced more superior families over the two crosses with 19, 18, 18 and 13 for mass selection, bulk, SPD and pedigree method respectively, representing 53, 50, 50 and 36 % of the total number of the families in the two crosses in the same order.

4,5The genetic parameters estimates of the F_6 seed yield (Table 6) include variance components, heritability and expected genetic advance. The bulk breeding method retained the largest amount of the genotypic and phenotypic variation followed by those of SPD, mass selection and pedigree breeding methods in each of or over the two crosses. The genotypic variance at the bulk method was 40, 84.2 and 84.2 % higher compared with that of SPD, mass selection and pedigree, respectively. Over the two crosses, the phenotypic variance was 22.6, 56.2 and 46.2 % higher compared with that of SPD, mass selection and pedigree in the same order. The same trend was obtained in the heritability estimates where the bulk method recorded consistently higher values compared with other three methods in each of or over the two crosses with 9.7, 12.5 and 28.6 % more for bulk method over SPD, pedigree and mass selection methods respectively over the two crosses. The expected and percent of genetic advance for the four breeding methods followed the same pattern in each of and over-the two crosses. The bulk method had 0.68 % genetic advance compared with 0.56, 0.48 and 0.45 % for each of SPD, mass selection and pedigree breeding methods.

Table 6: The genetic parameters estimated for seed yield and other agronomic traits of the F_6 families derived through the four breeding methods for the two crosses

Parameter	Yield (t/ha)			
	Pedigree	Bulk	SPD	Mass selection
Giza 2 x BPL 3876				
Genotypic variance ($\delta^2_{G)}$	0.12	0.25	0.11	0.12
Phenotypic variance ($\delta^2_{Ph)}$	0.14	0.27	0.13	0.13
Heritability (h^2)	0.86	0.93	0.85	0.89
Δ_G	0.57	0.85	0.54	0.57
Ph.C.V. %	13.13	17.73	15.61	13.11
G.C.V. %	12.15	17.06	14.36	12.60
Mean	2.85	2.93	2.31	2.75
Giza 2 x BPL 4068				
Genotypic variance ($\delta^2_{G)}$	0.07	0.10	0.14	0.07
Phenotypic variance ($\delta^2_{Ph)}$	0.12	0.11	0.18	0.10
Heritability (h^2)	0.54	0.87	0.78	0.70
Δ_G	0.33	0.51	0.58	0.39
Ph.C.V. %	15.06	12.56	20.59	13.12
G.C.V. %	11.50	11.98	18.16	10.98
Mean	2.30	2.64	2.06	2.41

The phenotypic and genotypic coefficients of variability estimate for seed yield of the F_6 families are presented in Table 6. In each of over the two crosses both estimates were consistently higher in both SPD and bulk methods compared with the other two methods.

From the data presented, it is obvious that bulk method has shown higher efficiency compared with the other three methods in the selection for high yield irrespective of the gene pool difference between the two crosses.

The amount of genetic variability retained by this method accounts for this result. Increasing the size of F_2 population (only 100 plants in the present study) would have an impact on the genetic variability and could ultimately increase the efficiency of the bulk breeding method.

Breeders have applied one or more different breeding methods in order to investigate or compare their efficiency in selecting high seed yield. Among those Torrie (1958), Allard and Adams (1969) and Omar (1989), working on barley, wheat and faba bean and using two or three methods of breeding, came to the conclusion that bulk method was more efficient than the visual pedigree selection as indicated by the number of superior lines retained by each. On the other hand, Reuper and Weber (1953) evaluated bulk and pedigree methods of breeding in four soybean crosses, found that the different methods of selection did not differ.

To sum up, the present study indicated that the bulk breeding method retained higher genetic and coefficient of variability as well as number of superior families compared to other three breeding methods. Considering the partial allogamous nature of the crop, it may be concluded that the bulk method was more efficient and less costly in breeding for high seed yield.

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يهدف هذا البحث إلى تقييم فاعلية أربعة طرق تربية مختلفة وهى النسب، التجميعى (انتخاب طبيعى) طريقة انتخاب القرن الواحد والإجمالي فى تحسين انتاجية محصول الفول البلدى وبعض الصفات الزراعية الأخرى. وقد نفذت هذه الدراسة فى خمسة مواسم زراعية 96/1995، 97/1996، 98/1997، 99/1998، 2000/1999 وذلك بمحطة البحوث الزراعية بسدس-محافظة بنى سويف. وقد اختيرت لهذه الدراسة عشيرتين ناتجتين من هجينين. وقد تم تقييم 18 عائلة فى الجيل السادس منشقة من كل طريقة استخدم تصميم القطاعات الكاملة العشوائية فى ثلاثة مكررات. وقد أظهرت النتائج وجود فروق معنوية بين عائلات الجيل السادس لكل هجين على حده عند استخدام طرق التربية الأربعة.

وقد حققت طريقة الانتخاب بطريقة التجميع أوسع مدى بين العائلات كما حققت طريقة التجميع تفوقا فى عدد العائلات عالية المحصول داخل كل هجين على حده وعلى أساس متوسط الهجينين وان عدد العائلات المتفوقة فى طريقة التجميع 19 عائلة فى حين تفوق 18، 15، 16 عائلة فى كل من طريقة الانتخاب للقرن الواحد من كل نبات، النسب، والانتخاب الإجمالي على الترتيب. كما أظهرت النتائج ان تقديرات التباين الوراثى والتباين المظهرى المقدرة فى كلا الهجينين أعلى عند استخدام طريقة التجميع مقارنة بالثلاثة طرق الأخرى. كما ان طريقة التجميع أظهرت أعلى قيمة فى تقديرات المكافئ الوراثى واعلى تحسين وراثى متوقع مقارنة بالطرق الثلاثة الأخرى. ويتضح من النتائج المتحصل عليها ان طريقة التجميع فى الفول البلدى هى اكثر الطرق كفاءة مقارنة بالثلاثة طرق الأخرى. وإذا أخذنا فى الاعتبار طبيعة هذا المحصول وهو خلطى جزئيا نجد ان هذه الطريقة اكثر كفاءة واقل تكلفة فى تربية هذه المحصول.

Table 1: Average seed yield (t/ha) and other agronomic traits of 18 F_6 families derived from the cross Giza 2 x BPL 3876 through Pedigree, Bulk, SPD and Mass selection breeding methods.

Family	Pedigree			Bulk			SPD			Mass selection		
	SYD	SYD/pl	100-SW	SYD	SYD/pl	100-SW	SYD	SYD/pl	100-SW	SYD	SYD/pl	100-SW
1	2.61	22.37	83.25	3.77	29.28	76.68	2.54	35.87	80.17	2.63	29.87	85.03
2	2.39	24.67	87.49	3.52	36.93	87.24	2.02	28.60	74.83	2.65	30.22	65.61
3	3.24	21.20	74.31	2.56	25.89	62.86	2.94	47.60	85.86	2.65	28.11	59.72
4	3.13	24.20	80.56	2.26	30.96	86.54	2.10	29.33	80.36	2.20	28.74	78.66
5	2.77	24.50	73.00	2.26	37.63	82.99	1.65	23.70	67.37	2.63	31.15	75.59
6	2.60	22.17	70.92	2.59	35.17	66.82	2.34	31.87	75.84	2.87	26.59	58.20
7	2.88	35.67	77.30	2.31	30.22	78.07	2.28	18.00	87.13	2.59	21.18	59.53
8	2.54	24.27	77.62	3.29	21.92	55.24	1.69	26.77	72.28	3.39	27.18	96.67
9	2.60	23.30	68.88	3.60	17.96	70.60	2.66	17.33	80.19	3.04	16.85	73.58
10	3.60	19.40	57.53	3.07	29.00	80.73	2.41	33.87	84.48	2.53	26.44	62.12
11	2.74	24.93	70.32	2.82	23.74	54.34	2.31	27.27	74.74	3.45	21.29	66.08
12	3.45	37.87	72.87	3.52	26.07	71.81	2.77	23.60	68.16	3.30	22.33	71.14
13	2.66	20.67	70.05	3.72	32.36	77.46	2.09	29.13	76.63	2.22	30.44	84.18
14	3.37	25.20	77.24	2.65	36.91	62.28	2.10	18.73	79.64	2.66	36.07	70.53
15	2.69	32.53	86.16	2.94	26.21	70.46	2.58	28.60	73.37	3.04	20.51	70.07
16	2.66	31.43	81.50	3.03	22.35	51.50	2.60	28.67	74.34	2.67	30.67	72.33
17	3.10	28.87	78.56	2.42	28.55	77.34	1.98	31.93	75.98	2.44	24.41	62.63
18	2.26	26.60	61.27	2.53	35.96	71.68	2.56	24.13	90.76	2.61	32.07	61.04
$LSD_{0.05}$	0.43	7.83	6.82	0.43	7.21	11.63	0.43	7.80	6.88	0.35	7.72	7.67

SYD= Seed yield (t/ha); SYD/pl. = Seed yield per plant (g); 100-SW= 100-seed weight (g)

Table 2: Average seed yield (t/ha) and other agronomic traits of 18 F_6 families derived from the cross Giza 2 x BPL 4068 through Pedigree, Bulk, SPD and Mass selection breeding methods.

Family	Pedigree			Bulk			SPD			Mass selection		
	SYD	SYD/pl	100-SW	SYD	SYD/pl	100-SW	SYD	SYD/pl	100-SW	SYD	SYD/pl	100-SW
1	2.83	22.47	69.10	2.99	20.47	74.71	1.94	22.47	69.20	2.32	22.53	67.32
2	1.98	24.07	76.23	2.66	29.20	80.93	1.78	25.07	73.46	2.19	13.43	62.55
3	1.85	26.27	71.39	3.21	24.93	77.27	1.89	22.13	65.95	2.88	27.33	69.44
4	2.11	29.73	70.91	2.86	22.20	72.23	2.18	17.30	62.76	2.65	21.00	64.73
5	2.51	26.87	78.66	2.28	27.77	75.69	2.08	13.30	76.53	2.77	21.77	77.84
6	2.76	23.53	60.54	3.10	20.93	68.44	2.70	17.47	71.01	2.09	17.93	63.15
7	2.21	18.40	62.74	1.99	25.57	72.55	1.56	27.83	56.73	1.97	28.13	81.14
8	2.23	19.20	65.83	2.98	30.40	79.07	1.65	21.40	66.69	1.96	28.67	80.27
9	2.63	17.70	66.86	3.02	23.40	69.88	2.71	26.40	70.13	2.68	15.33	67.23
10	2.25	20.53	64.43	2.72	25.07	80.81	2.35	18.33	77.14	2.10	18.20	62.20
11	1.62	17.87	77.86	2.48	22.73	81.70	2.42	18.67	70.27	2.52	22.23	70.53
12	2.52	19.87	62.49	2.40	21.20	63.64	2.46	13.67	62.86	2.22	19.00	76.43
13	2.45	15.07	77.32	2.41	33.43	68.38	2.11	17.60	57.44	2.04	21.10	65.53
14	1.72	14.87	62.35	2.46	14.00	76.69	1.53	20.80	64.64	2.74	16.60	74.41
15	2.27	16.27	67.84	2.17	29.20	86.53	2.77	19.53	69.97	2.41	19.00	63.39
16	2.58	21.33	68.67	2.71	32.93	77.49	1.83	15.93	55.38	2.64	21.73	66.69
17	2.57	19.73	66.67	2.65	25.53	72.76	1.66	15.60	62.43	2.39	20.07	76.11
18	2.00	18.27	80.77	2.50	28.77	72.69	1.51	21.80	67.25	2.85	20.60	66.00
$LSD_{0.05}$	0.70	10.65	6.42	0.38	7.18	6.09	0.58	9.15	7.01	0.49	5.93	5.93

SYD= Seed yield (t/ha); SYD/pl. = Seed yield per plant (g); 100-SW= 100-seed weight (g)

Table 4: Average F_6 seed yield (t/ha), seed yield/ plant (g) and 100 - seed weight (g) produced by applying four breeding methods in two crosses.

Crosses	Seed yield					Seed yield/plant					100-Seed weight				
	Pedigree	Bulk	SPD	Mass sel	Average	Pedigree	Bulk	SPD	Mass sel	Average	Pedigree	Bulk	SPD	Mass sel	Average
Giza 2 x BPL 3876	2.85	2.93	2.31	2.75	2.71	26.1	29.3	28.1	26.8	27.58	75.00	71.30	77.90	70.90	73.78
Giza 2 x BPL 4068	2.30	2.64	2.06	2.41	2.35	20.6	25.4	19.7	20.8	21.63	69.50	75.10	66.70	69.70	70.25
Average	2.58	2.79	2.19	2.58	2.59	23.35	27.35	23.90	24.22	24.71	72.25	73.20	72.30	70.30	72.01
						Crosses				Methods	Crosses				Methods
	Crosses				Methods	Crosses				Methods	Crosses				Methods
LSD at 0.05					0	0.53				098	0.94				1.70
0.01	.24					1.21				1.540	2.17				2.38
					0										
	.137														

Table 5: Range, population means of seed yield and other agronomic traits and number of superior families derived through the four breeding methods.

Parameter	Yield (t/ha)				Seed yield/plant (g)				100-seed weight (g)			
	Pedigree	Bulk	SPD	Mass selection	Pedigree	Bulk	SPD	Mass selection	Pedigree	Bulk	SPD	Mass selection
	Giza 2 x BPL 3876											
Range	2.39-3.60 (1.21)	2.26-3.77 (1.51)	1.65-2.94 (1.29)	2.20-3.45 (1.25)	19.4-37.87 (18.47)	17.96-37.63 (19.67)	17.33-47.60 (30.27)	16.85-36.07 (19.22)	57.53-87.47 (29.96)	51.50-87.24 (35.74)	67.37-90.76 (23.39)	58.20-96.67 (38.47)
Population mean (X)	2.85	2.92	2.32	2.76	26.1	29.27	28.06	26.77	74.99	71.31	77.9	70.71
No. of families exceeded (X)	7	9	9	6	6	9	10	10	9	10	8	8
Total number of tested Families	18	18	18	18	18	18	18	18	18	18	18	18
% of families > X	39.0	50	50	33.0	33.0	50	56	56	50	56	44.0	44.0
	Giza 2 x BPL 4068											
Range	1.62-2.83 (1.21)	1.99-3.21 (1.22)	1.51-2.77 (1.26)	1.96-2.88 (0.92)	14.87-29.37 (14.86)	14.00-33.43 (19.43)	13.30-27.83 (14.53)	13.43-28.67 (15.24)	60.54-80.77 (20.23)	63.64-86.53 (22.89)	55.38-77.14 (21.76)	62.20-81.14 (18.94)
Population mean (X)	2.29	2.64	2.06	2.41	20.57	25.39	19.74	20.81	69.50	75.08	66.66	69.70
No. of families exceeded (X)	8	10	9	8	7	9	8	9	7	10	8	7
Total number of tested Families	18	18	18	18	18	18	18	18	18	18	18	18
% of families > X	44.0	56.0	50.0	44.0	39.0	50.0	44.0	50.0	39.0	56.0	44.0	39.0