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Genetic Variability, Heritability Estimates, and Predicted Genetic Advance for Some Characters in Faba Bean *(Vicia faba* L.)

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Abstract. Differences were found among faba bean varieties and/or their F2 generations grown in the arid conditions of the central region (Riyadh), Saudi Arabia for the studied traits such as days to flowering, maturity, plant height, number of pods/plant, number of seeds/plant, yield weight/plant, and 100 seeds weight. Coefficients of variation, variance components, heritability and predicted genetic advance from selection were estimated for the formentioned traits. Broad sense heritability ratios were high for all the studied traits and ranged from 76.51% for number of pods/plant to 98.87% for plant height. Predicted genetic advance was high for yield weight (46.29%) and number of seeds/plant (30.37%). It was moderate for number of pods/plant (19.92%), 100 seed weight (18.43%), and plant height (15.91%). High values of heritability estimates and predicted genetic advance indicated that selection among the genotypes would be effective for improving yield, yield components, and plant height.

Differences in total protein content were found among the varieties and/or the F2 generations. Moreover, soluble protein of faba bean seeds when separated by SDS slab gel electrophoresis showed that the varieties and their F2 generations had different degrees of similarities. High percentage of similarity was found between Giza 2 (Egyptian) and ICARDA (Syrian) varieties. Slab gels when scanned with densitometer showed that each variety was unique in its protein profile.

Introduction

Faba bean *(Vicia faba* L.) is one of the most important leguminous crops. It is an important source of protein for human consumption and animal feed. As the area of cultivation is extended in the Kingdom of Saudi Arabia, faba bean could share the importance with wheat as a winter crop. Thus, farmers will be able to maximize better use of excessive labor, machinery and productivity of cultivated land. Therefore, it brings the plant breeder's attention to breed faba bean stable to grow in arid conditions with high yielding ability, high in percent of total protein content and early maturity. However, successful breeding program will depend on the magnitude of genetic variation in the population (base population). Moreover, reliable estimates of genetic and environmental variations will be helpful to estimate heritability ratio

and consequently predicted genetic advance from selection. These estimates are useful to initiate such breeding program in order to improve productivity and quality of that crop.

Genetic variance components of quantitative traits such as seed yield, number of pods per plant, 100 seed weight, protein content, and plant height have been studied under diverse environmental conditions by different investigators [1-4].

Heritability in broad and narrow sense estimates for earliness and maturity as well as other quantitative traits were also reported by different investigators [3-6].

Presence of genetic variability and heritability estimates would be helpful to the breeder to estimate genetic advance and to predict percentage of genetic advance in the population (s) under study. These informations can be used as a guide for making breeding decision and initiating breeding program(s). El-Hosary and Nawar [5] obtained large estimates of genetic gain and predicted genetic advance from selection for earliness and maturity in field beans.

Electrophoritic patterns of soluble protein were used to study similarities among varieties of brassica species [7, p. 417]. Meanwhile, electrophoritic patterns of soluble protein combined with densitometry was used to study genetic relationships among cultivars, species, and genera [8, pp. 215-240].

The present investigation was planned to study genetic variability, the inheritance of some important characteristics of faba bean, genetic advance and predicted genetic advance from selection under the arid conditions of the central region in Saudi Arabia. Moreover, attention has been given to study the similarities and distinction among varieties based on soluble protein slab gel electrophoresis and densitometer.

Materials and Methods

Three varieties of different origin of faba bean (*Vicia faba* L.) namely: 1. Turkey, 2. Giza 2, and 3. ICARDA that exhibit differences in some agronomic characters (Table 2) were used in this investigation. Crosses were made among these varieties at the plant production greenhouse, KSU, Riyadh, in winter of 1988. Five crosses were accomplished (Table 2). The three parents and their five crosses were grown in pots sized 30 cm (one plant per pot) at the greenhouse in 1989. Plants of each parent and cross were allowed to be self pollinated. Seeds of each selfed F1 cross plants were combined to obtain the corresponding F2 generation.

The obtained F2 seeds of the five crosses and the three parents were sown in a complete randomized block design experiment with six replicates in 1990 at the Research Station near Riyadh (Dirab, 24 N, 46 E Alt 600 m). Each block contained 8 plots (entries). Each entry contained 3 rows spaced 50 cm apart and five meters long. Plants were spaced 25 cm in the row at a rate of 20 plants per row. Cultural practices were followed as recommended for growing faba bean in the area. Data were collected on single plant basis of the middle row (the guarded one). The studied traits were days to flowering (DF), days to maturity (DM), plant height in cm (PH), number of pods per plant (NP/P), number of seeds per plant (NS/P), seed yield in gram per plant (YW/P), and 100 seed weight (100 SW).

Protein content

Total protein content in seeds was determined as a crude protein according to the standard methods outlined by the American Association Cereal Chemists [9].

Protein extraction and electrophoresis

Samples of whole seeds were ground for 3 minutes in a cooled microelectric mill. Extraction of the total soluble protein was made by mixing 0.5 gm of the flour with 5.0 ml of 0.625 M Tris (hydroxymethyl) aminomethan HCL (pH 6.8) which included 2% sodium dodecyl sulfate, 5% 2-mercaptoethanol, 10% glycerol, and 0.01% bromophenol blue. The mixture was allowed to stand for 1 hr with occasional agitation, followed by centrifugation at 3000 rpm for 10 minutes. Then a sample of 30 μl from the suprnatent was taken for electrophoresis.

Electrophoresis was performed in a vertical slab gel instrument (LKB 2001) at 10°C and consistent current of 30 mA. Separation gel was 12 × 14 cm × 1.5 mm, contained 10% acrylamide and 0.1% N, N methylene bis acrylamide (bis). Sticking gel was 4 cm in height and contained 3% acrylamide with 0.1% bis. Gel was stained for 15 min at 60°C using 0.115% Coomassi blue dye in water-ethanol -acetic acid (13:5:2 V/V/V). Destaining was done using a mixture of water, ethanol and acetic acid at the same ratio used for staining solution.

Slab gel was preserved and scanned in LKB 2202 Ultrascan laser densitometer. Percentage of similarity in total soluble protein bands among parents and 5 F2 generations was calculated according to Vaughan's formula [7].

Statistical analysis

Data were statistically analyzed on the mean plot (entry) bases. Significant differences were determined by F-tests [10]. Then, comparisons among the means of

the eight genotypes for the studied traits were done by using the least significant difference (LSD). Genetic and phenotypic variances were obtained, and broad sense heritability ratios were calculated for all traits. Genetic and phenotypic coefficients of variations were also estimated. The expected genetic advance from selection ($\triangle \hat{g}$) and the predicted genetic advance as percentage of population mean were calculated using the broad sense heritability ratio and selection intensity of 20% [11].

Results and Discussion

The analysis of variance indicated that variation among genotypes was highly significant for all the studied traits (Table 1). The T-test (LSD) which controls the

Table 1. Analysis of variance for some agronomic faba bean characters in eight different genotypes

Source of variation	d.f.	Mean square						
		DF	DM	PH	NP/P	NS/P	YW/P	100SW
Replications	5	8.92	8.90	54.30	1056.0**	8806.90**	3252.96**	22.65
Genotypes	7	157.61**	122.58**	2466.94**	748.8**	8950.20**	7554.01**	710.75**
Error	35	20.41	88.42	27.74	175.9	1576.30	635.34	134.11

** are significant at 1% level.

where, DF=days to flowering, DM= days to maturity, PH = plant height, NP/P= number of pods per plant, NS/P = number of seeds per plant, YW/P = total yield weight per plant, and 100 SW = 100 seed weight.

type 1 comparison wise error (Table 2) showed that the Turkey variety was the tallest and late matured variety. Moreover, it possessed low number of seeds per plant and low yield as compared with Giza 2 and ICARDA varieties. Low yield (YW/P) of the Turkey variety was concurrent with the desirable small seed size (100 seed weight was 47.7 gm). Meanwhile, Giza 2 variety possessed a shorter plant (123.0 cm) with high yield as seed number (NS/P) and seed weight (YW/P) and it produced medium sized seeds (100 SW = 75.2 g). The ICARDA variety was intermediate in plant height (140.2 cm) but it was late in maturity (174.8 days) as compared with the other two varieties. It produced higher number of seeds and seed yield per plant (Table 2). Some of the crosses showed significant differences among their means in the F2 generations. The F2 mean of the cross Turkey x ICARDA was late in the flowering and maturity and it exhibited tall plants. Moreover, it produced low seed yield and seed size. The other crosses obtained from cross Turkey × Giza 2 or Giza 2 × ICARDA were early in flowering and maturity, produced shorter plants, small to medium seed size and high yield (YW/P and NS/P). Significant variations among the F2 genera-

Table 2. Mean and least square differences for some agronomic characters in parents and f2 generations of faba bean.

Parents of crosses	Mean squares						
	DF	DM	PH	NP/P	NS/P	YW/p	100SW
1. Turky	59.7 b	171.8 c	162.2 a	56.5 a	63.8 c	142.3 b	47.7 d
2. Giza 2	56.5 bc	173.3 bc	123.0 d	65.2 a	120.3 ab	161.8 ab	75.2 ab
3. ICARDA	57.0 bc	174.8 b	140.2 b	70.5 a	147.2 a	192.7 a	75.5 ab
F2							
1 × 2	58.3 bc	173.0 bc	133.0 c	66.5 a	95.3 b	157.2 ab	61.1 cd
2 × 1	59.8 b	174.3 b	134.2 bc	68.0 a	113.1 b	164.0 ab	67.1 bc
2 × 3	57.7 b	174.8 b	140.3 b	58.8 a	117.4 b	147.5 ab	82.4 a
1 × 3	71.0 a	177.2 a	164.5 a	59.7 a	94.4 b	143.0 b	66.2 bc
3 × 1	53.8 c	172.3 c	101.7 e	35.2 b	46.7 d	59.2 c	60.5 cd
LSD	5.29	1.86	6.17	15.54	29.50	46.54	13.57

Means with the same letter within column are insignificant at 5% level.

tions were expected which facilitate selection for the desirable genotype(s). These results were comparable to those reported by El-Hosary and Nawar [5].

Phenotypic (Ph.V.) and genotypic (G.V.) variances as well as coefficient of variations are shown in Table 3. Moderate values of genotypic coefficient of variation were estimated for days to flowering, plant height, number of pods per plant and 100 seed weight (seed size). Low value was estimated for days to maturity. Meanwhile, high values estimated for number of seeds per plant in the present investigation were similar ot those reported by several authors [12, 5, 6, 4]. However, Dixit *et al.* [13] reported that high heritability and high G.C.V. were not always associated with high genetic advance.

The estimated values of the expected genetic advances ($\triangle$ g) presented in Table (4) showed low value for days ot maturity. Meanwhile, moderate values were estimated for days to flowering, number of pods per plant, and 100 seed weight. Moderately high values were estimated for number of seeds per plant (NS/P) and yield weight per plant (YW/P). Therefore, it is possible to gain from selection in this population for most of the studied characters especially for yield weight per plant (Table 3). Similarly, El-Hosary and Nawar [5] estimated different levels of G. C.V. in faba bean. Moreover, the differences between Ph. C.V. and G. C.V. were very narrow which indicated the importance of genetic variance in the inheritance of the studied characters. However, environments exert some effects on these traits. Meanwhile, Swarup and Changale [14] reported that both heritability ratio and G.C.V.% gave the best picture for expected genetic advance. Accordingly, one would expect advance from selection especially that the heritability values and the expected genetic advance for the studied traits were high, except that for days to maturity which exhibits low value (Table 4). Low values of expected genetic advance were reported earlier [5] for flowering and maturity dates. It should be mentioned that Johnson *et al.* [11] reported that selection based on both heritability and genetic gain is more effective than selection based on heritability ratio alone. Data in the present study showed high heritability ratios and high values of genetic advance.

The variety Giza 2 showed higher percentage of total protein content (24.41%). It was followed by ICARDA and Turkey varieties (24.27% and 23.67%, respectively). However, the differences among these varieties were insignificant (Table 5). The F2 generations among these varieties ranged from 21.54% protein (No. 8) up to 23.58 (No. 7), which exhibit significant differences among the F2 generations. Moreover, no one of the F2 generations reached any of their better parent. These results are in contrast with that reported by Omer *et al.* [2] who found that the protein content in F2 of some varietal crosses of *Vicia faba* was similar to the midparents.

Table 3. Phenotypic variance, genetic variance, phenotypic coefficient of variation, and genotypic coefficient of variation for the studied faba bean characters in parents and F2 generation.

Characters	Phenotypic variance	Genotypic variance	Phenotypic C.V.	Genotypic C.V.
Days to flowering (DF)	22.87	26.27	8.65	8.06
Days to maturity (DM)	2.49	2.92	0.98	0.90
Plant height (PH)	406.53	411.16	14.75	14.67
No. of pods/plant (NP/P)	95.48	124.79	18.60	16.27
No. of seeds/plant (NS/P)	1228.98	1491.69	26.46	24.01
Yield weight (YW/P)	1153.12	1259.01	36.13	34.58
100 seed weight (100 SW)	96.11	118.46	16.25	14.64

Table 4. Heritability ratio, expected genetic gain, and predicted genetic advance% for some agronomic characters in faba bean.

Characters	Heritability %	Expected genetic advance (g)	Predicted genetic advance % (ĝ%)
Days to flowering (DF)	87.05	62.24	10.54
Days to maturity (DM)	85.27	2.04	1.20
Plant height (PH)	98.87	21.85	15.91
No. of pods per plant (NP/P)	76.51	11.96	19.92
No. of seeds per plant (NS P)	82.38	44.33	30.37
Yield weight (YW/P)	91.58	45.45	46.29
100 seed weight (SW)	81.13	12.34	18.43

Expected genetic advance= $g = h2 \times 1.4 \times \sigma ph$

$\triangle \hat{g}\% = (g/x) \times 100$

where 1.4 = selection intensity at 20%, x is the population mean, and h2= broad sense heritability.

However, they are partially comparable to that reported by Sosa Baurdouil [15] who reported that protein content of F2 generations might be intermediate or resembles either partents.

The electrophoritic profile patterns of soluble protein in the seeds of 3 parents and the 5 F2 generations obtaind by the scanning are presented in Fig 1. Each one of the parental varieties and F2 generations showed differences among each others in density and/or number of peaks detected by densitometry. Moreover, the soluble

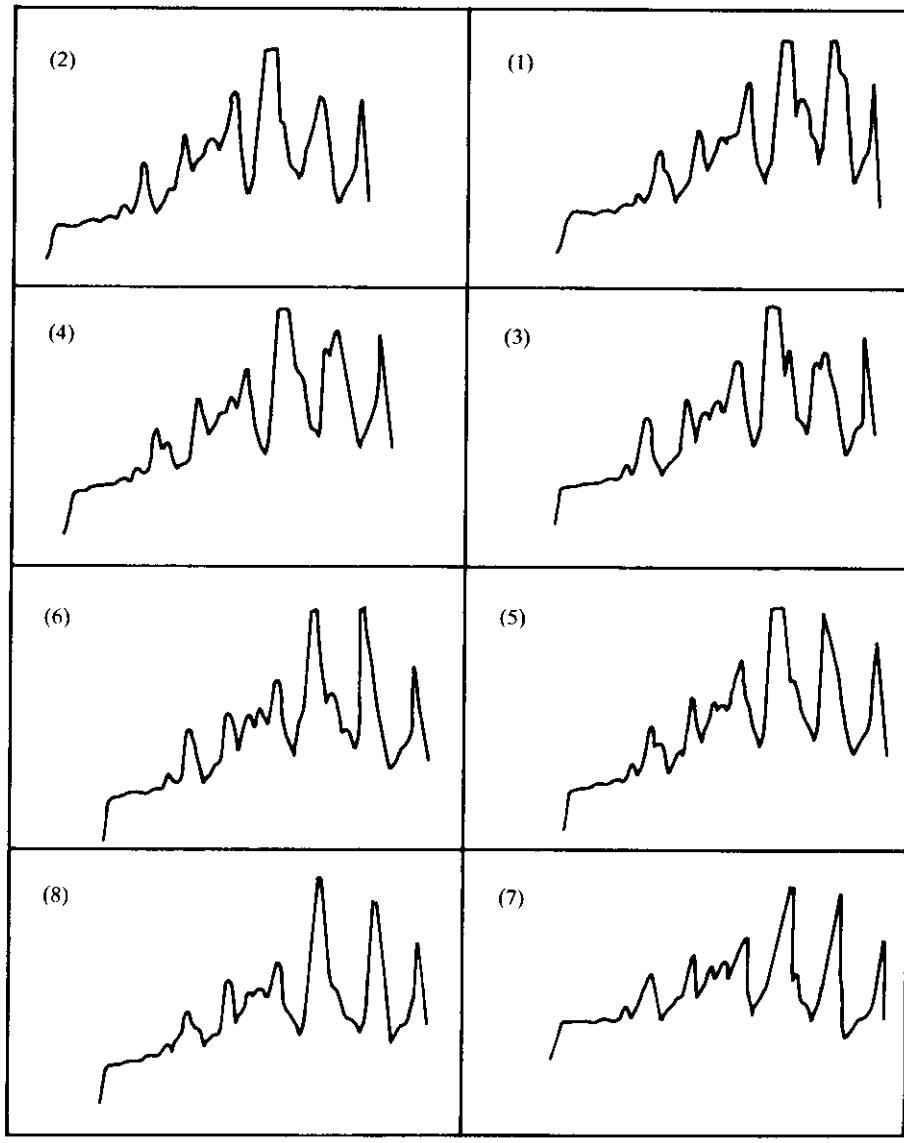

Fig. 1. Electrophoretic patterns of total soluable proteins of three faba bean varieties and five F2 generations separated with discontinuous SDS-slab gel and scanned in LKB 2202 ultrascan laser densitometer.

protein of the examined materials was separated into 25 bands (Fig. 2). The variety Turkey showed the least number of protein bands (9) followed by ICARDA (11). Where, Giza 2 showed 12 bands. Accordingly, SDS-PAGE pattern of protein can be used to differentiate faba bean varieties and more precisely to identify phenotypes [8].

Higher number of bands was observed for F2 No. 4, 6, 7 and 8 which represented each by 13 protein bands. These could be due to complementary gene effects.

The percentage of similarities among each one of the 3 parents and/or any F2 generation are given in Table 5. The highest degree of similarity in the soluble protein bands (91.6%) was found between both Giza 2 (from Egypt) and ICARDA (Syria) varieties and lower similarity was estimated (61.5%) between the variety Turkey and the variety Giza 2. High similarity could be due to the density of having similar genetic origin, especially most of the Egyptian varieties are introduced from ICARDA through the faba bean Nile Valley project.

Table 5. Percent of total protein and similarity percentage in bands of total soluble proteins among parental varieties and F2 crosses of faba bean.

Parents F2	Total protein %	Percent of similar bands P2	P3	(4)	(5)	(6)	(7)	(8)
Turkey (P1)	23.67 ab	61.5	66.6	46.6	40.0	37.5	29.4	20.0
Giza 2 (P2)	24.41 a		91.9	56.3	41.1	38.8	31.5	21.0
ICARDA (P3)	24.27 ab			60.0	43.8	41.2	33.3	20.0
F2								
P1XP2 (4)	22.97 b				56.2	52.9	36.8	30.5
P2XP1 (5)	22.52 d					66.6	56.2	46.1
P2XP3 (6)	22.89 c						52.9	52.9
P1XP3 (7)	23.58 b							62.5
P3XP1 (8)	21.59 d							100.0
LSD	0.81							

For the percent of total protein, means with the same letter are not significantly different (P=0.05) by LSD.

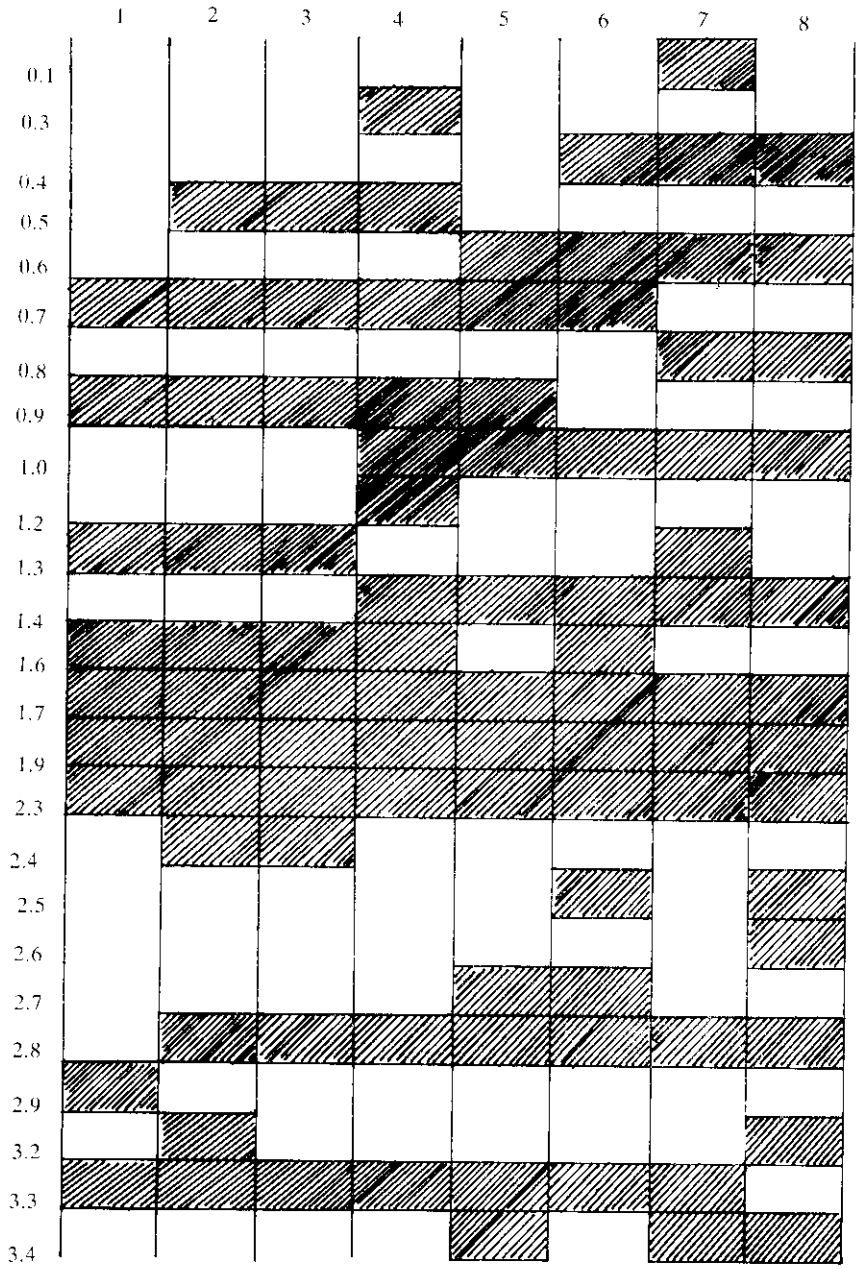

Fig. 2. Soluble protein banding patterns of 3 Faba bean varieties, i.e., Turkey 1 (P_1), Giza 2 (P_2) and ICARDA (P_3); and 5 F_2 generations $P_1 \times P_2$ (4), $P_2 \times P_1$ (5), $P_2 \times P_3$ (6), $P_1 \times P_3$ (7), and $P_3 \times P_1$ (8).

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التباين الوراثي ودرجة التوريث والتقدم الوراثي لبعض الصفات في الفول

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ملخص البحث. وجدت تباينات بين الأصناف المدروسة وعائلات الجيل الثاني في محصول الفول لكل من صفات موعد التزهير، موعد النضج، ارتفاع النبات، عدد القرون للنبات، عدد البذور، متوسط محصول النبات، ووزن ١٠٠ بذرة.

وتم حساب معامل التباين الظاهري والوراثي ودرجة التوريث في المدى الواسع والتقدم الوراثي المتوقع نتيجة للانتخاب للصفات المدروسة. وكانت درجة التوريث عالية لمعظم الصفات المدروسة حيث تراوحت بين ٧٦,٥١٪ لصفة عدد القرون، ٩٨,٨٥٪ لصفة ارتفاع النبات. كما كان التقدم الوراثي المتوقع من الانتخاب لصفة المحصول عالية (٤٦,٢٩٪) وعدد البذور للنبات (٣٠,٣٧٪) بينما كان معتدلاً لكل من صفة عدد القرون (١٩,٩٢٪) ووزن ١٠٠ بذرة (١٨,٤٣٪) وارتفاع النبات (١٥,٨١٪).

ونظرًا لارتفاع درجة التوريث وقيمة التقدم الوراثي المتوقع بين وداخل عشيرة الأساس فإن الانتخاب بين وداخل عشيرة الأساس يعتبر مجديًا لتحسين المحصول، وكذلك ارتفاع النبات.

كما وجدت اختلافات بين الأصناف وعائلات الجيل الثاني بالنسبة لنسبة البروتين في البذور.

كما أوضحت الدراسة للبروتينات الذائبة عن طريق استخدام طريقة SDS-slab gel electropheresis عن وجود درجات متفاوتة من التشابه بين الأصناف، وكان الصنف المصري أكثر تشابهًا مع الصنف السوري. كما كان لكل صنف نظام بروتيني مميز له عن بقية الأصناف الأخرى.