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GENETIC VARIABILITY, CORRELATION AND FACTOR ANALYSIS FOR YIELD AND YIELD COMPONENTS OF SOME FABA BEAN (*Vicia faba* L.) GENOTYPES

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ABSTRACT

Two field experiments were done during 2019/2020 and 2020/2021 seasons at the Agricultural Research of Faculty of Agriculture, Zagazig University, El-Khattara region, Sharkia Governorate, Egypt, using nine faba bean genotypes to estimate genetic variability, correlation as well as factor analysis of yield and yield component characters. The results revealed significant differences among faba bean genotypes for all the studied characters. Genotypes Giza 716, Sakha 4, L 33, L79, L 86 and Giza 843 performed well for yield and its component characters. Maximum phenotypic variance (V_{ph}) and genotypic one (Vg) values were recorded for number of branches/plant and 100 seed weight. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) ranged from 38.03 for number of branches/plant to 145.75% for number of pods/plant and from 26.16 for number of seeds/ pod to 142.72% for number of pods/plant, respectively. The highest heritability estimates were detected for number of pods/plant, number of seeds/pod, number of branches/ plant and plant height. The factor analysis technique divided the studied variables into two main factors. These two factors accounted about 77.012% of the total variability in the dependence structure of faba bean seed yield. The first factor included three variables and accounted 55.705%, whereas, the second one consists of two variables and accounted 21.107% of the total variability of faba bean seed yield.

INTRODUCTION

Faba bean is one of the most important legume crops in the Mediterranean region. It is one of the major winter sown legume crops, and has considerable importance as a low-cost food rich in proteins and carbohydrates (**Sepetoˇglu, 2002**). Seed yield improvement is a major breeding objective in faba bean. The success of faba bean breeding program depends on the choice of genotypes capable of producing progeny with desired trait combinations. Seed yield is affected by genotype and environmental factors because it is a quantitative trait. Many morphological and physiological traits that correlated with each other like plant height, number of branches and pods/plant, biological yield, 100-seed weight, days to flowering, and maturity are the most important traits in faba bean improvement for increasing seed yield due to direct and indirect correlation (**Loss and Siddique, 1997).** Using as selection criteria of characters, a direct relationship with seed yield increases the success of selection in plant breeding (**Karasu and Oz, 2010).**

The identify of genetic variability is the most important prerequisite for the crop improvement program. Seed yield is a complex trait and is reportedly associated with a number of component traits.

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Direct selection for yield could be misleading because successful seed selection depends on the information of genetic variability and association of yield component traits with seed yield. Hence, correlation studies accompanied with factor analysis provides accurate idea of the association of different traits with seed yield.

The knowledge of degree and direction of this relationship between different attributes and yield is invaluable to a breeder aiming to identify key traits that can profitably be exploited to achieve the desired level of seed yield improvement.

Several authors determined genetic variance for yield and its component characters in faba bean and showed moderate to high heritability as well as high phenotypic and genotypic coefficients of variability were observed for most of the yield and yield attributing characters studied in faba bean genotypes (**Mulualem *et al.*, 2013; Bakhiet *et al.*, 2015; Sharifi, 2017; Elshafei *et al.*, 2019; El-Shal and El-Sayed, 2019; Tadele *et al.*, 2021; Ton *et al.*, 2021).**

Yield is the final product of several characters. Relating these characters to define the most important contributing characters to yield is helpful as selection aims in breeding programs. Correlation coefficient is not only an important statistical procedure used to facilitate breeding programs for high yield, but it is also important to examine the direct and indirect contribution of yield components. **Salama *et al.* (2008), Bakhiet *et al.* (2015), Arab *et al.* (2018) and Astaraki *et al.* (2020)** revealed significant positive correlation values between seed weight/ plant and each of number of branches/ plants, number of pods/ plant and number of seeds/ pod.

Walton (1972) criticized some statistical techniques (Correlation, multiple and stepwise regression) and suggested factor analysis as a new technique to identify growth and plant characters related to yield in spring wheat. **Denis and Adams (1978)** used factor analysis to search for and identify patters of morphological characters in a set of faba bean cultivars which could relate to yield. According to factor analysis, number of pods/plant, number of seeds/pod and 100-seed weight were accounted the major contributing of seed yield/ plant **(Mehasen and Mohamed, 2004; Salama *et al.*, 2008; Arab *et al.*, 2018).**

This study aimed to estimate genetic variations and association between seed yield and its components of faba bean, which may be important to improve this valuable legume crop through selection of the more contributed characters to seed yield.

MATERIALS AND METHODS

The present study was carried out at the Agricultural Research Station, Faculty of Agriculture, Zagazig University, El-Khattara region, Sharkia Governorate, Egypt (30°36′N, 32°16′E), during two successive seasons 2019/2020 and 2020/2021, using nine faba bean genotypes (Line 33, Line 46, Line 79, Line 86, Sakha 4, Nubaria 2, Nubaria 3, Giza 716 and Giza 843) (Table 1) to estimate genetic variability, phenotypic and genotypic correlations as well as factor analysis of faba bean yield and yield contributing characters and its implication in improving faba bean seed yield. In both seasons, the genotypes were sown on 15th November in a randomized complete block design (RCBD) with three replications in ridges 3 meters long and 60 cm wide with single seed/ hill, spaced 20 cm apart on one side of the ridge.

At harvest, plant height, number of branches/plant, number of pods/plant, number of seeds/pod, 100-seed weight and seed yield (ton/fad.) were determined. The

Table 1. Pedigree and origin of the studied faba bean genotypes

Genotype	Pedigree	Origin
Line 33	Misr 3 x Cross 1906	Egypt
Line 46	Cross 943 x Cross 1906	Egypt
Line 79	Cross 943 x Cross 1907	Egypt
Line 86	Cairo 4 x Cairo 5	Egypt
Sakha 4	Sakha 1 X Giza 3	Egypt
Nubaria 2,	ILB1550 × Radiation2095/76	Egypt
Nubaria 3	Selected from Ahnacia line	Egypt
Giza 716	461/842/83/503/453/83	Egypt
Giza 843	461/854/83 x 561/2076/85	Egypt

obtained data were statistically analyzed by analysis of variances (ANOVA) according to **Steel *et al.* (1997).** The least significant differences ($P<0.05$) was calculated for the parameters exhibiting a significant effect and to compare treatments mean.

Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were calculated following the method of **Burton (1952)** as following:

$$PCV=\frac{\sqrt{\sigma 2P}}{\bar{x}} X\ 100$$

Where, σ^2 P = phenotypic variance and $\bar{x}$ = mean of the character being evaluated.

$$GCV=\frac{\sqrt{\sigma 2g}}{\bar{x}} X\ 100$$

Where, σ^2 g = genotypic variance and $\bar{x}$ = mean of the character being evaluated.

Broad-sense heritability (h^2) was calculated as the ratio of the genotypic variance to the phenotypic variance according to **Singh and Ceccarelli (1996)** as following:

$$h^2=\frac{\sigma 2g}{\sigma 2p} X100$$

Where, H= heritability in the broad sense, σ^2 g = genotypic variance and σ^2 P = phenotypic variance.

Genetic advance (GA) as percentage of the mean assuming selection of the superior 5% of the genotypes was also estimated following the procedure elaborated by **Singh and Chaudhary (2004)** as following**.**

$$GA = K \times \sigma P \times h^2$$

Where, GA = expected genetic advance, h^2 = heritability in the broad sense, K = the selection differential and σP = is phenotypic standard deviation on mean basis.

Factor analysis was calculated according to **Walton (1972).**

RESULTS AND DISCUSSION

Mean Performance

Mean performance of plant height, number of branches/plant, number of pods/ plant, number of seeds/pod, 100-seed weight and seed yield/fed (ton) (Tables 2 and 3) showed significant differences between the tested genotypes, suggesting that these genotypes differed in genes controlling these characters and would respond positively to selection.

It is interest to mention that, faba bean genotypes Giza 716, Nubaria 2 and Nubaria 3 gave the tallest plants among the all genotypes under the 1st season, meanwhile

Table 2. Mean performance of 9 faba bean genotypes for plant height, number of branches / plant and number of pods/plant

Character / Genotype	Plant height (cm)		Number of branches/plant		Number of pods/plant	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
L33	83.33	95.42	4.87	4.50	27.13	30.65
L46	76.67	104.72	3.13	4.83	16.87	31.36
L79	75.00	95.94	5.67	4.75	30.27	31.26
L86	75.67	100.75	4.47	4.37	21.98	35.17
Sakha 4	97.73	92.60	3.53	3.47	18.33	17.33
Nubaria 2	100.53	94.47	3.04	3.29	14.60	13.20
Nubaria 3	104.73	99.20	4.07	3.67	20.87	19.73
Giza 716	108.07	99.70	4.33	3.77	19.77	18.30
Giza 843	79.67	117.75	5.47	5.33	29.33	41.83
Mean	89.04	100.06	4.29	4.22	22.13	26.54
LSD $_{0.05}$	5.14	**4.32**	0.59	**0.46**	3.38	2.07

Table 3. Mean performance of 9 faba bean genotypes for number of seeds/pod, 100-seed weight and seed yield/fed (ton)

Character / Genotype	Number of seeds/pod		100-seed weight (g)		Seed yield (ton/ fad)	
	1st Season	2nd season	1st season	2nd season	1st Season	2nd season
L33	2.13	2.80	74.41	60.81	1.79	2.11
L46	2.63	1.88	70.72	69.80	2.41	2.27
L79	1.65	2.07	84.97	64.40	2.69	2.14
L86	2.49	2.86	60.96	60.78	1.81	2.19
Sakha 4	2.60	3.00	66.30	55.83	1.71	1.29
Nubaria 2	2.69	3.38	52.31	55.21	1.38	1.26
Nubaria 3	2.49	2.28	59.08	67.78	1.69	1.49
Giza 716	2.38	2.83	74.05	61.40	2.15	1.53
Giza 843	1.92	1.65	76.46	73.05	2.04	3.24
Mean	2.33	2.53	68.81	63.23	1.96	1.95
LSD 0.05	**0.30**	**0.21**	**3.88**	**4.54**	**0.41**	**0.13**

Giza 843, L46 and L 86 genotypes gave the tallest plants under the 2nd one. On the other hand, genotypes L 46 and Sakha 4 gave the shortest plants among all genotypes under the 1st season and the 2nd one, respectively, indicating that the possibility of using these genotypes in breeding programme to improving this character. In this respect, significant genetic variability was recorded for plant height **(Bakhiet *et al.*, 2015)**.

The results indicated that the faba bean genotypes L 33, L 79 and Giza 843 produced the highest values of number of branches/plant and number of pods/plant; Giza 716, Sakha 4, Nubaria 2 and L 86 were surpassed the other genotypes for number of seeds/plant; Giza 716, L 33, L 79 and Giza 843 gave the highest value for each of 100 seed weight and seed yield/fed (ton) under both seasons, suggesting that the studied genotypes differed in genes controlling seed yield and its components, indicating that these genotypes can be used in faba bean breeding programme to improving these characters. In this connection, significant differences among faba bean genotypes have been recorded for seed yield, number of branches/plant, number of pods/plant, number of seeds/pod and 100-seed weight by **Elshafei *et al.* (2019), El-Shal and El-Sayed (2019), Tadele *et al.* (2021) and Ton *et al.* (2021).**

Phenotypic and Genotypic Coefficients of Variation

The estimates of variance, coefficients of variation, heritability and genetic advance for all the six characters studied are showed in Table 4. Phenotypic coefficients of variation were equivalent to their relating genotypic coefficients of variation, showing few impacts of environment on the advertising of these traits. Nevertheless, great correspondence was recorded between genotypic coefficients of variation and phenotypic ones in every one of the traits. Maximum phenotypic variance (V_{ph}) values were recorded for 100 seed weight was (71.52) and number of pods /plant (51.69).

Whereas, the maximum genotypic variance (Vg) values were recorded for number of pods/plant (49.56), plant height (38.76) and 100 seed weight (36.15). Less difference in the assessments of genotypic and phenotypic variances and higher genotypic values compared to environmental one for all the characters except 100 seed weight (35.10) and seed yield (0.16), suggesting that the variations attendant among the genotypes were mainly through genetic reason with minimum effect of environment and hence heritable.

High phenotypic (PCV) and genotypic (GCV) coefficients of variation were detected for plant height, number of pods/plant and 100 seed weight, whereas the values of phenotypic (PCV) and genotypic (GCV) were low for the other characters.

Estimates of phenotypic coefficient of variation (PCV) were higher than their corresponding genotypic (GCV) one, indicating the little effect of environment on the expression of these characters. However, good correspondence was recorded between genotypic coefficient of variation and phenotypic one in all the characters under study.

The (PCV) and (GCV) ranged from 38.03% for number of branches/plant to 145.75% for number of pods/plant and from 26.16% for number of seeds/pod to 142.72% for number of pods/plant, respectively.

The highest heritability estimates were detected for number of pods/plant (95.89%), number of seeds/pod (90.20%), number of branches/plant (85.67%) and plant height (82.01%), meanwhile it was moderate for 100 seed weight (50.73%) and low for seed yield/fed (ton) (47.82). High heritability estimates and phenotypic and genotypic coefficients of variability were observed for most of the yield and yield attributing characters studied in faba bean genotypes

Table 4. Variance, phenotypic (PCV) and genotypic (GCV) coefficients of variability, broad sense heritability (h^2_b) and GA for the yield and yield components of faba bean genotypes (over two seasons)

Character Genetic parameter	Plant height (cm)	Number of branches/ plant	Number of pods/ plant	Number of seeds/ pod	100-seed weight (g)	Seed yield/fad. (ton)
Phenotypic Variance (σ^2ph)	47.26	0.62	51.69	0.18	71.25	0.30
Genotypic Variance (σ^2g)	38.76	0.53	49.56	0.17	36.15	0.14
Environmental Variance (σ^2e)	8.50	0.09	2.12	0.02	35.10	0.16
PCV (%)	70.70	38.03	145.75	27.54	103.89	39.11
GCV (%)	64.03	35.20	142.72	26.16	74.00	27.04
h^2_b (%)	82.01	85.67	95.89	90.20	50.73	47.82
GA	9.92	1.18	12.13	0.68	7.54	0.46

(**Mulualem *et al.*, 2013; Bakhiet *et al.*, 2015; Sharifi, 2017; Elshafei *et al.*, 2019; El-Shal and El-Sayed, 2019; Tadele *et al.*, 2021; Ton *et al.*, 2021).**

Correlation

Simple correlation coefficient values of seed yield with plant height, number of branches/plant, number of pods/plant, number of seeds/pod and 100 seed weight are shown in Table 5. The results indicated that positive and significant correlation coefficient values were recorded between seed yield (ton. /fad.) and each of number of pods/plant (0.844**), number of branches/plant (0.783**) and100 seed weight (0.861*); number of branches/plant and each of number of pods/plant (0.881**) and 100 seed weight (0.814**) as well as between number of pods/plant and100 seed weight (0.739**). This indicates that an increase in one-character leads to an increase in another associated one. On the other hand, negative and significant correlation between plant height and number of pods/plant (-0.441*).

Factor Analysis

Principal factor matrix after orthogonal rotations and summary of factor loading for some studied characters of faba bean (over two seasons) are presented in Tables 6 and 7. The factor analysis technique divided the studied variables into two main factors. These two factors accounted about 77.012% of the total variability in the dependence structure of faba bean seed yield. The first factor included three variables and accounted for 55.705%. These variables were number of branches/ plant (34.52%), number of pods/plant (34.12%) and 100-seed weight (31.36%). It is clear that these variables had high loading coefficients and participate much more on the dependence structure. Most of these variables exhibited positive and significant correlation values with faba bean seed yield as previously mentioned. The second factor consists of two variables and accounted for 21.107% of the total variability of faba bean seed yield. These two variables were plant height (31.31%) and number of seeds/pod (68.69%).

It could be concluded that selection for the most important yield traits particularly number of branches/plant, number of pods/ plant, number of seeds/pod and 100 seed weight would lead to maximizing total faba bean seed yield. **Mehasen and Mohamed (2004), Salama *et al.* (2008) and Arab *et al.* (2018),** obtained that number of pods / plant, number of seeds/pod and 100-seed weight were accounted the major contributing of seed yield/ plant.

Table 5. Simple correlation coefficient between seed yield and its contributing characters in faba bean (over two seasons)

Character	Plant height (cm)	Number of branches/ plant	Number of pods/ plant	Number of seeds/ pod	100-seed weight (g)
Plant height (cm)	1				
Number of branches/plant	-0.328ns	1			
Number of pods/plant	-0.441*	0.881**	1		
Number of seeds/pod	0.440ns	0.190ns	-0.013ns	1	
100-seed weight (g)	-0.166ns	0.814**	0.739**	0.029ns	1
Seed yield/fed (ton)	-0.323ns	0.783**	0.844**	0.021ns	0.861**

ns, * and ** indicate insignificant, significant at 5% and highly significant at 0.01%, levels of probability, respectively.

Table 6. Principal factor matrix after orthogonal rotations for studied characters of faba bean (over two seasons)

Variable	Common factors coefficients		Communality
	Factor 1	Factor 2	(%)
Plant height (cm)	-0.484	0.418	0.409
Number of branches/plant	0.954	0.152	0.934
Number of pods/plant	0.943	-0.103	0.900
Number of seeds/pod	0.097	0.917	0.850
100-seed weight (g)	0.867	0.760	0.750
Variance ratio	55.905	21.107	77.012

Table 7. Summary of factor loading for some important traits of faba bean (over two seasons)

Variable	Loading	Percentage of total
Factor 1		**55.905**
Number of branches/plant	0.954	34.52
Number of pods/plant	0.943	34.12
100-seed weight (g)	0.867	31.36
Factor 2		**21.107**
Plant height (cm)	0.418	31.31
Number of seeds/pod	0.917	68.69
Cumulative variance		**77.012**

Conclusion

The success of faba bean breeding program depends on the choice of genotypes capable of producing progeny with desired trait combinations. The identify of genetic variability is the most important prerequisite for the crop improvement program. Seed yield is a complex trait and is reportedly associated with a number of component traits. Therefore, the present study aimed to estimate genetic variability, correlation as well as factor analysis of yield and yield component characters in nine faba bean genotypes. The results revealed significant differences among faba bean genotypes for all the studied characters. Genotypes Giza 716, Sakha 4, L 33, L79, L 86 and Giza 843 performed well for yield and its component characters. Maximum phenotypic variance (V_{ph}) and genotypic one (Vg) values were recorded for number of branches/plant and 100 seed weight. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) ranged from 38.03 for number of branches/plant to 145.75% for number of pods/plant and from 26.16 for number of seeds/pod to 142.72% for number of pods/plant, respectively. The highest heritability estimates were detected for number of pods/plant, number of seeds/pod, number of branches/plant and plant height. The factor analysis technique divided the studied variables into two main factors. These two factors accounted about 77.012% of the total variability in the dependence structure of faba bean seed yield. The first factor included three variables and accounted 55.705%, whereas, the second one consists of two variables and accounted 21.107% of the total variability of faba bean seed yield.

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الملخص العربي

الاختلافات الوراثية، الارتباط وتحليل العامل للمحصول ومكوناته في بعض التراكيب الوراثية من الفول البلدي

هاني عبد الرؤوف وفا، رانيه محمد يحي هيكل

قسم الوراثة والهندسة الوراثية، كلية الزراعة، جامعة الزقازيق، مصر

أقيمت تجربتين حقليتين خلال الموسمين 2019 – 2020 و2020 – 2021 بالمزرعة البحثية بالخطارة، كلية الزراعة، جامعة الزقازيق، الشرقية، مصر. بغرض دراسة الاختلافات الوراثية بين 9 تراكيب وراثية من الفول البلدي (سلالة 33، سلالة 46، سلالة 79، سلالة 86، سخا 94، نوبارية 2، نوبارية3 ، جيزة 716و جيزة 843) وكذلك دراسة الارتباط وتحليل العامل بين محصول البذور ومكوناته. أشارت النتائج إلى وجود اختلافات عالية المعنوية بين التراكيب الوراثية في جميع الصفات تحت الدراسة. تفوقت التراكيب الوراثية جيزة 716، سخا 4، سلالة 33، سلالة 79، سلالة 86 و جيزة 843 في محصول البذور ومعظم مكوناته. سجلت كل من صفتي وزن المائة بذرة وعدد القرون /النبات أعلى تباين مظهري ووراثي. تراوحت قيم معامل الاختلاف المظهري ومعامل الاختلاف الوراثي من 38.03 لصفة عدد الأفرع/النبات الى 145.75% لصفة عدد القرون/النبات ومن 26.16 لصفة عدد البذور/النبات الى 122.51% لصفة عدد القرون /النبات، على التوالي. كانت قيم كفاءة التوريث مرتفعة لصفات عدد القرون/النبات، عدد البذور/النبات، عدد الأفرع/النبات و ارتفاع النبات، بينما كانت متوسطة لصفة وزن الـ 100 بذرة ومنخفضة لصفة محصول البذور (طن/الفدان). كان هناك ارتباط موجب ومعنوي بين محصول البذور وكل من عدد القرون /النبات، ووزن المائة بذرة. أظهر تحليل العامل تقسيم الصفات تحت الدراسة الى عاملين رئيسيين مثلا حوالى 77.01 % من الاختلافات في صفة المحصول. مثل العامل الأول حوالى 55.705% واشتمل على ثلاث متغيرات هي عدد الأفرع/النبات (34.52%) وعدد القرون/النبات (34.12%) ووزن 100 بذرة (31.36%) في حين مثل العامل الثاني حوالى 21.107 من الاختلافات الكلية لصفة المحصول واشتمل على متغيرين هما ارتفاع النبات (31.31%) وعدد البذور/القرن (68.69%).

الكلمات الإسترشادية: الفول، التباين الوراثى، الارتباط، تحليل العامل.

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