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Article

Studying the Genetic Parameters of Some Cultivars of Faba Bean (*Vicia faba* L.) and Evaluating Their Performance under Different Levels of Phosphorous

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Abstract
A field experiment was carried out during the winter season of 2021-2022 in the research station - College of Agricultural Engineering Sciences - University of Baghdad in order to study the genetic parameters of some cultivars of faba bean cultivars and evaluate their performance under different levels of phosphorus. Spilled plots were arranged according to randomized complete block design (RCBD) at three replications. The main plots included three levels of phosphorous fertilizer (80, 120 and 160 Kg ha^{-1}) and the control treatment (without fertilizer). In contrast, the subplots included four faba bean cultivars (Local, Spanish, Dutch and New Zealand). The results showed highly significant effects of phosphorous fertilizer levels on the most studied traits, as adding phosphorous fertilizer at 160 Kg gave the highest means of several pods per plant (17.78 pods $plant^{-1}$) and seed yield (4.403 tons ha^{-1}). Also, the results showed that the faba bean cultivars were significantly different in most studied traits, as the Local cultivar achieved the highest mean number of pods per plant (16.95pod $plant^{-1}$).
In contrast, the Dutch cultivar achieved the highest mean number of seeds per pod (5.78 seed pod^{-1}), whereas the Spanish cultivar achieved the highest mean weight of 100 seeds (86.95 g) and seed yield (5.295 ton ha^{-1}). The interaction between studied factors had a non-significant effect on all studied traits except the number of pods per plant. The genetic variance recorded greater values than the environmental variance in most of the studied traits, indicating that the genetic variance significantly contributed to the phenotypic variance.

Keywords: Genetic indicators, phosphorous, *Vicia faba* L., G.C.V., PCV.

Introduction

Faba bean (Vicia faba L.) is an essential leguminous seed crop belonging to the Fabaceae family. It is a staple food for millions of people in poor countries because it contains a high percentage of protein (23-37%) and carbohydrates (56%) in most cultivars[1]. Also, the faba bean has high importance in nutrition because it contains essential amino acids for the growth of humans and animals and contains many mineral elements and vitamins, increasing its economic importance in the world. Faba bean crop occupies the third place after Phaseolus vulgaris L. and Pisum sativum L. and[2] it is grown to obtain green pods or fresh or dry seeds[3] and is used forage for animals[4]. Also, faba beans are included in the

crop rotation to improve soil characteristics through their ability to fixation atmospheric nitrogen in the soil through root nodes with Rhizobium bacteria[5]. In Iraq, this crop suffers from a low rate of productivity as a result of the deterioration of the genotype structure of the local cultivars, well as the lack of environmental adaptation of the introduced cultivars, as cultivars vary in their genetic and physiological composition, which makes them differ in growth behavior and yield according to prevailing environmental conditions and crop management operations. In order to increase the productivity of the cultivars, different technologies must be used in crop management, including the use of various fertilizers to exploit the genetic potential of the cultivar towards benefiting from the service available during its growth to convert the available solar energy into biochemical energy through the process of photosynthesis to produce dry matter and its transporting from the source to the final since, i.e., seeds. Among the critical fertilizers is phosphorous fertilizer, which plays a regulatory role in the physiological processes of growth, increases branching and root spread, accelerates plant maturation and improves the quantity and quality of yield[7]. Therefore, this research was carried out to study the genetic parameters of some faba bean cultivars and evaluate their performance under different levels of phosphorus.

Materials and Methods

A field experiment was carried out during the winter season of 2021-2022 in the research station - College of Agricultural Engineering Sciences - University of Baghdad in order to study the genetic parameters of some cultivars of faba bean cultivars and evaluate their performance under different levels of phosphorus. Spilled plots were arranged according to randomized complete block design (RCBD) at three replications. The main plots included three levels of phosphorous fertilizer (80, 120 and 160 Kg ha^{-1}) and the control treatment (without fertilizer). In contrast, the subplots included four faba bean cultivars (Local, Spanish, Dutch and New Zealand). Soil management operations were conducted, and then the experimental land was divided into experimental units with an area of 6 m^2 (2 m x 3m), which contained 5 lines 70 cm apart. At the same time, the distance between hills was 20 cm to reach a plant density of 71428 plants ha-1. The seeds of faba bean cultivars were sown on 17/11/2021 at a depth of 5 cm 2 seeds per hill, which thinned to one seedling after emergence. Nitrogen fertilizer was added with 150 Kg N ha^{-1} as urea (46% N) at two equal doses, the first after 45 days of planting and the second after 75 days of planting[8]. In contrast, phosphorous fertilizer was added at one dose before the planting according to treatments. Crop management was carried out as needed, and the plants were harvested after the appearance of the maturity sign on 12/4/2022. The number of pods per plant, number of seeds per pod, weight of 100 seeds (g) and total seed yield (ton ha-1) were measured. The data were statistically analyzed using the GenStat program, and the least significant difference (L.S.D.) was used to compare between means at a probability level of 0.05. Also, the phenotypic, genetic, and environmental variance were estimated, and heritability broad sense was calculated according to the equations of[9].

Results

Number of pods per plant

The results in Table (1) indicate that there were significant differences between levels of phosphorous fertilizer in the number of pods per plant; the adding of phosphorous fertilizer at a 160 Kg ha^{-1} gave the highest mean of this trait amounting to 17.78 pods $plant^{-1}$with non-significant difference with adding of phosphorous fertilizer at a 120 Kg ha^{-1} which gave 17.04 pods $plant^{-1}$compared

with control treatment which gave the lowest mean amounted to 13.04 pods plant^{-1}. The increase in the number of pods per plant fertilized with phosphorous could be attributed to the role of this element in increasing the vegetative growth and then preparing the new growth sites with their food requirements and increasing the percentage of fertilization. Regarding the faba bean cultivars, the result in Table (1) reveals that the Local cultivar was significantly superior and achieved the highest mean of this trait (16.95 pod plant^{-1}) with a significant increase amounted to *16.*33, 11.22 and 6.27% with Spanish, Dutch and New Zealand cultivars respectively. The reason for different faba bean cultivars may be due to their difference according to their genetic composition in the distribution of photosynthesis products and their exploitation in the formation of pods.

Cultivars	**P_2O_5 (Kg ha^{-1})**				**Means**
	Control	80	120	160	
Local	15.00	16.87	17.07	18.87	**16.95**
Spanish	14.27	13.80	17.73	18.00	**15.95**
Dutch	12.47	15.87	16.07	16.53	**15.24**
New Zealand	11.20	12.07	17.27	17.73	**14.57**
LSD 0.05	1.49				**0.81**
Means	13.24	14.65	17.04	17.78	
LSD 0.05	0.65				

Table 1. Effect of Genetic parameters of cultivars of faba bean and levels of phosphorous on number of pods per plant.

Number of seeds per pod

Table (2) results indicate non-significant differences between phosphorous fertilizer levels in the number of seeds per pod. Otherwise, the faba bean cultivars significantly differed in this trait; the Dutch cultivar achieved the highest mean of this trait, amounting to 5.78 seed pod^{-1}with a significant increase amounted to 47.45, 33.49 and 6.25%, with Local, New Zealand and Spanish cultivars, respectively. The reason for the difference among faba bean cultivars may be their variation in genetic traits, the nature of their growth and their response to growth conditions, which was reflected in the number of seeds per pod.

Cultivars	**P_2O_5 (Kg ha^{-1})**				**Means**
	Control	80	120	160	
Local	3.67	3.97	4.00	4.03	**3.92**
Spanish	4.93	5.47	5.53	5.83	**5.44**
Dutch	5.37	5.63	6.03	6.10	**5.78**
New Zealand	4.10	4.33	4.30	4.57	**4.33**
LSD 0.05	N.S.				**0.31**
Means	4.52	4.82	4.97	5.13	
LSD 0.05	N.S				

Table 2. Effect of Genetic parameters of faba bean cultivars and phosphorous levels on number of seeds per pod.

Weight of 100 seeds (g)

The results in Table (3) show that the phosphorous fertilizer levels had a non-significant effect on the weight of 100 seeds. Otherwise, the faba bean cultivars significantly differed in this trait; the Spanish cultivar gave the highest mean of 100 seeds weight, amounting to 86.95 g, with a significant increase of 95.39 and 49.91% with New Zealand and Dutch cultivars, respectively.

Cultivars	P_2O_5 (Kg ha^{-1})				Means
	Control	80	120	160	
Local	82.70	85.30	86.00	91.00	**86.25**
Spanish	95.70	95.70	75.70	80.70	**86.95**
Dutch	68.70	53.30	49.70	60.30	**58.00**
New Zealand	47.30	50.70	39.70	40.30	**44.50**
LSD 0.05	N.S.				**14.64**
Means	73.60	71.25	62.78	68.08	
LSD 0.05	**N.S**				

Table 3. Effect of Genetic parameters of faba bean cultivars and phosphorous levels on weight of 100 seeds (g).

Seed Yield (ton ha^{-1})

The results in Table (4) reveal that the addition of phosphorous fertilizer at 160 Kg ha^{-1} was significantly superior and gave the highest mean of the seed yield, amounting to 4.403 ton $ha^{-1}$with a significant increase amounted to *21.*70 and 17.26%, with adding of phosphorous fertilizer at an 80 and 160 Kg ha^{-1} respectively, and 37.90% with control treatment which gave the lowest mean amounted to *3.*193 ton ha^{-1}.

Cultivars	P_2O_5 (Kg ha^{-1})				Means
	Control	80	120	160	
Local	3.210	4.070	4.160	4.910	**4.088**
Spanish	4.700	5.140	5.300	6.040	**5.295**
Dutch	3.270	3.420	3.460	4.330	**3.620**
New Zealand	1.590	1.840	2.100	2.330	**1.965**
LSD 0.05	N.S.				**0.64**
Means	3.193	3.618	3.755	4.403	
LSD 0.05	**0.480**				

Table 4. Effect of Genetic parameters of faba bean cultivars and phosphorous levels on seed yield (ton ha^{-1}).

Genetic parameters

Due to the presence of the significant effect of the genotypes on the most studied traits, this allowed the genetic analysis of the studied traits at each level of phosphorous fertilizer to know the genetic behavior of the faba bean cultivars. Genetic variations are among the primary factors for plant breeders. Therefore, the estimation of phenotypic, genetic and environmental variations, phenotypic coefficients variation (PCV), genetic coefficients variation (G.C.V.) and the heritability broad sense (h^2b.s) provide essential information that can be inferred on the most appropriate methods for crop improvement.

Genetic parameters at a level of 80 Kg ha^{-1}

Table (5) shows that the standard error values for all the studied traits were low, indicating that the data for the traits were similar and near the arithmetic mean. The data homogeneity can also be accepted because most of the studied traits' coefficient of variation (C.V.) was less than 20%, except for seed yield, indicating the samples' homogeneity. The values of genetic variance were more significant than the values of environmental variance in most of the studied traits, except the weight of 100seeds, as the genetic variance decreased about 51.2% from the environmental variance, and this indicates that the variation of studied traits of the cultivars, except the weight of the 100seeds, was primarily genetic and the environmental influence on these traits was little. Also, the high percentage of genetic variance to the environmental variance, which amounted to 7.22 for the number of seeds per pod and 5.35 for the number of pods per plant, indicates that the variance that exists between the cultivated cultivars in these traits was mainly due to genetic differences.

Genetic parameters	Studied traits			
	Number of pods per plant	Number of seeds per pod	Weight of 100 seeds (g)	Seed Yield (ton ha^{-1})
SE	0.92	0.83	1.29	**0.95**
C.V	6.54	12.75	5.09	**29.12**
$g^2\delta$	4.33	0.65	304.8	**1.48**
$e^2\delta$	0.81	0.09	624.7	**1.30**
$p^2\delta$	5.14	0.74	929.5	**2.78**
δ^2 g \$\delta^2$e	5.35	7.22	0.49	**1.14**
P.C.V.	15.47	17.74	42.79	**46.06**
G.C.V.	14.20	16.63	24.50	**33.60**
h^2.b.s%	84.23	87.81	32.79	**53.23**

Table 5. Values of genetic parameters and heritability of the studied traits of faba bean cultivars at the level (80 kg ha^{-1}) of phosphorous.

Genetic parameters at a level of 120Kg ha^{-1}

The results in Table (6) show that all the values of the measured traits' standard error were low, indicating that the data for the traits were similar and near the arithmetic mean. Also, the results in Table (6) show that the values of the coefficient of variation (C.V.) for most of the studied traits were less than 20%, except the seed yield, indicating the samples' homogeneity. The values of genetic variance were more significant than the values of environmental variance in most of the studied traits, except the number of pods per plant, and this indicates that the variance of studied traits of the faba bean cultivars was genetic primary variation and the influence of the environment on these traits was little, as evidenced by the high ratio of genetic variance to environmental variance, which amounted to 6.33 and 6.00 for the seed yield number of seeds per pod respectively. As for the values of the contribution of genetic variance to the phenotypic variance of the seed yield, the number of seeds per pod and weight of 100 seeds were 86.53, 85.63 and 84.23%, respectively, except the number of pods per plant was low. These percentages show that genetic variance significantly contributed to phenotypic variance and high heritability due to high

genetic variance and low environmental variance. Also, it is clear from the results in Table (6) that the G.C.V. values were near to the PCV values, and this confirms that these traits are genetically controlled, except the number of pods per plant, in which the environmental variation contributed 79.30% of the phenotypic variation. Table (6) results reveal that the heritability broad sense was high(86.53, 85.63 and 84.23%) for the seed yield, number of seeds per pod and weight of 100 seeds, respectively. This indicates the importance of genetic influences in the transport of the trait and the additive and non-additive effects of genes that control the inheritance of these traits.

Genetic parameters	Studied traits			
	Number of pods per plant	Number of seeds per pod	Weight of 100 seeds (g)	**Seed Yield (ton ha^{-1})**
SE	0.92	0.85	1.16	**0.87**
C.V	5.66	13.78	3.86	**20.45**
$g^2\delta$	0.22	0.90	422.8	**1.71**
$e^2\delta$	0.83	0.15	82.92	**0.27**
$p^2\delta$	1.05	1.05	525.7	**1.98**
δ^2 g \ δ^2e	0.27	6.00	5.09	**6.33**
P.C.V.	6.01	20.59	36.54	**37.45**
G.C.V.	2.73	19.06	33.54	**34.84**
h^2.b.s%	20.70	85.63	84.23	**86.53**

Table 6. Values of genetic parameters and heritability of the studied traits of faba bean cultivars at the level (120 kg ha^{-1}) of phosphorous.

Genetic parameters at a level of 160Kg ha^{-1}

The results in Table (7) show that the behavior of the standard error data at a level 160 Kg ha^{-1}was similar to its behavior in the previous two levels (80 and 120 Kg ha^{-1}), as all the standard error values for the measured traits were low, and this decrease in the standard error values indicates that the data of the studied traits were similar and near to the arithmetic mean. The results in Table (7) also show that the coefficient of variation C.V. values for all the studied traits was less than 20%, indicating the samples' homogeneity. The values of genetic variance were more significant than the values of environmental variance in all the studied traits, and this indicates that the variance of studied traits of the faba bean cultivars was genetic variation and the influence of the environment on these traits was little, as evidenced by the high percentage of genetic variation to the environment, which amounted to 7.23, 5.49 and 5.26 for the number of seeds per pod, weight of 100 seeds and seed yield respectively. Also, the value of the contribution of genetic variance to the phenotypic variance of 87.90, 84.59, 84.13 and 69.72 for the number of seeds per pod, the weight of 100 seeds, seed yield and number of pods per plant, respectively, indicates that the contribution of genetic variance was a significant contribution to phenotypic variance in these traits.

Genetic parameters	**Studied traits**			
	Number of pods per plant	**Number of seeds per pod**	**Weight of 100 seeds (g)**	**Seed Yield (ton ha^{-1})**
SE	0.89	0.84	1.17	**0.89**
C.V	4.56	12.95	3.59	**19.16**
$g^2\delta$	0.81	0.94	475.7	**2.26**
$e^2\delta$	0.35	0.13	86.64	**0.43**
$p^2\delta$	1.16	1.07	562.3	**2.69**

δ ² g \δ²e	2.31	7.23	5.49	**5.26**
P.C.V.	6.07	20.17	34.83	**37.26**
G.C.V.	5.06	18.91	32.03	**34.18**
h².b.s%	69.72	87.90	84.59	**84.13**

Table 7. Values of genetic parameters and heritability of the studied traits of faba bean cultivars at the level (160 kg ha^{-1}) of phosphorous.

Discussion

This result is consistent with [10,11], who noted that the number of pods per plant was significantly increased when adding phosphorous fertilizer.

This result is in agreement with[12,13,14] The interaction between studied factors had a significant effect on this trait; the Local cultivar with the addition of phosphorous fertilizer at 160 Kg ha^{-1} recorded the highest value (18.87 pod plant^{-1}), which significantly differed with control treatment and other levels of phosphorous fertilizer in the same cultivar as well as the other cultivars at the same phosphorous fertilizer level, except for the Spanish cultivar. In contrast, the New Zealand cultivar with the control treatment recorded the lowest value (11.20 pod plant^{-1}).

This result is in agreement with [15,16]. The interaction between studied factors had a non-significant effect on this trait.

However, there was a non-significant difference between Spanish and Local cultivars in this trait. This result is consistent with [17,18,19], who indicated significant differences between faba ben cultivars in the weight of 100 seeds. The interaction between studied factors had a non-significant effect on this trait.

The reason for the response of faba bean to phosphate fertilizer may be attributed to the low content of available phosphorous present in the soil (3.25 mg Kg^{-1}), which is less than the critical limit of its available content in Iraqi soils, which [20] is 7 mg Kg^{-1}, or the reason of increase the seed yield when adding of phosphorous fertilizer at a 160 Kg ha^{-1}could be due to an increase the number of pods per plant (Table 1). These results are in agreement. Regarding the faba bean cultivars, the result in Table (4) shows that the Spanish cultivar was significantly superior and achieved the highest mean seed yield (5.295 ton ha^{-1}) with a significant increase amounted to *29.53* and 46.27% with Local and Dutch cultivars, respectively and 169.47% with New Zealand cultivar which achieved the lowest mean (1.965 ton ha^{-1}). The difference among faba bean cultivars in the seed yield may be due to their genetic differences. On the other hand, the reason for the superiority of the Spanish cultivar in the seed yield could be due to its superiority in the number of seeds per pod (Table 2). This result is consistent with [16,19]. The interaction between studied factors had a non-significant effect on this trait.

Also, we can conclude from the value of the contribution of genetic variance to the phenotypic variance of the number of seeds per pod and several pods per plant (87.81 and 84.23%), respectively, that the variation in these traits between the cultivars was due to genetic differences between cultivars. These percentages show that genetic variation significantly contributed to the Phenotypic variance. These results are consistent with 22, while the weight of 100 seeds, which was the value of the contribution of genetic variance to phenotypic variance (heritability), amounted to 32.79. The results in Table (5) also show that the values of G.C.V. and PCV were near to each other for most traits, and this confirms that these traits are genetically controlled, except the weight of 100

seeds and seed yield, which gave the lowest heritability broad sense (32.79 and 53.23%)respectively, and this indicates that the influence of the environment was high in these traits. As for the traits in which G.C.V. values were near to the PCV values, such as the number of seeds per pod, which had high heritability values (87.81%), it indicates the importance of the additive and non-additive effects of genes that control the inheritance of traits[23].

Also, it is clear from the results in Table(7) that the G.C.V. values were near to the PCV values for all traits, i.e., the traits are genetically controlled. The plant's phenotype represents its genetic structure, which indicates the possibility of inheritability of these traits by selection because the additive genes are less affected by environmental conditions. These results agree with [24,25]. Also, it is noted that the values of heritability broad sense at 160 Kg ha^{-1} were higher than those of heritability broad sense at 80 and 120 Kg ha^{-1}in most of the studied traits.

Conclusion

We conclude that the faba bean cultivars responded to the addition of phosphorous fertilizer levels, and the addition of phosphorous fertilizer at 160 Kg ha^{-1} was significantly superior in the number of pods per plant and seed yield. Also, the faba bean cultivars varied in the studied traits, and the cultivar was significantly superior in the seed yield. In addition, selection can be used to improve the number of seeds per pod that recorded the highest heritability ratio due to the high ratio of genetic variance to phenotypic variance.

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