COMPONENTS OF PHENOTYPIC VARIATION OF GROWTH TRAITS AND YIELD OF FABA BEAN GENOTYPES AS A RESULT OF PLANT DENSITY

Wajeeha Abed Hassan[1*], Haider Hussein Muhammed[2*]and Sukaina AbdulMohsin AbdulJabbar[3*]
[1,2,3]Field Crop Dept. Coll. Agri. Engin. Sci. University of Baghdad.
wajeeha@coagri.uobaghdad.edu.iq
haider.hassoun1906@coagri.uobaghdad.edu.iq
sukaina.abd2006@coagri.uobaghdad.edu.iq

ABSTRACT

With the aim of evaluating the performance of genotypes of beans (Spanish, Italian, local) and testing them under two levels of plant density (80 and 160 thousand plants ha^{-1}), and determining which genotypes give a higher yield and at what plant density, and calculating some of their genetic parameters, a field experiment was carried out in the winter season 2023-2024 in Station A in the Department of Field Crops - College of Agricultural Engineering Sciences-University of Baghdad-Al-Jadriya, a Randomized Complete Block Design (RCBD) was used with three replications, in a split plot arrangement. Plant densities represented the main plots and the secondary plots represented the genotypes. Studying the traits plant height, the number of branches, the number of leaves, the number of pods, the wet weight of the pods, the length of the pod, the number of seeds in it, the dry weight of the pods, the weight of 10 seeds, the plant yield, and the unit area yield. The results showed that there were significant differences between the plant densities, the high density excelled by giving its plants the highest mean yield per unit area was 16,802 tons/ha^{-1}, due to the increase in the number of plants per unit area. The genotypes also differed significantly, and the Spanish genotype excelled in giving highest mean yield per unit area, reached to 14,950 tons/ha^{-1}, followed by the local genotype with mean of 13,004 tons/ha^{-1}, that the Spanish genotype was superior due to its superiority in yield components and giving it the highest pod length (21.00 cm) and the highest seed weight (15.67 g). The results also showed that the interaction was significant between the genotypes and plant densities for most of the studied traits. The results also showed that the values of genetic variation for most studied traits were higher than environmental variation at the two plant densities, with the exception of the traits of number of pod seeds and individual plant yield at low and high densities, respectively. Broad-sense heritability was high at low densities, reaching 99%, 87%, 96%, 88%, 61%, 96%, 98%, 99%, 99%, and 99% for the traits of plant height, number of branches, the number of leaves, the number of pods, the length of the pod, the number of its seeds, the weight of wet and dry pods, the yield of an individual plant, the weight of 10 seeds, and the yield of unit area, respectively. However, at high density, the heritability was high for the traits of plant height, number of leaves, number of pods, number of pod seeds, weight of wet and dry pods, weight of 10 seeds, and yield of unit area, reached 99%, 89%, 88%, 67%, 99%, 84%, 83% and 93%, respectively, which indicates the possibility of improving these traits through selection for their high genetic variation.

Keywords: Broad-sense heritability, *Vicia faba* L., genotypes.

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Introduction

The bean plant (*Vicia faba* L.) belongs to the leguminous family (Fabaceae). It is a multi-purpose crop. It is of nutritional importance to humans and serves as a main food for approximately 18-40% of the population of the Middle East and North Africa, it is also important as fodder for animals. It is a very important source of protein ranging from The protein in seeds is between 22-37%, and it is used for industrial purposes, in addition to its importance in soil fertility, it is also one of the important and basic food crops for millions of people in poor countries, because it contains a high percentage of protein and large quantities of sugars and starches and some vitamins, and it is used as animal feed, either the plant remains after harvest or the use of its dried seeds as a source of protein in concentrated diets (15). Plant density is one of the important factors influencing crop productivity, and it varies for each genotype depending on the climatic conditions, the ideal plant density varies according to the crop or genotype and the difference in strength, length, branching, planting date and growing season, the ideal plant density for limited-growth legume genotypes is higher than it is. for genotypes with unlimited growth, the second gives a greater yield than the first at all plant densities, and this is due to the greater vegetation cover, and the ideal density of beans varies according to the type and nature of growth, determined and undetermined growth (11). (7) found, when they studied the response of five genotypes (local, Spanish, Giza, Hama, and Nubaria) of legumes to plant density (166.66, 83.333, and 55.555 thousand plants ha^{-1}), that the low plant density (55.555 thousand plants ha^{-1}) the highest mean was recorded for most traits such as leaf area (4096 cm^2), number of pods per plant (13.09 pods plant^{-1}), and number of seeds per pod (3.85 seeds pod^{-1}), the weight of 100 seeds was (148.5 g), while the high density (166.66 thousand plants ha^{-1}) was superior and gave the highest average crop growth rate, reaching 7.73 g m^2 day^{-1}, and the highest yield per unit area of seeds reaching 5.60 tons ha^{-1}, and the Spanish genotype outperformed with the highest mean in most traits, it gave the highest total seed yield of 7.06 tons ha^{-1}, the highest percentage of effective fertility in flowers (11.54%), the highest number of pods per plant (16.17 pods per plant), and the highest mean seed yield (8.55 tons ha^{-1}). (17) Found at they studied the effect of three plant densities (8.3, 12.5, and 25 plants m^2) on growth characteristics and yield in beans, the leaf area decreased with increasing plant density, and the first density (8.3 plants m^2) gave the highest average leaf area of 573 cm^2, and the highest dry matter weight of 6.67. kg plant^{-1}, while the relative area of leaves (which is a ratio between the tissues in which we perform photosynthesis) increased at high density and gave the highest relative area of leaves amounting to 88.7%.

Bean genotypes vary in many morphological traits, and one of the difficulties facing plant breeders is the criteria that he follows in selecting parents to know the genetic differences in the most important traits, such as yield and its components, which can be used as selection criteria (10). The ideal choice for plant breeders is to rely on traits that are linked to yield and are highly heritable, because the yield trait is a quantitative trait, and genetic improvement for any desired trait depends primarily on the size and nature of genetic variation and the heritability rate of the desired trait, as estimating heritability is a guide to breeding methods (14). Environmental genetic

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interaction is one of the important factors that control the crop and its components, and it is affected by changes in environmental conditions represented by climate or methods of serving the crop and soil, including the use of optimal density, therefore, the interaction of genotypes and environments is important for determining breeding methods to improve genotypes adapted to specific conditions. (5) found, when he studied the genetic deterioration and expected genetic improvement of second-generation hybrids in beans, that heritability in both the narrow and broad senses was high for all the traits studied (plant height, number of branches, flowering time, maturity date, number of pods, and pod length), as the heritability in the broad sense of these reached traits were 82%, 80%, 68%, 96%, 69%, and 98%, respectively, while narrow-sense heritability reached 58%, 655, 18%, 26%, 44%, and 75%, respectively. (13) found, when they studied two plant densities, that the genetic variance in the first density is higher than the environmental variance for most of the traits studied (plant height, number of leaves, dry weight, weight of plant pods, number of seeds, pod length, and seed yield), that is, genetics is responsible for the inheritance of traits, and therefore the heritability in the broad sense was high for these traits, reaching 98%, 99%, 85%, 70%, 87%, 99%, 83%, while the heritability was low for the traits of number of branches and pods, reaching 34%, 37%. Which means that the environment controls the inheritance of these two traits. While the variation in the second density was of genetic origin, meaning that genetics was the one that controlled the inheritance of all the studied traits, and the heritability in the broad sense reached 98%, 59%, 99%, 94%, 78%, 90%, 84%, 96%, 86. %. (2) found, when he studied genotypes of beans and calculated some of their genetic parameters, that the genetic variance was higher than the environmental variance for all the traits studied, and therefore, heritability in the broad sense was high for all traits (plant height, number of branches, number of leaves, number of pods, pod length, number Seeds per pod, weight of 100 seeds, dry weight, and seed yield reached 96%, 95%, 99%, 70%, 94%, 88%, 97%, 84%, respectively. Therefore, the aim of the research was to study genotypes of beans, compare them with the local genotype under two plant densities, and calculate some genetic parameters at each plant density.

Material and Methods

With the aim of evaluating the performance of genotypes of beans (Spanish, Italian, local) and testing them under two levels of plant density (80 and 160 thousand plants ha^{-1}), estimating some of their genetic parameters, and determining which genotypes give a higher yield at what plant density, an experiment was carried out. Field crops in the winter season of 2023-2024 at Station A in the Department of Field Crops - College of Agricultural Engineering Sciences - University of Baghdad - Al-Jadriyah. The land was prepared for cultivation at the experimental location by plowing, smoothing and leveling. The land was divided into boards (2 x 2.7 m) and the board was divided into 6 lines, the distance between one line and another is 50 cm and between one plant and another is 25 cm. A Randomized Complete Block Design (RCBD) was used with three replications, in a split plot arrangement. Plant densities represented the main plots, and genotypes represented the secondary plots. Planting took place on 23/11/2023. With two seeds per hole, it was reduced to one plant after the plants reached the stage of two leaves per plant in the plots representing the first

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density (80 thousand plants ha^{-1}), and the other plots were left with two seeds per hole to give the second plant density (160 thousand plants ha^{-1}). Fertilization with nitrogen fertilizer 90 kg N ha^{-1} in the form of urea (46% N) in two batches, the first two weeks after germination and the second at the beginning of the flowering stage. Manual weeding and the rest of the field operations were carried out whenever necessary. After the plant reached maturity, characteristics were measured. The plant high, the number of branches, the number of leaves, the number of pods, the wet weight of the pods, the length of the pod, the number of seeds in it, the dry weight of the pods, the weight of 10 seeds, the plant yield, and the unit area yield, by taking five central plants for each experimental unit that were chosen randomly, excluding the peripheral plants.

All traits were statistically analyzed according to analysis of variance (ANOVA), and significance was tested with the F test at a significance level of 0.05, and the arithmetic means were compared using the least significant difference (LSD) with a significance level of 0.05 for all means according to (12) using the Genestat 2014 program.

Estimation of some statistical criteria and genetic parameters.

After confirming the significance of the traits, genetic analysis was carried out and the coefficient of variation (C.V.%) was calculated to estimate the homogeneity between the samples. Genetic, environmental and phenotypic variation and heritability in the broad sense of each plant density were estimated using the genetic analysis program SPAR 2.0 according to what was stated by (16).

Genetic, environmental, and phenotypic variances

were calculated as follows:

$\sigma^2 G = (MSg-MSe)/r$

$\sigma^2 E = MSe$

$\sigma^2 P = \sigma^2 G + \sigma^2 E$,

where:

MSg: the mean square of the genotypes.

MSe: The mean square of the experimental error

r : the number of replicates

$\sigma^2 G$, $\sigma^2 E$, and $\sigma^2 P$ = genetic, environmental, and phenotypic variances, respectively.

The genetic coefficient of variation (G.C.V) and the phenotypic coefficient of variation (P.C.V) were also estimated as follows:

$G.C.V\% = \sqrt{(\sigma^2 g)} / \bar{x} \times 100$

$P.C.V\% = \sqrt{(\sigma^2 p)} / \bar{x} \times 100$

The degree of heritability was also calculated. In the broad sense $h^2_{b.s}$ according to the following equation:

$h^2_{b.s} = \sigma^2 g / \sigma^2 p \times 100$,

and the ranges were adopted for heritability in the broad sense according to (3) and as follows:

less than 40% low, - 40-60% medium and more than 60% high.

Results and Discussion

Plant height

Table (1) shows that there are significant differences between plant densities and genotypes and the interaction between them. The high density (160 thousand plants ha^{-1}) gave the highest plant height of 110.33 cm, while the low-density plants (80 thousand plants ha-1) gave The lowest plant height was 104.67 cm. The reason for the superiority of high plant density in plant height is due to the shading caused by the crowding of plants per unit area and increased shading and thus increased auxin, which causes increased cell division and thus increased plant height. This

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is consistent with what was found by (6) who found that height Plant growth was higher at high density.

Table 1 also shows that the genotypes differed significantly, and the Italian genotype excelled by giving the highest mean plant height of 123.67 cm, while the Spanish genotype gave the lowest plant height of 98.00 cm. It did not differ significantly from the local genotype, which gave a mean plant height of 100.83 cm, because the reason The difference between genotypes in the traits of plant height is due to the genetic nature, which is reflected in the extent to which the genetic compositions respond to the environmental conditions surrounding them and the extent to which the genetic composition benefits from them, thus increasing cell division and elongation and increasing the height of the plant. This agrees with what was found by (8) who found that the genotypes differed significantly in traits of plant height, the American genotype was superior in terms of the highest plant height.

The table shows that the interaction was significant between the genotypes and plant densities, that the combination of the Italian genotype and the low plant density achieved the highest plant height of 125.67 cm, while the lowest plant height for the interaction treatment between the Spanish genotype and the low plant density was 90.67 cm.

Table 1. Response of Plant height (cm) for genotypes of fababean for two plant densities for winter season 2023-2024.

genotypes	plant density (thousand plants ha^{-1})		Means
	80	160	
local genotype	97.67	104.00	100.83
Italian genotype	125.67	121.67	123.67
Spanish genotype	90.67	105.33	98.00
LSD $_{0.05}$	3.31		2.34
Means	104.67	110.33	
LSD $_{0.05}$	2.91		

Number of branches

Table (2) shows the presence of significant differences between plant densities and there are no significant differences between genotypes and the interaction between them and plant densities. The low density (80 thousand plants^{-1}) excelled in giving its plants the highest number of plant branches, amounting to 6.78 branches plant^{-1}, while it gave High density plants the lowest number of branches in the plant was 3.67 branches plant^{-1}. The reason for the superiority of low plant density in terms of the number of branches in the plant is due to the lack of density and the presence of sufficient space for the plant to branch, and the small number of branches in high density is due to the presence of intense competition between plants. Plants crowd out per unit area. This can also be explained by the fact that high density limits the lateral growth of plants, and apical dominance is strongest under the influence of competition for surrounding weather conditions, and this agrees with what was found by (1).

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Table 2 also shows that there are no significant differences between the genotypes and the interaction between them and plant densities.

Table 2. Response of number of branches (branch plant^{-1}) for genotypes of fababean for two plant densities for winter season 2023-2024.

genotypes	plant density (thousand plants ha^{-1})		Means
	80	160	
local genotype	6.33	4.33	5.33
Italian genotype	7.00	3.00	5.00
Spanish genotype	7.00	3.67	5.33
LSD $_{0.05}$	N.S		N.S
Means	6.78	3.67	
LSD $_{0.05}$	0.48		

Number of leaves

Table (3) shows that there are significant differences between plant densities and genotypes and the interaction between them. The low density excelled in giving its plants the highest number of leaves, reaching 125.67 leaves plant^{-1}, while the high-density plants gave the lowest number of leaves per plant. It reached 65.33 leaves per plant^{-1}. The reason for the superiority of the low plant density in trait of the number of leaves is that the plants of this density excelled by giving the highest number of branches, amounting to 6.67 branch plant^{-1} (Table 2), and thus the total number of leaves of the plant decreased, and this agrees with what was found by (13) who found an increase in the number of leaves at low density.

Table 3 also shows that the genotypes differed significantly, and the Spanish genotype excelled in giving the highest mean number of leaves, reached 107.50 leaves per plant, while the local genotype gave the lowest number of leaves, amounting to 87.50 leaves per plant, and did not differ significantly from the Italian genotype, which gave an average number of leaves. The leaves reached 91.50 leaves per plant^{-1}. The reason for the difference between the genotypes in the number of plant leaves is due to the genetic nature, which is reflected in the extent to which the genotypes respond to the plant density and environmental conditions surrounding them and the extent to which the genotype benefits from them. This is consistent with what (13) they found a difference in the number of leaves according to the genotypes.

The table shows that the interaction was significant between the genotypes and plant densities, and that the interaction between the Spanish genotype and the low plant density achieved the highest number of leaves, reached 138.33 leaves plant^{-1}, while the lowest number of plant leaves for the interaction treatment was between the Italian genotype and the high density, with a mean of 52.00 leaves.

ISSN 2072-3857

Table 3. Response of number of leaves (leaf plant^{-1}) for genotypes of fababean for two plant densities for winter season 2023-2024.

genotypes	plant density (thousand plants ha^{-1})		Means
	80	160	
local genotype	107.67	67.33	87.50
Italian genotype	131.00	52.00	91.50
Spanish genotype	138.33	76.67	107.50
LSD $_{0.05}$	7.09		5.11
Means	125.67	65.33	
LSD $_{0.05}$	10.04		

Number of pods

Table (4) shows that there are significant differences between the densities of plants and genotypes and the interaction between them in the number of pods. The low density (80 thousand plants ha^{-1}) excelled in giving its plants the highest number of pods of 17.11 plant pod^{-1}, while the high-density plants (160 thousand plants ha^{-1}) gave the lowest number of pods was 10.89 plant pod^{-1}. The reason for the superiority of low plant density in terms of the number of pods is that, the plants with this density excelled by giving them the highest number of branches, which amounted to 6.67 branches of plant^{-1} (Table 2), and thus the number of pods increased. The total number of plants, and this is consistent with what was found by (7), who found that the highest number of pods (13.09 plant pod^{-1}) was at the low density (55.55 thousand plants ha^{-1}).

Table (4) also shows that the genotypes differed significantly, and the local genotype excelled in giving its plants the highest mean number of pods, amounting to 15.67 pods per plant, while the Spanish genotype gave the lowest number of pods, amounting to 13.00 pods per plant, and did not differ significantly from the Italian genotype, which it gave a mean number of pods of 13.33 plant pod^{-1}. The reason for the difference between genotypes in the number of pods is due to the genetic nature, which is reflected in the extent to which the genotypes respond to the plant density and environmental conditions surrounding them and the extent to which the genotypes benefit from them, and this is consistent with what (7) found. Who found significant differences between genotypes in the number of pods.

The table shows that the interaction was significant between the genotypes and plant densities, and that the interaction treatment between the Italian genotype and the low plant density achieved the highest number of pods, reaching 19.00 plant pod^{-1}, and the combination between the local genotype and the low plant density did not differ significantly from it, with the number of pods reaching 18.00 plant pod^{-1}. While the lowest number of pods was for the interaction treatment between the Italian genotype and the high density, with a mean of 7.67 plant pod^{-1}.

ISSN 2072-3857

Table 4. Response of number of pods (pod plant^{-1}) for genotypes of fababean for two plant densities for winter season 2023-2024.

genotypes	plant density (thousand plants ha^{-1})		Means
	80	160	
local genotype	18.00	13.33	15.67
Italian genotype	19.00	7.67	13.33
Spanish genotype	14.33	11.67	13.00
LSD $_{0.05}$	1.83		1.29
Means	17.11	10.89	
LSD $_{0.05}$	2.53		

Pod wet weight

Table (5) shows that there are significant differences between plant densities and genotypes and the interaction between them in traits of the pod wet weight. The low density was superior in giving its plants the highest pod wet weight of 513.3 gm, while the high-density plants gave the lowest pod wet weight of 323.7. gm, the reason why low plant density is superior to the wet weight of pods is because the plants of this density excelled by having the highest number of branches (Table 2) and thus the total weight of pods of the plant increased. This result is consistent with what (6) found when He studied two plant densities and found that the low density gave the highest yield of green pods (9.99 tons ha^{-1}).

Table (5) also shows that the genotypes differed significantly, and the local genotype excelled in giving its plants the highest mean pod wet weight of 457.5 g, while the Italian genotype gave the lowest pod wet weight of 361.3 gm, and did not differ significantly from the Spanish genotype, which gave a mean of pod wet weight reached 436.7 gm. The reason for the difference between genotypes in the wet weight of the pods of a single plant is due to the genetic nature, which is reflected in the extent of the response of the genotypes to the plant density and the surrounding environmental conditions. This result is consistent with what was found by (6), who found that the weight of wet pods varied depending on the cultivars.

The table shows that the interaction was significant between the genotypes and plant densities, and that the interaction treatment between the Spanish genotype and the low plant density achieved the highest wet pod weight of 540.0 gm, and the combination between the local genotype and the low plant density did not differ significantly from it, with a wet pod weight of 530.0 g, while it was less weight of the wet pods for the interaction treatment between the Italian genotype and the high density, with a mean weight of the wet pods reaching 252.7 grams.

ISSN 2072-3857

Table 5. Response of pod wet weight(g) for genotypes of fababean for two plant densities for winter season 2023-2024.

genotypes	plant density (thousand plants ha^{-1})		Means
	80	160	
local genotype	530.0	385.0	457.5
Italian genotype	470.0	252.7	361.3
Spanish genotype	540.0	333.3	436.7
LSD $_{0.05}$	10.40		7.35
Means	513.3	323.7	
LSD $_{0.05}$	16.62		

Pod length

Table (6) shows that there are significant differences between the genotypes, and there are no significant differences between plant densities and the interaction between them and the genotypes in this trait. although the high density (160 thousand plants ha-1) gave its plants the highest mean pod length of 20.67. cm, but this value did not differ significantly from the pod length in low density plants (19.56 cm).

Table (6) also shows that the genotypes differed significantly, and the Spanish genotype excelled in giving its plants the highest mean pod length of 21.00 cm. It did not differ significantly from the Italian genotype, which gave a mean pod length of 20.17 cm, while the local genotype gave its plants the lowest mean pod length of 19.17 cm. Also, it did not differ significantly from the Italian genotype. The reason for the difference between the genotypes in the trait of pod length is due to the genetic nature, which is reflected in the extent to which the genotypes respond to the plant density and environmental conditions and the extent to which the genotype benefits from them. This is consistent with what was found by (6) who found a difference between the genotypes in this trait, and the Hama 1 genotype was superior in terms of the highest pod length (13.5 cm).

The table shows that the interaction was not significant between genotypes and plant densities.

ISSN 2072-3857

Table 6. Response of pod length (cm) for genotypes of fababean for two plant densities for winter season 2023-2024.

genotypes	plant density (thousand plants ha^{-1})		Means
	80	160	
local genotype	18.33	20.00	19.17
Italian genotype	20.33	20.00	20.17
Spanish genotype	20.00	22.00	21.00
LSD $_{0.05}$	N.S		1.19
Means	19.56	20.67	
LSD $_{0.05}$	N.S		

Number of pod seeds

Table (7) shows that there are differences between the genotypes, and the absence of significant differences between plant densities and the interaction between them and the genotypes trait in the number of pod seeds.

Table (7) shows that the genotypes differed significantly, and the Italian genotype excelled in giving its plants the highest mean number of pod seeds, amounting to 5.50 pod seeds^{-1}, while the local and Spanish genotypes gave the lowest number of pod seeds, amounting to 4.83 pod seeds^{-1} for both of them, and they did not differ significantly from each other. The reason for the difference between genotypes in the number of seed pods in the plant is due to the genetic nature, which is reflected in the extent to which the genotypes respond to the plant density and environmental conditions surrounding them and the extent to which the genotype benefits from them. This is consistent with what (7) found when they studied five genotypes. Genetics of beans (local, Spanish, Giza, Hama, Nubaria) and the Spanish genotype is superior to the highest mean in most traits. It also agrees with what was found by (13) who found a difference between the genotypes in terms of the number of seeds per pod.

The table shows that the interaction was not significant between genotypes and plant densities.

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Table 7. Response of number of pod seeds (seed pod^{-1}) for genotypes of fababean for two plant densities for winter season 2023-2024.

genotypes	plant density (thousand plants ha^{-1})		Means
	80	160	
local genotype	4.67	5.00	4.83
Italian genotype	5.67	5.33	5.50
Spanish genotype	5.33	4.33	4.83
LSD $_{0.05}$	N.S		0.59
Means	5.22	4.89	
LSD $_{0.05}$	N.S		

Dry weight of pods

Table (8) shows that there are significant differences between plant densities and genotypes and the interaction between them in the dry weight of pods. Low density excelled in giving its plants the highest mean dry weight of pods, amounting to 127.1 gm plant^{-1}, while high density plants gave the lowest mean dry weight of pods, amounting to 84.0 gm plant^{-1}. The reason for the superiority of low plant density in terms of dry weight of pods is that the plants of this density excelled by giving the highest number of branches (Table 2) and thus gave the highest total number of pods per plant, and this is consistent with what (7) found, also agrees with (17) who found that dry weight increased at low density.

The table also shows that the genotypes differed significantly, and the Spanish genotype excelled in giving its plants the highest mean dry weight of pods, amounting to 116.3 gm plant^{-1}. It did not differ significantly from the local genotype, which gave a mean dry weight of pods of 114.6 gm plant^{-1}, while the Italian genotype gave less, the dry weight of the dried pods reached 85.7 gm Plant^{-1}. The reason for the differences between the genotypes in the dry weight of the pods in the plant is due to the genetic nature, which is reflected in the extent of the response of the genotypes to the plant density and the genetic factors that characterize the genotype and the extent of its influence on environmental factors, as this characteristic is determined. Due to the genetic factor, with the limited influence of other growth factors, the reason for the superiority of the Spanish genotype in the dry weight of pods is also due to the superiority of this genotype in the characteristic of pod length (Table 6).

The table also shows that the interaction was significant between the genotypes and plant densities, and that the interaction treatment between the Spanish genotype and the low plant density achieved the highest dry weight of the pods, amounting to 146.1 gm plant^{-1}, while the lowest dry weight of the pods was for the interaction treatment between the Italian genotype and the high density, with a mean of 66.9 gm Plant^{-1}.

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Table 8. Response of dry weight of pods (g) for genotypes of fababean for two plant densities for winter season 2023-2024.

genotypes	plant density (thousand plants ha^{-1})		Means
	80	160	
local genotype	130.5	98.6	114.6
Italian genotype	104.5	66.9	85.7
Spanish genotype	146.1	86.5	116.3
LSD $_{0.05}$	10.1		7.11
Means	127.1	84.0	
LSD $_{0.05}$	8.6		

Weight of 10 seeds

Table (9) shows that there are significant differences between the genotypes in seed weight, and there are no significant differences between plant densities and the interaction between them and the genotypes.

Table (9) shows that the genotypes differed significantly, and the Spanish genotype excelled in giving its plants the highest mean weight of 10 seeds, reached 15.67 grams, followed by the local genotype, which gave a mean weight of 10 seeds, amounting to 13.60 grams per plant, while the Italian genotype gave the lowest mean weight of 10 seeds, amounting to 11.05 grams. The reason for the superiority of the Spanish genotype in seed weight is that it gave the highest number of branches (Table 2), the highest number of leaves (Table 3), the highest pod length (Table 6), and the highest dry weight of pods (Table 8). This is consistent with what (13) found who found a difference between the genotypes in the weight of 100 seeds, and the local genotype was superior with the highest weight reaching 180.00 grams.

The table shows that the interaction was not significant between genotypes and plant densities.

Table 9. Response of weight of 10 seeds (g) for genotypes of fababean for two plant densities for winter season 2023-2024.

genotypes	plant density (thousand plants ha^{-1})		Means
	80	160	
local genotype	13.47	13.72	13.60
Italian genotype	10.61	11.49	11.05
Spanish genotype	15.90	15.44	15.67
LSD $_{0.05}$	N.S		0.82
Means	13.33	13.55	
LSD $_{0.05}$	N.S		

plant yield (g)

Table (10) shows that there are significant differences between plant densities and genotypes and the interaction between them in trait of single plant yield. Low density excelled in giving its plants the highest mean single plant yield of 105.0 gm plant^{-1}, while high density plants gave the lowest mean single plant yield. It reached 71.7 gm plant^{-1}. The reason for the superiority of low plant density in terms of individual plant yield is that the plants of this density excelled by giving the highest number of branches (Table 2) and the highest number of leaves that represent the source (Table 3), and thus gave the highest number of plant pods (Table 4) Also the highest dry weight of pods (Table 8). This is consistent with what was found by (7) who found that the highest number of plant pods (plant yield) was at low density.

Table (10) also shows that the genotypes differed significantly, and the Spanish genotype excelled by giving its plants the highest mean yield of a single plant, reached 99.4 gm plant^{-1}, and it did not differ significantly from the local genotype, which gave a mean yield of a single plant, amounting to 95.1 gm plant^{-1}. The local genotype differs significantly from it with a yield of 95.1 gm plant^{-1}, while the Italian genotype gave the lowest yield per single plant of 70.5 gm plant^{-1}. The reason for the difference between the genotypes in the character of the yield of a single plant is due to the genetic nature of the genotype. Likewise, the reason for the superiority of the Spanish genotype is due to it gave the highest number of branches (Table 2), the highest number of leaves (Table 3), the highest pod length (Table 6), the highest dry weight of pods (Table 8), and the highest seed weight (Table 9). This is consistent with what (7) found.

The table also shows that the interaction was significant between the genotypes and plant densities, and that the interaction treatment between the Spanish genotype and the low plant density achieved the highest yield for the single plant, amounting to 124.6 gm plant^{-1}, while the lowest yield for the single plant was for the interaction treatment between the Italian genotype and the high density, with a mean of 58.9 gm Plant^{-1}.

Table 10. Response of plant yield (g) for genotypes of fababean for two plant densities for winter season 2023-2024.

genotypes	plant density (thousand plants ha^{-1})		Means
	80	160	
local genotype	108.4	81.9	95.1
Italian genotype	82.1	58.9	70.5
Spanish genotype	124.6	74.2	99.4
LSD $_{0.05}$	14.4		10.2
Means	105.0	71.7	
LSD $_{0.05}$	12.2		

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Yield per unit area (tons ha^{-1})

Table (11) shows that there are significant differences between plant densities and genotypes and the interaction between them in trait of unit area yield. The high density outperformed by giving its plants the highest mean unit area yield of 16.802 tons ha^{-1}. While low density plants gave the lowest mean yield per unit area, reached 8,401 tons ha^{-1}. The reason for the superiority of high plant density in yield per unit area is due to the increase in the number of plants per unit area, which compensates for regarding the decrease in the components of yield and individual plant yield, this result agreed with what was found by (7) who found that the highest yield per unit area was at high density (166.66 thousand plants ha^{-1}).

Table (11) also shows that the genotypes differed significantly, and the Spanish genotype excelled by giving its plants the highest mean yield per unit area of 14,950 tons ha^{-1}, followed by the local genotype, which gave a mean yield per unit area of 13,004 tons ha^{-1}, while the Italian genotype gave the lowest yield reached 9,851 tons ha^{-1}. The reason for the difference between the genotypes in the characteristic of the yield per unit area of the plant is due to the genetic nature of the genotype, and that the Spanish genotype was more adapted to the prevailing environmental conditions than the rest of the genotypes, as well as to its superiority in the components of the yield for the two characteristics of pod length (Table 6) and seed weight. (Table 9) This result agreed with what was found by (7), who found that the highest yield per unit area (8.55 tons ha^{-1}) was for the Spanish genotype.

The table shows that the interaction was significant between the genotypes and plant densities, and that the interaction treatment between the Spanish genotype and the high plant density achieved the highest yield per unit area of 19.933 tons ha^{-1}, while the lowest yield per unit area was for the interaction treatment between the Italian genotype and the low density, with a mean yield of 6,567 tons ha^{-1}.

Table 11. Response of yield per unit area (tons ha^{-1}) for genotypes of fababean for two plant densities for winter season 2023-2024.

Varieties	plant density (thousand plants ha^{-1})		Means
	80	160	
local genotype	8.669	17.339	13.004
Italian genotype	6.567	13.134	9.851
Spanish genotype	9.967	19.933	14.950
LSD $_{0.05}$	0.161		0.114
Means	8.401	16.802	
LSD $_{0.05}$	0.731		

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Some genetic parameters for the traits studied at the density 80 thousand plants ha^{-1}

Table (12) shows some genetic parameters for the traits studied at the first density, shows that the values of the coefficient of variation (CV) for all the traits studied were low and less than 10, and this is evidence of the homogeneity of the samples for the traits studied. These values are statistically acceptable.

The same table (12) shows that the values of genetic variance for all studied traits were higher than the environmental variance, with the exception of the trait number of pod seeds, for which the environmental variance was higher than the genetic variance. This means that the percentage of genetic variance lower than the environmental variance amounted to 39.29%, the percentage of genetic variance from Phenotypic variance (inheritance in the broad sense) is high in the traits of plant height, number of branches, number of leaves, number of pods, pod length, number of pod seeds, weight of wet and dry pods, individual plant yield, weight of 10 seeds, and unit area yield. Selection for the trait of number of pod seeds is difficult because it is greatly affected by the environment.

The values of the genetic coefficient of variation (GCV) were very close to the values of the phenotypic coefficient of variation (PCV) for the traits whose genetic variation was higher than the environmental one. This is evidence that the phenotypic variation was more than the genetic variation and that these traits are governed by genes (inheritance) in their transmission from generation to generation. To another, the influence of the environment is small. As for the trait of the number of seeds of the pod, the environmental variation of which was greater than the genetic variation, the coefficient of genetic variation in it was far from the coefficient of phenotypic variation, and thus this trait is governed by the environment, and the heritability percentage in the broad sense of this trait was low, amounting to 38. %. As for the rest of the traits (plant height, number of branches, number of leaves, number of pods, pod length, number of pod seeds, wet and dry weight of pods, plant yield, weight of 10 seeds, and quotient per unit area), the heritability in the broad sense was high, reaching 99%, 87%, 96%, 88%, 61%, 96%, 98%, and 99%. 99 and 99%, respectively, which indicates the possibility of improving these traits through selection for their high genetic variation. These results are consistent with the results of (13) who found that most of the traits were genetically controlled and the heritability rates in the broad sense were high, reaching 98 and 99. 85, 70, 87, 99, and 83% for the traits of plant height, number of leaves, dry weight, weight of plant pods, number of seeds, pod length, and seed yield, respectively. It also agrees with the results of (2), who studied some genetic parameters of beans, and found that the genetic variance is higher than the environmental variance for all the traits studied. Therefore, heritability in the broad sense was high for all traits (plant height, number of branches, number of leaves, number of pods, pod length, number of seeds in the pod, weight of 100 seeds, dry weight, and seed yield) reaching 96%, 95%, 99%, 70%, 94%, 88. %, 97%, 84% respectively

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Table 12. Some genetic parameters for the studied traits of Faba bean genotypes at density of 80 thousand plants ha^{-1} for the winter season 2023-2024.

Characteristics	$\bar{x}$	C.V	$\sigma^2 p$	$\sigma^2 g$	$\sigma^2 e$	P.C.V	G.C.V	h^2.b.s
Plant height	104.67	1.46	344.55	342.22	2.33	17.73	17.67	0.99
Number of branches	6.78	4.84	2.61	2.28	0.33	22.27	23.83	0.87
Number of leaves	125.67	2.47	262.89	253.22	9.67	12.90	12.66	0.96
Number of pods	17.11	5.15	6.56	5.78	0.78	14.96	14.05	0.88
Length of pod	19.56	4.00	1.56	0.94	0.61	6.38	4.97	0.61
Number of seeds in pods	5.22	10.09	0.44	0.17	0.28	12.77	7.82	0.38
Wet weight of pods	513.3	1.49	1472.22	1413.8	58.33	7.47	7.33	0.96
Dry weight of pods	127.1	2.49	448.05	438.04	10.01	16.66	16.47	0.98
Plant yield	105.0	0.64	460.16	459.70	0.45	20.43	20.42	0.99
Weight of 10 seeds	13.33	0.96	7.04	7.02	0.01	19.91	19.89	0.99
Yield tons ha^{-1}	8.40	0.64	2.94	2.94	0.00	20.43	20.42	0.99

Some genetic parameters for the studied traits at a density 160 thousand plants ha^{-1}

Table (13) shows some genetic parameters for the studied traits at high density, and shows that the coefficient of variation (CV) values for most of the studied traits were low and less than 10, and this is evidence of the homogeneity of the samples for the studied traits. These values are statistically acceptable, with the exception of the individual plant yield trait, for which the coefficient of variation was 15.07%, which is also statistically acceptable.

The same table shows that the values of genetic variation for most of the studied traits were higher than the environmental variation, with the exception of the individual plant yield trait. The values of environmental variation were higher than the genetic variation. This means that the percentage of decrease in genetic variation over the environment amounted to 41.27%, and the percentage of genetic variation was phenotypic variation is large in the traits of plant height, number of leaves, number of pods, number of pod seeds, number of pod seeds, weight of wet and dry pods, weight of 10 seeds, and yield per unit area. Selection for the trait of individual plant yield is difficult because it is greatly affected by the environment.

The values of the genetic coefficient of variation (GCV) were very close to the values of the phenotypic coefficient of variation (PCV) for the traits whose genetic variation was higher than the environmental one. This is evidence that the phenotypic variation was more than the genetic variation and that these traits are governed by genes (inheritance) in their transmission from generation to generation. To another, the influence of the environment is small. As for the individual plant yield trait, the environmental variation of which was greater than the genetic variation, the coefficient of genetic variation in it was far from the coefficient of phenotypic variation, and thus this trait is governed by the environment, and the percentage of heritability in the broad sense of this trait was low, amounting to 46%. As for the rest of the traits (plant height, number of leaves, number of pods, number of pod seeds, wet and dry weight of pods, weight of 10 seeds, and unit area), the heritability in the broad sense was high, reaching 99%, 89%, 88%, 67%, 99%, 84%, 83%, and 93%, respectively, which indicates the possibility of improving these traits. The traits were selected through selection because they had high genetic variation. As for the traits of number of branches and pod length, the heritability was on average at 50% for both of them, which means that their genetic variation is completely equal to their environmental variation. These results are consistent with the results of (4). as well the results of (13) agree, who found that most traits were genetically controlled, and the rates of heritability in the broad sense were high, reaching 98%, 99%, 85%, 70%, 87%, 99%, and 83% for the traits of plant height, number of leaves, dry weight, weight of plant pods, number of seeds, pod length, and seed yield respectively, it also agrees with (9) who found that genetic variation is higher than environmental variation for most of the traits studied.

Table 13. Some genetic parameters for the studied traits of Faba bean genotypes **at density of 160 thousand plants ha^{-1} for the winter season 2023-2024.**

Characteristics	$\bar{x}$	C.V	$\sigma^2 p$	$\sigma^2 g$	$\sigma^2 e$	P.C.V	G.C.V	h^2.b.s
Plant height	110.33	0.82	97.33	96.50	0.83	8.94	8.90	0.99
Number of branches	3.67	15.75	0.66	0.33	0.33	22.27	15.75	0.50
Number of leaves	65.33	6.61	167.56	148.89	18.67	19.81	18.68	0.89
Number of pods	10.89	9.68	9.22	8.11	1.11	27.89	26.16	0.88
Length of pod	20.67	4.84	2.00	1.00	1.00	6.84	4.84	0.50
Number of seeds in pods	4.89	6.82	0.33	0.22	0.11	11.81	9.64	0.67
Wet weight of pods	323.7	0.50	4449.89	4447.22	2.67	2.61	20.60	0.99
Dry weight of pods	84.0	8.16	287.71	240.71	47.00	20.18	18.46	0.84
Plant yield	71.7	15.07	214.56	97.89	166.67	20.44	13.80	0.46
Weight of 10 seeds	13.55	6.37	4.431	3.69	0.74	15.54	14.17	0.83
Yield tons ha^{-1}	16.80	2.99	4.56	4.22	0.33	11.04	10.63	0.93

Conclusion

We note that there are significant differences between plant densities. The low-density excelled in most of the traits studied, but the high density excelled by giving its plants the highest mean yield per unit area due to the increase in the number of plants per unit area and compensating for the deficiency in the individual plant yield. The genotypes also differed significantly, and the Spanish genotype excelled by giving its plants the highest mean for the yield per unit area, followed by the local genotype, and the Spanish genotype excelled because of its superiority in yield components such as pod length and seed weight. We also note that the values of genetic variation for most of the studied traits it was higher than environmental variation at both plant densities, and broad sense heritability was high for most traits and

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at low and high plant densities, which indicates the possibility of improving these traits through selection because they have high genetic variation

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