Evaluation of the performance of some cultivars of Faba Bean *Vicia faba* L. under different levels of phosphorus

Ali Hussein Alwan Algraishi[1*] , Faez Fayad Mohammed Alogaidi[2]

[1] Directorate of Agriculture, Wassit, Iraq
[2]Department of Field crops, College of Agricultural engineering Sciences, University of Baghdad, Baghdad, Iraq
***Corresponding author email:** ali.hussein1206a@coagri.uobaghdad.edu.iq

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Abstract

A field experiment was carried out during winter season of 2021-2022 to study growth and yield performance of four faba bean cultivars (lo-cal, Spanish, Dutch and New Zealand) and evaluate their performance under three levels of phosphorus fertilizer (80, 120 and 160 kg ha-1). The experiment was applied in split plot design with three replications. results showed highly significant effects of fertilization on all measured traits, as the third level (160 kg ha-1) superior in all measured traits, and gave plant dry weight (171.33 g) and seed yield (4.403 Mg ha-1). local cultivar was superior in traits: plant height, total phosphorus content, phosphorus use efficiency and plant dry weight. As for New Zealand cultivar excelled in: number of branches, number of leaves, and phosphorus concentration in shoot. while Spanish cultivar was superior in total seed yield (5.295 Mg ha-1).

Keywords: phosphorus, fertilization levels, faba bean Cultivars, growth and yield.

Introduction

Faba bean *Vicia faba* L. is one of the important and basic food crops for millions of people in poor countries because it contains a high percentage of protein, and is grown in many countries of the world, including China, which is one of the largest countries in the production and consumption of faba beans [1]. Faba bean crop is cultivated for the purpose of obtaining green pods or fresh or dry seeds, in addition to its use as animal fodder. It is also included in the crop rotation with the aim of improving soil qualities. The total production of this crop in Iraq reached 9190 tons of dry and green beans for the year 2020 [2], but this crop in Iraq suffers from a low productivity as a result of deterioration of the genotypes of the local cultivar and the possibly of environmental adaptation of the introduced cultivars. Cultivars vary in their genetic and physiological structure, which makes them differ in growth behavior and productivity depending on the prevailing environmental conditions and the nature of the crop and soil managements [3], and among the important fertilizers is phosphorus fertilizer, which contributes and plays a regulatory role in physiological processes of growth and works to increase branching and spread of roots and increases the maturity of plant and improves the quality of the agricultural yield [4], so the aims were the possibility of improving the performance of faba bean crop by evaluating cultivars in growth and yield under different levels of phosphorus , as well as knowing which of them more efficient in utilizing the absorbed phosphorus .

Materials and Methods

A field experiment was carried out in the experimental field of Field Crops Department - College of Agricultural Engineering Sciences - University of Baghdad - Al-Jadriya, located within 44° east longitude and 33° north latitude, during the winter season of 2021-2022 in order to evaluate the performance of four cultivars of faba bean crop *Vicia faba* L. under four treatments (0, 80, 120 and 160 kg ha^{-1}), that referred to as T0, T1, T2, and T3 in this study in growth traits and yield. The experiment was carried out in split plot design with three replications where fertilizing levels of phosphorus were randomly assigned in main plots, while four cultivars of faba bean crop (local, Spanish, Dutch and New Zealand) were distributed randomly in sub-plots. Soil service operations were carried out from plowing, smoothing and leveling, then the experimental land was divided into experimental units with an area of 6 m^2 with dimensions (2 x 3) m, which contained 5 lines with a length of 2 m and the distance between one line and another was 70 cm, while the distance between one plant and another was 20 cm. The seeds of faba bean cultivars were sown on 17/11/2021 at a depth of 5 cm, with 2 seeds per hole, which thinned out to one plant after two weeks of planting, so the plant density accounted for 71,428 plants per hectare. The experiment field was fertilized with nitrogen fertilizer in the form of urea (46% nitrogen) with an amount of 150 kg N ha^{-l} in two times, the first after 45 days of planting and the second after 75 days of planting [5], and triple superphosphate fertilizer was added at once before planting in three levels of fertilization in addition to the control treatment (without fertilization). Weeding and the rest of the field managements were done whenever needed. The plants were harvested when the plants reached the stage of full maturity on 12/4/2022. The traits measured were plant height (cm) and number of branches (plant $branch^{-1}$), number of leaves (leaf $plant^{-1}$), concentration of phosphorus in the shoot (mg g^{-1}), total phosphorus content in the shoot (mg), phosphorus use efficiency (PUE), the dry weight of plant (g) and total seed yield. the data was statistically analyzed using the GenStat program, and the least significant difference (L.S.D) test was used to compare the means at the 0.05 probability level.

Total phosphorus in shoot and phosphorus use efficiency were calculated according the following equations:

Total phosphorus in shoot = (phosphorus concentration in shoot (mg g^{-1}) x shoots dry weight (g))

Phosphorus use efficiency (PUE) = [shoot dry weight (g) / total phosphorus in shoot (mg)]

Results and Discussion

Plant height (cm)

The results in Table 1 and Table 2 showed a significant effect of phosphorus fertilizer treatments (P=0.019) as well as cultivars (P<0.001). as the fertilization level (160 kg h^{-1}) achieved the highest mean of plant height (97.83 cm), with a significant increase of 11.07%, compared to the control treatment, which gave the lowest mean of plant height (88.08 cm). The reason for the increase in plant height may be due to the role of phosphorus in the growth and development of roots, which helps to distribute and spread the root and thereby increase their absorption of nutrients [6], Phosphorus also plays an important role in photosynthesis [7] and plant cell division [8] and this is reflected in plant growth and thus increasing plant height. These results are in agreement with [9,10 and 11], who indicated in their study that there is a significant effect of fertilization levels on plant height of faba bean yield.

Dutch cultivar was the most responsive to phosphorus fertilization, as it recorded the highest percentage of plant height at the fertilizer level of 160 kg ha^{-1}, which reached 15.92% compared to the control treatment, while the Spanish cultivar showed the least responsiveness to phosphorus fertilization, as it recorded at the fertilizer level 160 kg ha^{-1} a percentage of an increase of 7.79% compared to the control treatment.

Table (1): Analysis of variance according to means of squares (M.S) for the effect of phosphorus fertilization and cultivars and the interaction between experiment factors on the studied traits

S.O.V	d.f	Plant height (cm)	Number of branches in plant	number of leaves in plant	Phosphorus concentration in shoot
Replicates	2	18.52	0.670	224.02	0.02771
fertilizer treatment	3	213.91*	11.574	3996.80**	0.30965**
error	6	28.66	3.474	112.97	0.00965
Cultivars	3	1914.41**	62.183**	38256.24**	1.05076**
Cultivars × fertilizer treatment	9	22.74	1.168	387.35**	0.05243
error	24	19.68	1.173	43.87	0.05139
S.O.V	**d.f**	**Total phosphorus content in shoot**	**phosphorus use efficiency (PUE)**	**Plant Dry Weight (g)**	**total seed yield**
Replicates	2	1794	0.001702	51.44	0.8652
fertilizer treatment	3	63344**	0.012508**	4874.50**	3.0183**
first error	6	178	0.000224	17.94	0.2311
Cultivars	3	24637**	0.040002**	2897.56**	22.8124**
Cultivars × fertilizer treatment	9	3383*	0.003443*	688.39**	0.1223
second error	24	1363	0.001424	24.03	0.5837

**Significant at *P*=0.01. * Significant at *P*=0.05.

Table (2): Response of faba bean cultivar to levels of phosphorus fertilization in plant height trait (cm)

Cultivars	Phosphorus (P2O5) fertilization levels kg h^{-1}				mean
	T0	T1	T2	T3	
Local	101.33	102.33	110.33	112.33	106.58

Spanish	72.67	75.00	77.67	78.33	75.92
Dutch	90.00	91.00	93.00	104.33	94.58
New Zealand	88.33	94.33	95.00	96.33	93.50
LSD	**n.s**				**3.74**
mean	88.08	90.67	94.00	97.83	
LSD	**5.35**				

As for the effect of cultivars, the results indicate a significant difference between them, due to genetic differences between cultivars, as the local cultivar recorded the highest mean plant height of 106.58 cm, while the Spanish cultivar achieved the lowest mean plant height of 75.92 cm. The local cultivar has the genetic and physiological ability to take advantage of local conditions to achieve the highest plant height. There was no significant interaction between two factors.

Number of branches (branch plant^{-1})

It is clear from the results presented in Table (1) and Table (3) that number of branches was significantly affected by cultivars (P<0.001), as New Zealand cultivar gave the highest mean number of branches per plant reached 11.38 branch plant $^{-1}$, while the Spanish cultivar gave the lowest mean number of branches per plant, which reached 6.23 branch plant $^{-1}$, and it did not differ significantly from both the local and the Dutch cultivars in this trait. This difference between the cultivars is due to difference in the nature of genetic structure between cultivars, and this is consistent with what was found by [12 and 13] who indicated in their study that there is a significant difference between cultivars in the number of branching of faba bean plants.

Table (3): Response of faba bean cultivar to levels of phosphorus fertilization in the trait of number of branches per plant (branche Plant^{-1})

Cultivars	Phosphorus (P2O5) fertilization levels kg ha^{-1}				mean
	T0	T1	T2	T3	
Local	6.80	7.27	8.20	8.13	7.60
Spanish	5.53	5.80	6.60	7.00	6.23
Dutch	5.87	7.13	7.47	7.87	7.09
New Zealand	9.07	11.33	11.60	13.53	11.38
LSD	**n.s**				**0.91**
mean	6.82	7.88	8.47	9.13	
LSD	**n.s**				

This trait was not affected by the treatments of phosphorus fertilizer, and this does not agree with what was found by [14, 9 and 10] who indicated that there are significant differences between fertilization levels in the number of branches of faba bean plants. The interaction between phosphorus treatments and cultivars was not significant in this trait as well.

Number of leaves per plant (leaf plant^{-1})

The results of Table 4 and analysis of variance presented in Table (1) indicate that there is a significant effect of phosphorus fertilizer treatments (P<0.001) and cultivars (P<0.001), as well as the interaction (P<0.001) between in this trait. The levels of phosphorus 80, 120 and 160 kg ha^{-1}showed a significant increase in the mean number of leaves, which reached14.24%, 25.58% and 33.49%, compared to the control treatment respectively. The reason of this increase in the number of leaves may be due to phosphorus role in increasing vital activities and increase the division and growth of meristematic cells. This result is consistent with what was stated by [15].

As for the effect of cultivars, the results presented in Table 4 indicate that there are significant differences (P<0.001) in this trait due to the effect of cultivars, as New Zealand cultivar recorded the highest mean number of leaves per plant reached 229.15 leaf per plant, while the Spanish cultivar recorded the lowest mean for this trait reached 98.00 leaf per plant. This increase in the number of leaves in New Zealand cultivar was a reflect of the increase in the number of branches of this cultivar (Table 3).

Table (4): Response of faba bean cultivar to levels of phosphorus fertilization in the trait of number of leaves per plant (Leaf plant^{-1})

Cultivars	Phosphorus (P2O5) fertilization levels kg ha^{-1}				mean
	T0	T1	T2	T3	
Local	119.30	127.70	147.70	158.70	138.35
Spanish	85.00	91.70	107.00	108.30	98.00
Dutch	115.30	118.00	134.30	146.00	128.40
New Zealand	182.30	236.00	241.30	257.00	229.15
LSD	**13.28**				**5.58**
mean	125.48	143.35	157.58	167.50	
LSD	**10.62**				

The response of the cultivars to the phosphorus fertilizer was varied, as New Zealand cultivar achieved at the fertilizer level of 160 kg ha-1 the highest increase in the number of leaves reached 40.98%, and Dutch cultivar had the lowest response rate of 26.63% compared to the control treatment. These different responses to genotypes and their different behavior under the influence of fertilizer treatments led to a significant interaction (P<0.001) between the two factors (phosphorus fertilizer treatments x cultivars), as the New Zealand cultivar with 160 kg ha^{-1} gave the highest mean number of leaves in the plant 257 leaves per plant, which differed significantly from the control treatment and other fertilizer levels as well as the rest of the other cultivars at the same fertilizer level, while the Spanish cultivar with the control treatment gave the lowest mean number of leaves per plant reached 85 leaves per plant.

Phosphorus concentration in the shoot (mg g^{-1})

Results of the analysis of variance Table 1 and Table 5 showed a significant effect of phosphorus fertilizer treatments (P<0.001) as well as cultivars (P<0.001), as the fertilization level 160 kg ha^{-1}gave the highest mean for the trait 2,650 mg g^{-1} and an increase of 17.72%, 36.67% and 59.63% compared to the fertilization levels of 120 kg ha^{-1}, 80 kg ha^{-1}, and control treatment which gave the lowest mean for the trait reached

2.275 mg g^{-1} respectively. The reason for this increase may be due to the increase in phosphorus availability in the rhizosphere of the roots as a result of phosphorus addition, which led to an increase in its uptake by the plant. This result is consistent with [16].

regarding the effect of the cultivars, the results of the same Table indicate that there are significant differences in the phosphorus concentration between the cultivars, as New Zealand cultivar achieved the highest mean amounting to 2.725 mg g^{-1} with a significant increase of 31.83%, 9.35% and 2.52% compared to the Spanish, local and Dutch cultivar respectively. The reason for this may be attributed to the nature of genetic structure of the cultivars and the cultivar variation in absorption of phosphorus .

Table (5): Response of faba bean cultivar to levels of phosphorus fertilization on phosphorus concentration in shoot (mg g^{-1})

Cultivars	Phosphorus (P2O5) fertilization levels kg ha^{-1}				mean
	T0	T1	T2	T3	
Local	2.300	2.300	2.600	2.767	2.492
Spanish	1.667	2.133	2.233	2.233	2.067
Dutch	2.533	2.733	2.700	2.667	2.658
New Zealand	2.600	2.667	2.700	2.933	2.725
LSD	**n.s**				**0.01**
mean	2.275	2.458	2.558	2.650	
LSD	**0.01**				

Cultivar response to levels of phosphorus fertilizer added to the soil differed, as Spanish cultivar excelled in recording the highest response to the added phosphorus. New Zealand and the Dutch had a response of 20.30%, 12.81% and 5.29% compared to the control treatment. The Spanish cultivar was the most capable of absorbing phosphorus added to the soil. There was no significant interaction in this trait between cultivars and phosphorus fertilization treatment.

Total phosphorus content in the shoot (mg $plant^{-1}$)

Results presented in Table 6 and Table 1 indicate that there is a significant effect of phosphorus fertilizer treatments ($P<0.001$) and cultivars ($P<0.001$), as well as the interaction ($P=0.036$) between phosphorus treatments and cultivars in this trait. Fertilization level of 160 kg ha^{-1}had the highest mean for the trait reached 452.825 mg, with an increase of 17.72%, 36.76% and 59.63% compared to treatment of the fertilization levels 120 kg ha^{-1}, 80 kg ha^{-1} and the control treatment that gave the lowest mean for the trait reached 283.675 respectively. The reason for the increase in phosphorus content with an increase in the level of phosphorus fertilizer may be attributed to the role of phosphorus fertilizer in improving plant growth and increasing yield. The results shown in the traits plant height (Tables 2), number of branches (Tables 3) and number of leaves (Tables 4)were reflected in the total phosphorus content in the shoot.

Table (6): Response of faba bean cultivar to levels of phosphorus fertilization on the trait of total phosphorus content in shoot (mg)

Cultivars	Phosphorus (P2O5) fertilization levels kg ha^{-1}				mean
	T0	T1	T2	T3	
Local	370.700	381.700	436.000	478.700	416.775
Spanish	188.300	299.300	354.700	385.000	306.825
Dutch	300.000	341.300	344.000	502.300	371.900
New Zealand	275.700	303.000	404.000	445.300	357.000
LSD	**54.82**				**31.10**
mean	283.675	331.325	384.675	452.825	
LSD	**13.31**				

The results shown in Table 6 showed a significant effect of the cultivars on the total phosphorus content of the shoot, as the local cultivar recorded the highest mean for the trait amounting to 416.775 mg $shoot^{-1}$ with a significant increase of 12.07%, 16.74% and 35.83% compared to Dutch, New Zealand and Spanish cultivars respectively. The lowest mean for the trait was recorded by Spanish cultivar 306.825 milligrams. The reason for this may be attributed to the differences between cultivars in their genotypes, the nature of their growth and mechanisms that can be exploited to enhance efficiency of phosphorus acquisition by plant [17]. One of these mechanisms is to modify the spread of roots and increase root secretions or increase the growth of root hairs [18]. Cultivars varied in their response to phosphorus added to the soil in this study, as Spanish cultivar excelled in recording the highest response to added phosphorus. The plant's grown at the fertilizer level 160 kg ha^{-1} achieved an increase of 104.46% compared to the control treatment, while Dutch, New Zealand and local cultivars achieved an increase of 67.43%, 61.52% and 29.13% compared to the control treatment. This difference in behavior of the cultivars in their response to the levels of phosphorus added to the soil led to a significant interaction between the two factors of the study (phosphorus levels and cultivars), as the Dutch cultivar with the level of 160 kg ha^{-1} had the highest mean for phosphorus content reached 502.33 mg $shoot^{-1}$, while Spanish cultivar with control treatment gave the lowest mean for the phosphorus content reached188.33 mg $shoot^{-1}$.

Phosphorus use efficiency

The results presented in Table 1 and Table 7 indicate that there are significant differences between phosphorus levels ($P<0.001$) and cultivars ($P<0.001$) and the interaction ($P=0.041$) between Two factors in this trait, as the control treatment gave the highest mean of the trait 0.456 with a significant increase of 19.37%, 15.44% and 10.68% compared to the levels of fertilization 160, 120 and 80 kg ha^{-1}, respectively. As for the effect of cultivars, there was significant difference due to cultivars, as Spanish cultivar recorded the highest mean of the trait amounting to 0.494, with a significant increase of 21.67%, 31.38% and 34.24% compared to local, Dutch and New Zealand cultivars respectively. The reason for this may be due to the highest phosphorus concentration in the shoot that recorded by Spanish cultivar under fertilization level of 160 kg ha^{-1} (Table 5), and this cultivar also gave the highest significant increase under the same fertilization level in the total phosphorus content trait (Table 6).

Table (7). Response of faba bean cultivar to levels of phosphorus fertilization in, phosphorus use efficiency trait

Cultivars	Phosphorus (P2O5) fertilization levels kg ha^{-1}				mean
	T0	T1	T2	T3	
Local	0.437	0.437	0.387	0.363	0.406
Spanish	0.607	0.470	0.450	0.450	0.494
Dutch	0.393	0.367	0.370	0.373	0.376
New Zealand	0.387	0.373	0.373	0.340	0.368
LSD	**0.06**				0.03
mean	0.456	0.412	0.395	0.382	
LSD	**0.01**				

There was a significant interaction between the two factors, as Spanish cultivar with the control treatment recorded the highest mean for the trait, that reached 0.607. While New Zealand cultivar with fertilization level of 160 kg ha^{-1} gave the lowest mean reached 0.340.

Plant Dry Weight (gm)

The results of analysis of variance presented in Table (1) and Table (8) indicate that there is a significant effect of phosphorus fertilizer treatments (P<0.001) and cultivars (P<0.001). The interaction between phosphorus treatments and cultivars was significant (P<0.001) in this trait. Effects of phosphorus fertilizer levels on plant height (Table 2), number of branches (Table 3) and number of leaves (Table 4) reflected on the dry weight of the plant, as the fertilizer level 160 kg ha^{-1} achieved an increase of 13.59%, 25.75% and 37.53% compared to fertilizer levels 120 kg ha^{-1}, 80 kg ha^{-1} and the control treatment that gave the lowest mean for the trait reached124.58 g plant^{-1} respectively.

The reason for the increase may be attributed to the role of phosphorus in improving growth and consequently increasing the dry matter yield accumulated in the plant [19]. This result is consistent with [14 and 9], who indicated in their studies that there were differences between phosphorus treatments in dry weight of the plant of faba bean plants.

Table (8): Response of faba bean cultivar to levels of phosphorus fertilization in plant dry weight (gm)

Cultivars	Phosphorus (P2O5) fertilization levels kg ha^{-1}				mean
	T0	T1	T2	T3	
Local	161.00	166.00	167.67	173.00	166.92
Spanish	112.67	140.33	159.00	172.33	146.08
Dutch	118.33	125.00	127.33	188.33	139.75
New Zealand	106.33	113.67	149.33	151.67	130.25

LSD	**7.91**				**4.13**
mean	124.58	136.25	150.83	171.33	
LSD	**4.23**				

As for effect of cultivars, there were significant differences between cultivars. The results presented in Tables 2, 3, and 4 indicate the superiority of local cultivar in the traits: plant height, number of branches and number of leaves, that were reflected on the dry weight of plant. local cultivar achieved the highest mean dry weight amounting to 166.92 gm plant^{-1} with a significant increase of 14.27%, 19.44% and 28.15% compared to Spanish, Dutch and New Zealand cultivars, which achieved the lowest mean for this trait of 130.25 gm plant^{-1}, respectively. The reason for this may be attributed to the nature of the cultivars and the extent to which they vary in plant height, number of branches, and their adaptation to the prevailing environmental conditions, and the extent to which they exploit the available growth factors. This result agrees with [20 and 16].

The cultivars also differed in their response to the phosphorus fertilizer, as Dutch cultivar achieved at the fertilizer level 160 kg ha^{-1} the highest increase in dry weight of plant reached 59.16%, and the local cultivar had the lowest response of 7.45% compared to the control treatment. These different responses for the cultivars and their different behavior under the influence of different fertilizer treatments led to a significant interaction ($P<0.001$) between the two factors (phosphorus fertilizer treatments X cultivars), as Dutch cultivar with 160 kg ha^{-1} gave the highest mean dry weight plant^{-1} 188.55 g, which differed significantly from the control treatment and other fertilizer levels as well as significantly different from the rest of the other cultivars at the same fertilizer level (160 kg ha^{-1}), while the New Zealand cultivar with control treatment gave the lowest mean dry weight of the plant 106.33 g plant^{-1}.

Seed yield (Mg **ha^{-1})**

Results of analysis of variance presented in Table 1 and Table 9 indicate a significant effect of phosphorus fertilizer treatments ($P = 0.005$) and cultivars ($P < 0.001$). Adding of phosphorus fertilizer at 160 Kg ha^{-1} was significantly superior and gave the highest mean of seed yield reached to 4.403 Mg ha^{-1} with a significant increase reached to 21.70 and 17.26% with adding of phosphorus fertilizer at a 80 and 160 Kg ha^{-1} respectively and 37.90% with control treatment which gave a lowest mean amounted to 3.193 Mg ha^{-1}.

The reason of faba bean response to phosphate fertilizer may be attributed to low content of available phosphorus present in the soil (3.25 mg Kg^{-1}), which is less than the critical limit of its available content in Iraqi soils which is 7 mg Kg^{-1} [21]. These results are in agreement with [9 and 11].

Table (9): Response of faba bean cultivar to levels of phosphorus fertilization in the trait of total seed yield (Mg ha^{-1})

Cultivars	Phosphorus (P_2O_5) fertilization levels kg ha^{-1}				mean
	T0	T1	T2	T3	
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	**n.s.**				0.64
mean	3.193	3.618	3.755	4.403	
LSD	0.48				

Regarding effect faba bean cultivars, the result in Table 9 shows that Spanish cultivar was significantly superior and achieved the highest mean of seed yield (5.295 Mg ha^{-1}) with a significant increase amounted to 29.53 and 46.27% compared with Local and Dutch cultivars respectively and 169.47% with New Zealand cultivar which achieved a lowest mean (1.965 Mg ha^{-1}). The reason of difference among faba bean cultivars in seed yield may be attributed to their genetic differences. This result is consistent with [22, 23, 24]. As for the interaction between phosphorus fertilization and cultivars, it had no significant effect on this trait.

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