Nodulation, Growth and Yield of Faba Bean as Affected by Irrigation Interval, Organic Manuring and P and K Fertilization Levels Under Sandy Soil Conditions

AbdulGalil, A. A.*, S. A. Mowafy*, A. E. Omar* and T. S. Mokhtar**
*Agron. Dept. Fac. Agric., Zagazig University, Egypt
**Ministry of Social Solidarity

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Abstract: This investigation was carried out for two seasons (2004/2005 and 2005/2006) in a sandy soil in the Agricultural Research Station of the Faculty of Agriculture at El-Khattara, Zagazig University. The study aimed to find out the effect of irrigation interval (7 and 10 days), organic manuring (addition of $30m^3$of FYM compared with a check), P (0, 15.5, 31.0 and 46.5 kg P_2O_5/ fad)and K (24 and 48 kg K_2O/ fad) fertilization levels on nodulation, root and shoot growth attributes and seed yield of faba bean (Nubaria 1 cultivar). Narrowing the irrigation interval or addition of $30m^3$ farmyard manure (FYM) enhanced nodulation as expressed in larger number of nodules / plant as well as their dry weight and their percentage to total root dry weight. These favourable effects were reflected on shoot growth as expressed in leaf area index (LAI) and branching and hence the seed yield / fad and almost all of its attributes which were increased. The data of combined analysis revealed that increasing P or K levels significantly increased each of nodulation, growth attributes and seed yield / fad and almost all of its attributes. But nodules dry weight / plant and their percentage to total root dry weight, LAI and seed index were not affected significantly by K application. Significant first order interactions were detected between factors under study. The most important interactions were between P levels and each of irrigation interval and organic manuring. In all cases, the response of seed yield to added P was positive diminishing where lower predicted P levels could have produced higher yield maximums due to narrowing the irrigation interval or the addition of FYM. Accordingly, seed yield / fad could have been maximized to 11.22 and 11.73 ardab / fad if the P level could have been increased to 52.9 or 53.8 kg P_2O_5/ fad for the frequently irrigated or organic manured plots, respectively. Therefore, addition of $30m^3$/ fad of FYM and frequent irrigation at seven days interval along with the addition of 54 kg P_2O_5/ fad are recommended to maximize the faba bean seed yield / fad under sandy soil conditions.

Keywords: Faba bean, organic manure, irrigation intervals.

INTRODUCTION

Faba bean is the most important pulse crop in Egypt as it is used mainly for human and animal feeding in addition to its role in enriching soil fertility from fixed nitrogen. However, its production does not meet the local consumption. Therefore, maximizing faba bean production is one of the major targets of the agricultural policy. This could be achieved through expanding its acreage in the newly reclaimed land and sustaining its productivity per unit area.

Irrigation management is a vital problem in Egypt, due to the progressive shortage of water at certain growth stages caused a noticeable decrease in most growth characters and hence yield and its attributes of faba bean (El-Far, 1999 and Masood *et al.,* 2000). Ali and Abd El-Mottaleb (1997) revealed that prolonging irrigation interval from 7 to 11 and then to 15 days significantly decreased plant height, number of pods and seeds / plant, weight of pods and seeds / plant and seed, straw and biological yields/fad. El-Murshedy (2002) noticed that skipping the second irrigation (60 days after sowing, DAS) significantly reduced plant height, number of branches / plant and straw yield / fad, while skipping the third irrigation (90 DAS) significantly decreased seed yield and its components, whereas normal irrigation treatment (4 monthly irrigations) increased seed yield and its components. Ibrahim *et al.,* (2003) observed that faba bean plants supplied with three irrigations were the tallest, produced the highest number of pods / plant, as well as, the highest seed and straw yields / fad. Also, Kassab (2004) reported that skipping one irrigation at pod formation or pod filling stages significantly reduced all the tested growth parameters i.e plant height, the dry matter of root and stem and total plant as compared with control treatment. Similar tendency was noticed regarding yield characters i.e number and weight of pods / plant, seed yield / plant and seed index as well as seed, straw and biological yields / fad. Moreover, Awaad(2007) reported that three irrigations gave the highest values for seed yield / plant, plant height, number of branches and seed yield /m^2 compared with control (one irrigation).

Sandy soils are poor not only in plant nutrients but also in organic matter content where under such conditions; the productivity of different crops tends to decrease. In addition, the losses of mineral fertilizers particularly N, from these soils are excessive where the use of organic N resources is essential (Makary, 2002). Therefore, organic manures play a direct role in sustaining soil fertility through various processes and mechanisms i.e. providing nutrients after decomposition and acting as an energy source for soil organisms, increasing the soil cation-exchange capacity and thereby improving nutrient retention against leaching (El-Fakhrani, 1999). In this connection, root-nodule bacteria which fix atmospheric N symbiotically in legume crops may suffer from low contents of soil organic matter which can be improved by the addition of organic fertilizers (Mahmoud and El-Far, 2000). Many researches showed an increase in plant growth, yield and its components of faba bean due to seed inoculation with bio-fertilizers (Abd El-Fattah and Arisha, 2000;Saleh *et al.*,2000 and El-Sawi *et al.*,2001). Also, El-Yaza (2001) found that, high rates of poultry or farmyard manures (10 and 15 ton / fad) increased greatly faba bean plant growth parameters and yield and its components. Similar results were also reported by Attia (1999) and Attia and El-Dsouky (2001). Moreover, Mohamed and El-Ganaini (2003) noticed that the fertilized plants with bio-fertilizers, farmyard manure and mineral fertilizer (especially at the rate of 5 ton / fad and 100% NPK) each alone or combined generally increased growth parameters and yield and its components of faba bean .

Phosphorus is essential in supplying phosphate which is not always available. In this connection several research workers got significant response to its fertilizers application up to 22.5 kg P_2O_5 / fad(Nawar and Moussa,2002 and Nawar and Khalil,2004). Also, others got similar response when they added 30 kg P_2O_5 / fad (Mohamed *et al.*,1999; Mehana and Abdul Wahid,2000;Saad and El-Kholy,2000 and Khalil *et al.*,2004). Moreover, El-Shouny *et al.*,(1998), El-Mancy *et al.*,(1999),Zeidan and Abd El- Lateef (2001), Rahmou (2003) and Rehan *et al.*, (2003) found this response reaching 46.5 kg P_2O_5 / fad. Furthermore, Hegazy *et al.*, (1996) and Kotb *et al.*, (1999) got similar response when they added 60 kg P_2O_5 / fad. In all these responses, the significant increase of yield was attributed to the significant increase of yield attributes. El-Khawaga *et al.*,(2003) reported that supplying faba bean plants with any of ten bio- chemical fertilization regimes produced significant increments in total dry weight / plant, most of nodulation characteristics and yield and its components. Also,El-Set, Abdel-Aziz (2005) noticed that application of phosphorus fertilizer (22.5 kg P_2O_5 / fad) + phosphorin induced significant increase in each of plant height, number of nodules / plant, dry weight of nodules / plant, LAI, number of branches / plant, number of pods and seeds / plant, 100-seed weight and seed and straw yields / fad.

Potassium is necessary for many plant functions, including carbohydrates metabolism, enzyme activation, osmotic regulation and efficient use of water, N uptake and protein synthesis and translocation of assimilates. Many investigators found that K application resulted in significant increase in faba bean yield and some of its components (Shehata *et al.*,1991; El-Bana and Soliman,1994 and Abd Allatif *et al.*,2002). Also, Nawar and Said(2002) reported that faba bean yield was significantly increased as K level was increased up to 48 kg K_2O / fad. Moreover, AbdulGalil *et al.*,(2003-a)noticed that K additions up to 24 kg K_2O / fad significantly enhanced root dry weight / plant, nodules dry weight / plant, total root dry weight / plant, nodule / total root dry weights percentage, number of nodules / plant and single nodule dry weight. Furthermore, Ismail and Hagag (2005) reported that application of K as foliar spray or seed soaking treatments secured significant increase in seed and straw yields faba bean.

Therefore, the present study was undertaken to find out the effect of irrigation interval, farmyard manure and P and K levels on root and nodule growth attributes, shoot growth attributes and seed yield and its components under sandy soil conditions using Nubaria 1 faba bean cultivar and flood irrigation method.

MATERIALES AND METHODS

This investigation was conducted at the Agricultural Research Station of the Faculty of Agriculture, Zagazig University at El-Khattara, Sharkia Governorate for two growing seasons (2004 / 2005 and 2005 / 2006). The study aimed to investigate the response of faba bean (Nubaria 1 cultivar) to irrigation interval, farmyard manuring and P and K fertilization levels under sandy soil conditions. The soil of the experimental site is sandy in texture where it had a particle size distribution of 89.1, 6.6 and 4.3% for sand, silt and clay, respectively. The soil had an average pH of 8.1 and organic matter content of 0.28%. The average available N, P and K contents were 15.4, 3.5 and 91.7 ppm, respectively.

Factors under study :

1. Irrigation interval (I) :
   a. Irrigation every 10 days.
   b. Irrigation every 7 days.
2. Farmyard manure (FYM) :
   a. Without addition.
   b. Addition of 30 m^3 / fad.
3. Mineral fertilization :
   a. Phosphorus levels:
      1) Without addition (Check).
      2) 15.5 kg P_2O_5 / fad.
      3) 31.0 kg P_2O_5 / fad.
      4) 46.5 kg P_2O_5 / fad.
   b. Potassium levels:
      1) 24.0 kg K_2O / fad.
      2) 48.0 kg K_2O / fad.

Farmyard manure (FYM) as delivered from the Agricultural Research Station of the Faculty of Agriculture had the following nutrient contents : 302 ppm N, 440 ppm P, 1131 ppm K, 13.01% organic matter, with a pH of 7.03 in the first season and 311 ppm N, 452 ppm P, 1143 ppm K, 13.52 organic matter, with a pH of 6.89 in the second season. Farmyard manure was soil incorporated before sowing. Flood irrigation was scheduled at seven or ten days intervals after thinning (15 days after planting). Phosphorus as superphosphate (15.5% P_2O_5) and potassium as potassium sulphate (48%K_2O) were mixed and hand band placed below the seeding level in two equal doses at thinning (15 days after planting, DAP) and 7 and 10 days later according to the irrigation interval. Nitrogen as ammonium sulphate (20.5% N) at the rate of 100 kg / fad was applied at planting as activating dose.

A split-split plot design with four replications was used where the main plots were occupied by the irrigation interval and the first order and second order sub- plots were occupied by FYM and P x K levels combination, respectively. The plot area(14 m^2) included 7 rows of 4 m length and 50 cm apart. The two outer rows were left as borders. The next two outer rows to a three central ones, were devoted for determination of nodulation, flowering and yield attributes. The three central rows were devoted for final yield determination. Three seeds of faba bean (Nubaria 1 cultivar) were sown in hills 15 cm apart on the first week of November in both seasons. Faba bean was preceded by a fallow in the two seasons. After 15 days from planting the seedlings were thinned to two plants / hill (112 thousand plants / fad). Seeds were inoculated with the proper inoculum (*Rhyzobium leguminosarum br. Viceae*) at the rate of 25 gm / 10 kg of seeds. All the other cultural practices were kept the same as recommended. Harvest was made in the first week of May in the two seasons.

At flowering (60 days after sowing), six plants of three successive hills, from the specified rows, were hand pulled after making a proper groove. This was an easy job as the soil is sandy and light enough to have, as possible, uninjured roots where the following nodulation attributes were recorded, after oven drying at 70°C to a constant weight:

1- Root dry weight / plant (gm).
2-Nodules dry weight / plant (gm) .
3-Total root dry weight / plant (gm) i.e 1+2.
4 - Number of nodules / plant.
5-Single nodule dry weight (mg) i.e 2/4.
6-Percentage of nodules to total root dry weights (%) i.e 2/3 x 100.
7-Leaf area index (using disk method).

At harvest, five guarded hills(10 plants) from the specified rows were taken where the following measurements were recorded :

Plant height (cm), number of branches / plant, number of pods / plant, number of seeds / pod, seed index (gm), seed yield /plant (gm). The three central rows were harvested to determine final total biomass and seed yields / fad and hence harvest index.

Analysis of variance and combined analysis for the two seasons were carried out as described by Snedecor and Cochran (1981). For comparison between means, Duncan's multiple range test was applied (Duncan, 1955). The response of seed yield and its attributes to phosphorus fertilization levels was also calculated according to Snedecor and Cochran (1981) using the orthogonal polynomial tables for the significant interactions between factors under study. The significancy of the linear and quadratic components of each of these equations was tested, then the response could be described as linear (first order) or quadratic (second order). The maximum predicted average (Y max) which could have been obtained due to addition of the predicted maximum P level (X max) was calculated according to Neter *et al.,* (1990) and AbdulGalil *et al.,*(2003-b). In interaction tables, capital and small letters were used to compare rows and columns means, respectively. For simple comparison between levels averages of any factor under study, the main effect tables are provided with the percentage change in any character due to prolonging irrigation interval, addition of FYM or the increase of P and K levels.

RESULTS AND DISCUSSION

Root and nodule growth attributes:

Root and nodule dry weights / plant:

Table (1) shows root, nodules and total root dry weights of faba bean as affected by irrigation interval, farmyard manure and levels of P and K fertilization and their interactions in the two seasons and their combined.

Irrigation interval effect :

In both seasons and their combined, narrowing the irrigation interval from 10 to 7 days resulted in a highly significant decrease in root dry weight / plant but, however, a highly significant increase in nodules dry weight and hence the total root dry weight / plant. The percentage changes in the averages of these characters due to narrowing the irrigation interval was – 4.6%, + 50.8% and + 11.6%, in respective order. These results clearly indicate that the nodules dry weight per plant was so much sensitive for prolonging the irrigation interval than the root dry weight per plant though the former was decreased whereas the second was increased due to prolonging the irrigation interval to 10 instead of 7 days.

The increase of root dry weight due to prolonging the irrigation interval indicate that faba bean water stressed plants partitioned more photosynthates for root growth in order to tolerate drought and hence support the plant with more available water from deeper and possibly more wet soil depth. However, the decrease of nodules dry weight / plant due to prolonging the irrigation interval, is rather expected as water stressed plants, always, suffer from shortage of photosynthates and hence a hindered nodules growth (Sprent, 1972).

Farmyard manure effect:

It is quite evident from Table (1) that addition of farmyard manure (FYM) enhanced root and nodule growth as expressed in a highly significant increase in their dry weights / plant and hence the total root dry weight / plant. Here again, the nodule dry weight / plant was much more increased (23.1%) than the root dry weight (12.1%) due to addition of FYM. The average increase of total root dry weight / plant due to this addition amounted to 15.8%.

The soil of the experimental site is sandy, therefore the addition of 30m^3 / fad of FYM was effective to improve soil physical, chemical and biological properties (Russel, 1973). These improvements afforded faba bean plants better soil growing conditions which were reflected in more enhanced root and nodule growth and hence increased their dry weights / plant.

Phosphorus level effect:

It is quite interesting to note from Table (1) that the addition of phosphorus and the increase of its level of application up to 46.5 kg P_2O_5 / fad was accompanied by a highly significant increase in each of root and nodules dry weights / plant and hence the total root dry weight / plant. These increases in respective order were 47.8%, 43.4% and 38.2% due to the increase of P level from zero to 46.5 kg P_2O_5 / fad.

The role of phosphorus in root multiplication and extension is extensively reported in the literature

(Tisdale and Nelson, 1975). The increase of root extension, might have had increased the sites of nodulation(Cassman *et al.*, 1980) and could account herein for the highly significant increase in nodule dry weight / plant. AbdulGalil *et al* (2003-a) noticed that K additions up to 24 Kg K_2O/fad.significantly enhanced root weight/plant and nodules dry weight/plant and its attributes.

Potassium level effect:

Doubling the potassium fertilization level to 48 kg K_2O / fad reflected a highly significant increase in root dry weight and total root dry weight / plant but was without significant effect on nodules dry weight per plant (Table 1). This was true in both seasons and their combined. The average increase in root and total root dry weights per plant was 3.4 and 3.1%, respectively. These results clearly show that the increase of K level was needed by faba bean plants to improve their root growth. The role of potassium in this respect was so much limited compared to the role of phosphorus, as the latter had much more effect on root growth, as well as, nodule growth (Tisdale and Nelson, 1975).

Interaction effect:

Root and nodules dry weights / plant were significantly affected by the first order interactions between factors under study (Table 1). The most frequent significant interactions were those of irrigation x manuring, irrigation x phosphorus level and manuring x phosphorus level and are presented in Tables (1-a), (1-b) and (1-c), respectively, as obtained from the combined analysis.

It is evident from Table (1-a) that root dry weight / plant was significantly increased due to prolonging irrigation interval in the un-manured plots. This was not true in the manured plots where the root dry weight was not significantly affected. Also, addition of FYM with frequent irrigation in 7 days interval was more effective in increasing root dry weight / plant than its addition with less frequent irrigation. This was also true in nodules dry weight / plant and hence the total root dry weight / plant. It is quite evident, also, that narrowing the irrigation interval was more positively affecting the nodules dry weight / plant and hence the total root dry weight / plant in the manured plots than the un manured plots.

These results clearly indicate that addition of FYM and the frequent irrigation complemented the favourable effect of each other as far as nodules dry weight and hence the total root dry weight / plant.

It is evident from Table (1-b) that both the root and nodules dry weights / plant were significantly increased due to the increase of P level but with different magnitudes in the frequent and the less frequent irrigated plots. The response equations showed that both root growth attributes responded linearly to the increase of P level but this response was greater in the less frequent irrigated plots regarding root dry weight/ plant. The reverse was true regarding nodules dry weight / plant where this response was greater in the frequently irrigated plots than in the less frequently irrigated ones.

These results clearly indicate that more phosphorus than 46.5 kg P_2O_5 was needed to maximize both the root and nodules dry weight / plant. However, this increase was more needed by the water stressed plants in order to maximize their root dry weight / plant but, on the other hand, was more needed by the well irrigated plants than by the worse irrigated ones in order to maximize their nodules dry weight / plant. This differential response to phosphorus clears that under drought soil conditions, root growth had a priority over nodule growth as it was more enhanced by the increase of P level.

It is obvious from Table (1-c) that all root growth attributes, were significantly affected by the organic manuring x phosphorus level interaction. Both the root and nodules dry weights and hence the total root dry weight were positively and significantly responded to the increase of P level but with different magnitudes in the manured and un- manured plots. In all cases the response was linear and higher in the manured than in the un- manured plots.

These results are quite interesting and ascertain the role of organic matter in sustaining the availability of phosphorus to crop plants as explained by Tisdale and Nelson (1975) and many other authors(El-Fakhrani, 1999and Makary, 2002). The release of CO_2 during matter decomposition along with the release of organic anions, such as citrate, oxalate and tartarte, as, chelating compounds, protect added phosphorus from fixation by calcium particularly under alkaline soil conditions which is the case of the soil of the experimental site herein.

Nodulation attributes:

The nodule number, single nodule dry weight and percentage of nodule to total root dry weights as affected by irrigation interval, organic manuring and P and K fertilization levels are shown in Table (2).

Irrigation interval effect:

In both seasons and their combined, narrowing the irrigation interval to 7 instead of 10 days significantly improved nodulation of faba bean plants as expressed in a highly significant increase in the number of nodules / plant. According to the combined analysis, this increase amounted to 49.6%. However, the single nodule dry weight showed two opposite trends in the two seasons. In the first season this weight was insignificantly increased, but on the other hand was significantly decreased in the 2nd season due to narrowing the irrigation interval. Therefore, the combined analysis ascertained the insignificancy of the increase of in single nodule dry weight due to narrowing the irrigation interval. These results clearly indicate that the increase in the number of nodules / plant was not on the expense of single nodule dry weight. They further indicate that narrowing the irrigation interval was in favour of nodulation i.e the formation of nodules, as well as, nodule growth as expressed in single nodule dry weight. Therefore the total nodules dry weight / plant was significantly increased as aforemention and observed in Table (1). The question which could be raised herein, is the increase of nodulation was on the expense of root growth? i.e was there a nodule inter root competition for photosynthates as earlier reported by Cassman *et al.*,(1980) in soybean ? This question could be easily answered using the percentage of nodules to total root dry weight as a guide in this connection. It is quite evident from Table (2) that narrowing the irrigation interval was followed by a highly significant increase in the percentage of nodules to total root dry weight, in both seasons and their combined. This percentage was increased from 28.97% to 39.36% according to the combined analysis due to narrowing the irrigation interval. These results refer to a nodule inter root competition for photosynthates caused by shortage of available soil moisture. This competition was in favour root growth (Table 1) rather than nodulation or nodule growth, since their percentage on dry weight basis was significantly decreased when the irrigation interval was increased.

Farmyard manure effect:

Addition of FYM was followed by a highly significant increase in the number of nodules / plant. However, the single nodule dry weight was not significantly affected by this addition. This was true in both seasons and their combined. It is, also, obvious from Table (2) that the percentage of nodules to total root dry weight was significantly increased due to manuring in the first season and was ascertained by the combined analysis.

These results clearly indicate that addition of FYM afforded faba bean plants an adequate soil environmental conditions which enhanced both nodulation and nodule growth. This was in turn reflected in larger number of nodules / plant with normal growth, as expressed in their single dry weight which was not significantly affected by the increase in their number. The results further indicate that addition of FYM was in favour of both root and nodule growth with more preference to nodules where their percentage to the total root dry weight was significantly increased due to this addition (Table 2). Organic manures play a direct role in sustaining soil fertility through various processes and mechanisms (El-Fakhrani, 1999). In this connection, root-nodule bacteria which fix atmospheric N symbiotically in legume crops may suffer from low contents of soil organic matter which can be improved by the addition of bio or organic fertilizers (Mahmoud and El- Far, 2000).

Phosphorus level effect:

Addition of phosphorus and the increase of its level of application up to the highest level (46.5 kg P_2O_5) was followed by a highly significant increase in the number

Table (1): Root, nodules and total root dry weights of faba bean as affected by irrigation interval, farmyard manure and P and K fertilization levels and their interactions in the two seasons and their combined.

Main effects and interactions	Root dry weight / plant (gm)			Nodules dry weight / plant (gm)			Total root dry weight / plant (gm)		
	1st	2nd	Comb.	1st	2nd	Comb.	1st	2nd	Comb.
Irrigation interval effect : (I)									
Every 10 days	2.736	2.796	2.766	1.090	1.184	1.137	3.826	3.981	3.903
Every 7 days	2.560	2.720	2.640	1.696	1.732	1.714	4.256	4.451	4.354
F test	**	N.S.	**	**	**	**	**	**	**
Difference (%)			**-4.6**			**50.8**			**11.6**
Farmyard manure effect: (M)									
Without	2.587	2.511	2.549	1.227	1.329	1.278	3.814	3.841	3.827
30 m^3 / fad	2.709	3.005	2.857	1.559	1.587	1.573	4.268	4.591	4.430
F test	**	**	**	**	**	**	**	**	**
Difference (%)			**12.1**			**23.1**			**15.8**
Phosphorus level effect : (P)									
Zero (Check)	2.166 d	2.318 d	2.242 d	1.083 d	1.248 d	1.166 d	3.250 d	3.966 c	3.608 d
15.5 kg P_2O_5 / fad	2.353 c	2.596 c	2.475 c	1.271 c	1.378 c	1.324 c	3.623 c	3.975 c	3.799 c
31.0 kg P_2O_5 / fad	2.639 b	2.923 b	2.781 b	1.528 b	1.553 b	1.541 b	4.167 b	4.475 b	4.321 b
46.5 kg P_2O_5 / fad	3.433 a	3.195 a	3.314 a	1.690 a	1.653 a	1.672 a	5.123 a	4.847 a	4.985 a
F test	**	**	**	**	**	**	**	**	**
Difference (%)			**47.8**			**43.4**			**38.2**
Potassium level effect : (K)									
24.0 kg K_2O / fad	2.609	2.706	2.658	1.376	1.440	1.408	3.985	4.145	4.065
48.0 kg K_2O / fad	2.687	2.810	2.748	1.410	1.476	1.443	4.097	4.287	4.192
F test	**	**	**	N.S.	N.S.	N.S.	**	**	**
Difference (%)			**3.4**			--			**3.1**
Interaction effects :									
I x M	**	**	** (1-a)	**	N.S.	** (1-a)	**	**	** (1-a)
I x P	N.S.	**	* (1-b)	*	N.S.	* (1-b)	N.S.	N.S.	N.S.
I x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
M x P	**	**	** (1-c)	**	N.S.	** (1-c)	**	*	** (1-c)
M x K	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
P x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

*, ** and N.S indicate significant at 0.05, 0.01 and insignificant, respectively.

Table (1-a): Root, nodules and total root dry weights/plant of faba bean as affected by irrigation interval x farmyard manure interaction (Comb.).

Irrigation interval	Farmyard manure (m^3 / fad) Without	30	Difference (%)
	Root dry weight / plant (gm)		
	B	A	
Every 10 days	2.682 a	2.850 a	**6.3**
	B	A	
Every 7 days	2.417 b	2.862 a	**18.4**
Difference (%)	**9.9**	--	
	Nodules dry weight / plant (gm)		
	B	A	
Every 10 days	1.055 b	1.219 b	**15.6**
	B	A	
Every 7 days	1.501 a	1.927 a	**28.4**
Difference (%)	**42.3**	**58.1**	
	Total root dry weight / plant (gm)		
	B	A	
Every 10 days	3.737 b	4.069 b	**8.9**
	B	A	
Every 7 days	3.918 a	4.789 a	**22.2**
Difference (%)	**4.8**	**17.7**	

Table (1-b): Root and nodules dry weights / plant of faba bean as affected by irrigation interval x P level interaction and the response equations (Comb.).

Irrigation interval	P levels (kg P_2O_5 / fad) Check	15.5	31.0	46.5	Response equations $\hat{Y} = a + bx - cx^2$
			Root dry weight / plant (gm)		
	D	C	B	A	
Every 10 days	2.309 a	2.496 a	2.839 a	3.420 a	$\hat{Y} = 2.116 + 0.663^{**}x$
	D	C	B	A	
Every 7 days	2.175 b	2.454 a	2.722 a	3.208 b	$\hat{Y} = 2.083 + 0.337^{**}x$
			Nodules dry weight / plant (gm)		
	C	B	A	A	
Every 10 days	0.881 b	1.088 b	1.240 b	1.340 b	$\hat{Y} = 0.881 + 0.153^{**}x$
	C	C	B	A	
Every 7 days	1.451 a	1.562 a	1.841 a	2.002 a	$\hat{Y} = 1.412 + 0.231^{**}x$

Table (1-c): Root, nodules and total root dry weights/ plant of faba bean as affected by farmyard manure x P level interaction and the response equations (Comb.).

Farmyard manure (m^3 / fad)	P levels (kg P_2O_5 / fad) Check	15.5	31.0	46.5	Response equations $\hat{Y} = a + bx - cx^2$
			Root dry weight / plant (gm)		
	D	C	B	A	
Without	2.179 a	2.339 a	2.564 b	3.116 b	$\hat{Y} = 1.996 + 0.304^{**}x$
	D	C	B	A	
30	2.306 a	2.610 a	2.997 a	3.512 a	$\hat{Y} = 2.202 + 0.560^{**}x$
			Nodules dry weight / plant (gm)		
	C	B	A	A	
Without	1.069 b	1.209 b	1.363 b	1.471 b	$\hat{Y} = 1.066 + 0.160^{**}x$
	D	C	B	A	
30	1.262 a	1.440 a	1.718 a	1.871 a	$\hat{Y} = 1.251 + 0.229^{**}x$
			Total root dry weight / plant (gm)		
	D	C	B	A	
Without	3.247 b	3.549 b	3.927 b	4.587 b	$\hat{Y} = 3.078 + 0.708^{**}x$
	D	C	B	A	
30	3.568 a	4.050 a	4.716 a	5.383 a	$\hat{Y} = 3.327 + 1.166^{**}x$

of nodules / plant in both seasons and their combined. This increase amounted to 106.8% due to the increase of P level to 46.5 kg P_2O_5 / fad according to the combined analysis (Table 2). On the other hand, the single nodule dry weight was significantly decreased due to addition of P and the increase of its level up to 31.0 kg P_2O_5 / fad where the further increase to 46.5 kg P_2O_5 / fad was not followed by a further decrease in single nodule dry weight. The percentage of nodules to total root dry weight tended to increase significantly due to the increase of P level in the first season and the combined analysis.

The present results clearly indicate that the increase of the number of nodules / plant due to the increases of P level was on the expense of single nodule dry weight. This could be attributed to the tremendous increase of nodule number which amounted to 106.8% due to the increase of P level to 46.5 kg P_2O_5 / fad. This indicates an intra nodule competition for photosynthates when their number was increased. The decrease of single nodule dry weight was not significant when the level of P was increased from 31.0 to 46.5 kg P_2O_5 / fad indicating that this increment was in favour of total nodules dry weight / plant as previously observed in Table (1).

Table (2): Number of nodules / plant, single nodule dry weight and percentage nodules to total root dry weights of faba bean as affected by irrigation interval, farmyard manure and P and K fertilization levels and their interactions in the two seasons and their combined.

Main effects and interactions	Number of nodules / plant			Single nodule dry weight (mg)			Nodules to total root dry weights(%)		
	1st	2nd	Comb.	1st	2nd	Comb.	1st	2nd	Comb.
Irrigation interval effect : (I)									
Every 10 days	32.11	26.36	29.24	37.41	49.54	43.48	28.22	29.72	28.97
Every 7 days	44.67	42.81	43.74	40.47	41.35	40.91	39.62	39.09	39.36
F test	**	**	**	N.S.	**	N.S.	**	**	**
Difference (%)			**49.6**			--			--
Farmyard manure effect: (M)									
Without	34.02	32.20	33.11	39.77	45.34	42.56	31.97	34.43	33.20
30 m³ / fad	42.76	36.97	39.87	38.11	45.55	41.83	35.87	34.38	35.13
F test	**	**	**	N.S.	N.S.	N.S.	**	N.S.	**
Difference (%)			**20.4**			--			--
Phosphorus level effect : (P)									
Zero (Check)	23.43 d	23.99 d	23.71 d	49.59 a	57.04 a	53.32 a	32.46 b	34.64	33.55 b
15.5 kg P_2O_5 / fad	33.19 c	29.67 c	31.43 c	39.43 b	48.44 b	43.94 b	34.69 ab	34.46	34.58 a
31.0 kg P_2O_5 / fad	43.40 b	40.18 b	41.79 b	35.19 b	39.09 c	37.14 c	36.08 a	34.55	35.32 a
46.5 kg P_2O_5 / fad	53.54 a	44.51 a	49.03 a	31.55 b	37.21 c	34.38 c	32.45 b	33.96	33.21 b
F test	**	**	**	**	**	**	**	N.S.	**
Difference (%)			**106.8**			**35.5**			--
Potassium level effect : (K)									
24.0 kg K_2O / fad	37.06	33.74	35.40	40.68	46.69	43.69	33.98	34.59	34.29
48.0 kg K_2O / fad	39.72	35.43	37.58	37.20	44.20	40.70	33.86	34.22	34.04
F test	*	**	**	N.S.	N.S.	*	N.S.	N.S.	N.S.
Difference (%)			6.2			6.8			--
Interaction effects :									
I x M	*	N.S.	* (2-a)	N.S.	N.S.	N.S.	N.S.	**	N.S.
I x P	*	N.S.	** (2-b)	N.S.	**	** (2-b)	*	N.S.	** (2-b)
I x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
M x P	N.S.	N.S.	N.S.	N.S.	**	N.S.	N.S.	*	N.S.
M x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
P x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

*, ** and N.S indicate significant at 0.05, 0.01 and insignificant, respectively.

Table (2-a): Number of nodules / plant of faba bean as affected by irrigation interval x farmyard manure interaction (Comb.)

Irrigation interval	Farmyard manure (m³ / fad)		Difference (%)
	Zero	30	
	B	A	
Every 10 days	26.87 b	31.60 b	17.6
	B	A	
Every 7 days	39.35 a	48.13 a	22.3
Differences (%)	46.4	52.3	

The role of phosphorus in root multiplication and extension and hence the increase in the number of nodulation sites was extensively reported in the literature. El-Khawaga *et al.,* (2003) noticed that supplying faba bean plants with any of ten bio-chemical fertilization regimes produced significant increments in total nodule dry weight / plant and most of nodulation characteristics.

Potassium level effect:

The increase in the level of potassium fertilization level from 24 to 48 kg K_2O / fad was followed by a significant increase in the number of nodules / plant in both seasons and their combined. However, the single nodule dry weight was not significantly affected by the increase of K level in the two seasons, though the combined analysis revealed a significant decrease in this weight. Also, the percentage of nodules to total root dry weight was not affected by doubling the level of K fertilization (Table 2).

The present results indicate that nodulation was favoured by the increase of K level but not to the extent caused by the increase of P level. The results further indicate that in both cases the increase of nodule number was on the expense of their growth and development as expressed in the significant decrease of single nodule dry weight particularly when the level of K was increased. The role of potassium in enhancing the photosynthate partitioning to root nodules was documented by Mengel *et al.*(1974) in faba bean.

Interaction effect:

According to the combined analysis, the irrigation interval x organic manuring interaction affected significantly the number of nodules / plant (Table 2-a). Also, the irrigation interval x phosphorus level interaction affected significantly all nodulation attributes (Table 2-b).

It is obvious from Table (2-a) that addition of FYM in the frequently irrigated plots, was more effective on the number of nodules / plant than its addition in the less frequently irrigated ones. In the former, nodule number was increased by 22.3% compared with an increase of 17.6% in the latter. Likewise, shortening of irrigation interval in the organic manured plots, was more effective than in the un-organic manured ones where the percentage increase in nodule number per plant amounted to 52.3% and 46.4% in respective order. These results clearly demonstrate that frequent irrigation and addition of FYM complemented the favourable effect of each other. However, the effect of irrigation interval had more pronounced effect on nodule number than organic manuring as indicated by the percentages of differences caused by varying each of them.

Results in Table (2-b) show that the number of nodules / plant was significantly increased with each P increment in the frequent and the less frequent irrigated plots but with different magnitudes. The response equations indicate that the response of nodule number to P increments was linear and higher (10.44 / unit P) in the less frequent than in the frequent irrigated (8.03 / unit P) plots.

These results clearly show that water stressed faba bean plants were in more bad need for the increase of P level than water un- stressed ones. This could be attributed to the role of P in enhancing root growth and hence penetration to more wet and deeper soil depth. This explanation is based on the significant increase of root dry weight / plant due to the increase of P level up to 46.5 kg P_2O_5 / fad (Table 1). The interaction between irrigation interval and P level in Table (1-b) showed that root dry weight / plant response to added P was linear but was more greater in the less frequent than in the frequent irrigated plots as observed herein in the number of nodules / plant.

The single nodule dry weight showed different responses to the increase of P level which was greatly influenced by the irrigation interval. This response was negative non-diminishing in the frequently irrigated plots but negative diminishing in the less frequently irrigated ones.

It is evident that frequent irrigations compensated for the decrease in single nodule dry weight which was caused by the increase of P level and hence the percentage of nodules to total root dry weights did not vary among the different P levels.

Shoot growth attributes:

Table (3) shows plant height and branching at harvest as well as LAI, at flowering as affected by irrigation interval, organic manuring and P and K levels in the two seasons and their combined.

Irrigation interval effect:

Narrowing the irrigation interval to 7 instead of 10 days was effective to enhance faba bean shoot growth as expressed in height, branching and LAI. The percentage increase in these growth attributes was 51.3%, 25.4% and 26.9% respectively according to the combined analysis. These results clearly show that plant elongation was not on the expense of branching. They further indicate that well watered plants had more photosynthic leaf area surface than worse watered ones.

Results in Table (1) showed that water stressed plants had significantly heavier root dry weight / plant than non- stressed ones. The results, herein, indicate that the formers were shorter and had fewer branches and smaller LAI than the latters. This refers to an intensive root- shoot intercompetition for photosynthates by the water stressed plants where the dry matter partitioning towards root growth was on the expense of shoot growth. In the literature, several authors reported that shortage of water at certain growth stages caused a noticeable decrease in most growth attributes of faba bean plants (El-Far, 1999 and Masood *et al.*, 2000).

Farmyard manure effect:

Organic manuring enhanced shoot growth of faba bean plants in both seasons (Table 3). Organic manured plants were longer and carried larger number of branches and hence had larger LAI than un-manured ones. The percentages of increase in these shoot attributes were 31.5%, 15.5% and 21.6%, in respective order according to the combined analysis. The present results show that organic manuring had a favourble role on shoot growth, but irrigation interval had more favourble role in this respect. In the literature several authors reported the favourble effect of organic manuring or bio-fertilizers addition on shoot growth of faba bean (Abd El-Fattah and Arisha, 2000 ;Saleh *et al.*, 2000 and El-Sawi *et al.*, 2001).

Under the present study added FYM enhanced root growth (Table 1) and all nodulation attributes (Table 2) and could account for the improvements observed herein in shoot growth.

Phosphorus level effect:

The increase in the level of P fertilization reflected a significant increase in plant height but with greater magnitude in the second than in the first season. According to the combined analysis, plant height was increased due to the increase of P level up to only 31.0 kg P_2O_5 which ascertained the results of the first season. Both the number of branches / plant and LAI were significantly increased with each P increment up to the addition of 46.5 kg P_2O_5 / fad. However, P addition had more pronounced effect on LAI (54.7%) than on either plant height (39.3%) or branching (38.7%), according to the combined analysis (Table 3).

Similar effects were observed on root growth (Table 1) and nodulation attributes (Table 2) and could account for the increase observed herein in shoot growth to added phosphorus. El-Set, Abdel-Aziz (2005)observed that application of 22.5 kg P_2O_5 / fad + Phosphorin induced significant increase in each of plant height, number of nodules / plant, dry weight of nodules / plant, LAI and number of branches / plant.

Potassium level effect:

Doubling the level of K fertilization to 48 kg K_2O / fad was accompanied by a significant increase in both of plant height and number of branches / plant but was without significant influence on LAI (Table 3). The increase in these shoot growth attributes was so much limited being 2.9% and 2.1% according to the combined analysis.

Similar improvements were obtained due to K increments on root and nodulation growth attributes (Tables 1 and 2).

Interaction effect:

The irrigation interval x manuring affected significantly all shoot growth attributes (Table 3-a). Also, these attributes were significantly affected by the manuring x P level interaction (Table 3-c). However, the irrigation interval x P level affected significantly only, the number of branches / plant and LAI (Table 3-b).

It is evident from Table (3-a) that the longest plants were obtained due to narrowing the irrigation interval and the addition of FYM. However, frequent irrigations were more effective on height of un- manured plants than the manured ones as indicated by the higher percentage increase (73.8%) in the former than in the latter (36.6%). Similar trends but of lower magnitudes were observed in the number of branches / plant and LAI.

These results indicate that frequent irrigations could partially compensate for the addition of FYM as far as shoot growth is concerned, and in particular plant height.

Results in Table (3-b) show that the response of plant branching and LAI to the increase of P level varied according to the frequency of irrigation. This response was positive and diminishing by the frequently irrigated plants, but was non-diminishing by the less frequently irrigated ones. It is quite evident that both the number of branches / plant and LAI of the frequently irrigated plants could have been maximized to 4.42 and 6.01 if the level of P had been increased to 59.42 and 67.96 kg P_2O_5 / fad respectively.

It is clear from Table (3-c) that the three shoot growth attributes of faba bean were significantly affected by the organic manuring x P level interaction. It was quite evident that organic manuring maximized the favourable effect of added phosphorus where higher plant height, number of branches / plant and LAI averages could have been obtained with lower level of P for the manured plants compared with the un-manured ones. The response equations indicate that the response of these shoot growth attributes was quadratic for the manured plants, but linear, except plant height, for the un-manured ones. This clearly indicates that organic manuring maximized the effect of added phosphorus.

Seed yield and its components:

Tables (4) and (5) show seed yield and its components as affected by irrigation interval, organic manuring and levels of P and K fertilization in the two seasons and their combined.

Irrigation interval effect:

Narrowing the irrigation interval to 7 instead of 10 days was accompanied by a highly significant increase in the seed yield / plant and hence per fad due to a highly significant increase in each of its components and harvest index. According to the combined analysis, the seed yield / plant was increased by 53.1% and the seed yield / fad by 45.7% due to narrowing the irrigation interval (Table 5). The seed yield per plant increase could mainly be attributed to the increase of the number of seeds / pod (27.7%) followed by the increase of seed index (11.4%) and the increase of the number of pods / plant (4.6%) as shown in table (4).

The increase observed herein of the seed yield / fad and all of its components could be attributed to the improvements previously observed in nodulation (Table 2) as well as in shoot growth (Table 3).

It seems evident that the availability of soil moisture played a significant role in improving faba bean plant growth which in turn improved seed yield potentiality as observed herein in seed yield and all its components. The increase of harvest index in both seasons and their combined indicate that more photosynthates were partitioned for seed filling as the sink size, as expressed in the significant increase of the number of seeds / pod, was so much increased due to scheduling irrigation at 7 instead of 10 days intervals. Shortage of water at certain growth stages caused a noticeable decrease in most growth characters and hence yield and its attributes of faba bean plants (Ali and AbdEl- Mottaleb, 1997; El-Murshedy, 2002; Ibrahim *et al.*, 2003; Kassab, 2004 and Awaad, 2007).

Farmyard manure effect:

It is clear from Tables (4) and (5) that addition of FYM increased both the seed yield / plant and per fad, by percentage increase of 64.3% and 59.7% in respective order according to the combined analysis. Similar significant increase was observed in each of number of pods/plant (18. 5%), number of seeds / pod (30.5%) and seed index (4.5%). Moreover, the harvest index was also, significantly increased (9.1%).

Here again, the number of seeds / pod was the most affected by organic manuring compared with either the number of pods / plant or the seed index. These results confirmed those obtained by others (Attia, 1999 ; Attia and El-Dsouky, 2001 ; El-Yaza, 2001 and Mohamed and El-Ganaini, 2003) and could be attributed to the improvements of root (Table 1) and shoot (Table 3) growth attributes.

Phosphorus level effect:

In the second season and the combined of the two seasons, each P increment produced a significant increase in both the seed yield / plant and per fad (Table 5). Similar increases were observed in the first season but up to the addition of only 31.0 kg P_2O_5 / fad where the further P increment did not add a further significant increase in either the seed yield / plant or the seed yield / fad. Also, a consistent significant increase was observed in both the number of pods / plant and the seed index due to each P increment. However, the increase in the number of seeds / pod was up to the addition of only 31.0 kg P_2O_5 / fad (Table 4). Moreover, the harvest index was significantly increased in the second season due to each P increment up to the addition of 46.5 kg P_2O_5 / fad in the second season and was confirmed by the combined analysis.

The percentage increase in seed yield / plant and / fad due to the addition of 46.5 kg P_2O_5 / fad compared with the check P treatment amounted to 113.3% and 114.5%, respectively. This increase could mainly be attributed to the increase of the number of pods / plant (45.7%) followed by the number of seeds/pod (27.5%) and the seed index (14.8%). Moreover, the harvest index was increased by 10.1%.

These results are quite interesting as they clear the role of phosphorus in sustaining the seed yield and all of its components. They clearly indicate the pronounced effect of P on flowering and pod set as expressed herein in the number of pods / plant which was the most favourably affected yield attribute by the increase of P level. Several authors documented the role of phosphorus on flowering and pod set in legumes. Mokhtar, (2003) reported that the increase of P level resulted in a significant increase in the number of young pods / plant and significant decrease in flower, young pods and total shedding percentages.

It is interesting to note down here that the favourable effect of narrowing the irrigation interval or the addition of FYM was most obviously observed on the number of seeds / pod whereas the effect of P fertilization was most obviously observed on the number of pods / plant. It seems possible that the more long acting effect of narrowed irrigations or, that of manuring, could explain their pronounced effect on seed set as observed in greater number of seeds / pod.

The increase of seed yield / fad and all of its components due to the addition of phosphorus was also reported by Nawar and Moussa, 2002 and Nawar and Khalil, 2004 due to the addition of 22.5 kg P_2O_5 / fad. Also, other got similar response when they added 30 kg P_2O_5 / fad (Mohamed *et al.*, 1999 ; Mehana and Abdul Wahid, 2000 ; Saad and El-Kholy, 2000 and Khalil *et al.*, 2004). Moreover, El-Shouny *et al.*,(1998), El-Mancy *et al.*, (1999), Zeidan and Abd El-Lateef (2001), Rahmou (2003) and Rehan *et al.*, (2003) found this response reaching 46.5 kg P_2O_5 / fad. Furthermore, Hegazy *et al.*, (1996) and Kotb *et al.*, (1999) got similar response when they added 60 kg P_2O_5 / fad. In all these responses, the significant increase of yield was attributed to the significant increase of yield attributes.

Potassium level effect:

The seed yield / plant and / fad were significantly increased due to doubling the level of K to 48 kg K_2O/ fad in both seasons and their combined (Table 5). This was also observed in the number of pods / plant in both seasons and in the number of seeds / pod and seed index in the second season and was confirmed by the combined analysis for the former only (Table 4). Harvest index was, also, increased due to the increase of K level in the second season and this increase was significantly confirmed by the combined analysis (Table 5).

The percentage increase in seed yield / plant was 4.9% and that in seed yield / fad was 5.2%. These increases could be attributed to the increase of the number of pods / plant (2.5%) and number of seeds / pod (1.8%). These results clearly indicate the limited significant effect of K increment on seed yield and its components.

In the literature many investigators found that K application resulted in significant increase in faba bean seed yield and some of its components (Shehata *et al.*, 1991; El-Bana and Soliman, 1994 ; Abd Allatif *et al.*, 2002 and Nawar and Said, 2002). The later author reported that faba bean yield was significantly increased as K level was increased up to 48 kg K2O / fad. Moreover, Ismail and Hagag (2005) noticed that application of K as foliar spray or seed soaking treatments secured significant increase in seed and straw yields of faba bean. Under the present study the increase of K level improved root growth (Table 1), nodulation (Table 2) and shoot growth (Table 3).

Interaction effect:

The irrigation interval x manuring affected significantly seed yield / plant and / fad, number of seeds / pod and seed index. This was observed in the two seasons and was confirmed by combined analysis (Tables 4 and 5). It is quite clear from Table (6) that addition of FYM had more pronounced significant effect on both the seed yield / plant and / fad of the frequently irrigated plants than of the less frequently irrigated ones. Also, narrowing the irrigation interval for

Table (2-b) : Number of nodules/plant, single nodule dry weight and percentage nodules to total root dry weights of faba bean as affected by irrigation interval x P level interaction and the response equations, as well as, predicted maximum($\hat{Y}$ max) and P level (X max) (Comb.).

Irrigation interval	P level (kg P_2O_5 / fad) Check	15.5	31.0	46.5	Response equations $\hat{Y} = a + bx - cx^2$	$\hat{Y}$ max	X max (kg P_2O_5/fad)
Number of nodules / plant							
	D	C	B	A			
Every 10 days	15.01 b	23.71 b	35.43 b	42.79 b	$\hat{Y} = 14.67 + 10.44^{**}x$	--	--
	D	C	B	A			
Every 7 days	32.41 a	39.14 a	48.15 a	55.25 a	$\hat{Y} = 32.02 + 8.03^{**}x$	--	--
Single nodule dry weight (mg)							
	A	B	C	C			
Every 10 days	58.06 a	47.28 a	35.96 a	32.58 b	$\hat{Y} = 58.49 - 14.33^{**}x + 1.85^{*}x^2$	30.74	60.0
	A	B	B	B			
Every 7 days	48.56 b	40.58 b	38.34 a	36.16 a	$\hat{Y} = 48.27 - 8.29^{**}x$	--	--
Percentage nodules to total root dry weights (%)							
	B	A	A	A			
Every 10 days	26.99 b	30.25 b	30.42 b	28.20 b	$\hat{Y} = 27.03 + 4.49^{*}x - 1.37^{*}x^2$	30.71	25.4
	A	A	A	A			
Every 7 days	40.11 a	38.89 a	40.21 a	38.21 a	$\hat{Y} = 40.21 - 1.02^{NS}x$	--	--

Table (3): Plant height, No. of branches / plant and leaf area index of faba bean as affected by irrigation interval, farmyard manure and P and K fertilization levels and their interactions in the two seasons and their combined.

Main effects and interactions	Plant height (cm) 1st	2nd	Comb.	Number of branches / plant 1st	2nd	Comb.	Leaf area index 1st	2nd	Comb.
Irrigation interval effect : (I)									
Every 10 days	73.27	82.69	77.98	3.32	2.75	3.03	3.78	3.72	3.75
Every 7 days	119.13	116.88	118.01	3.87	3.72	3.80	4.81	4.71	4.76
F test	**	**	**	**	**	**	**	**	**
Difference (%)			**51.3**			**25.4**			**26.9**
Farmyard manure effect: (M)									
Without	81.27	88.02	84.65	3.31	3.03	3.17	3.85	3.82	3.84
30 m^3 / fad	111.13	111.55	111.34	3.88	3.44	3.66	4.74	4.61	4.67
F test	**	**	**	**	**	**	**	**	**
Difference (%)			**31.5**			**15.5**			**21.6**
Phosphorus level effect : (P)									
Zero (Check)	74.75 c	83.52 d	79.14 c	2.92 d	2.72 d	2.82 d	3.32 d	3.27 d	3.29 d
15.5 kg P_2O_5 / fad	95.89 b	94.24 c	95.07 b	3.48 c	3.09 c	3.29 c	3.80 c	3.68 c	3.74 c
31.0 kg P_2O_5 / fad	107.70 a	107.34 b	107.52 a	3.87 b	3.41 b	3.64 b	4.96 b	4.84 b	4.90 b
46.5 kg P_2O_5 / fad	106.46 a	114.04 a	110.25 a	4.10 a	3.72 a	3.91 a	5.10 a	5.08 a	5.09 a
F test	**	**	**	**	**	**	**	**	**
Difference (%)			**39.3**			**38.7**			**54.7**
Potassium level effect : (K)									
24.0 kg K_2O / fad	94.71	98.52	96.62	3.57	3.18	3.38	4.26	4.18	4.22
48.0 kg K_2O / fad	97.69	101.05	99.37	3.62	3.29	3.45	4.33	4.25	4.29
F test	**	**	**	**	**	**	N.S.	N.S.	N.S.
Difference (%)			**2.9**			**2.1**			--
Interaction effects :									
I x M	**	**	** (3-a)	N.S.	**	** (3-a)	**	**	** (3-a)
I x P	N.S.	N.S.	N.S.	**	**	** (3-b)	**	**	** (3-b)
I x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	*	N.S.
M x P	**	**	** (3-c)	**	**	** (3-c)	*	**	** (3-c)
M x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
P x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

*, ** and N.S indicate significant at 0.05, 0.01 and insignificant, respectively.

Table (3-a): Plant height, number of branches / plant and leaf area index of faba bean as affected by irrigation interval x farmyard manure interaction (Comb.).

Irrigation interval	**Farmyard manure (m^3 / fad)**		**Difference (%)**
	Without	**30**	
	Plant height (cm)		
	B	A	
Every 10 days	61.83 b	94.11 b	**52.2**
	B	A	
Every 7 days	107.45 a	128.57 a	**19.7**
Difference (%)	**73.8**	**36.6**	
	Number of branches / plant		
	B	A	
Every 10 days	2.81 b	3.25 b	**15.7**
	B	A	
Every 7 days	3.53 a	4.06 a	**15.0**
Difference (%)	**25.6**	**24.9**	
	Leaf area index		
	B	A	
Every 10 days	3.41 b	4.09 b	**19.9**
	B	A	
Every 7 days	4.26 a	5.26 a	**23.5**
Difference (%)	**24.9**	**28.6**	

Table (3-b): Number of branches / plant and leaf area index of faba bean as affected by irrigation interval x P level interaction and the response equations, as well as, predicted maximum ($\hat{Y}$ max)and P level (X max) (Comb.).

Irrigation interval	**P level (kg P_2O_5 / fad)**				**Response equations**	**$\hat{Y}$ max**	**X max (kg P_2O_5/fad)**
	Check	**15.5**	**31.0**	**46.5**	**$\hat{Y} = a + bx - cx^2$**		
	Number of branches / plant						
	D	C	B	A			
Every 10 days	2.53 b	2.94 b	3.13 b	3.52 b	$\hat{Y} = 2.55 + 0.33^{**}x$	--	--
	D	C	B	A			
Every 7 days	3.11 a	3.64 a	4.14 a	4.30 a	$\hat{Y} = 3.10 + 0.69^{**}x - 0.09^{*}x^2$	4.42	59.4
	Leaf area index						
	D	C	B	A			
Every 10 days	2.97 b	3.26 b	4.24 b	4.52 b	$\hat{Y} = 2.90 + 0.57^{**}x$	--	--
	C	B	A	A			
Every 7 days	3.61 a	4.21 a	5.56 a	5.66 a	$\hat{Y} = 3.51 + 1.14^{**}x - 0.13^{*}x^2$	6.01	68.0

Table (3-c): Plant height , number of branches / plant and leaf area index of faba bean as affected by farmyard manure x P level interaction and the response equations , as well as, predicted maximum ($\hat{Y}$ max) and P level (X max) (Comb.).

Farmyard manure (m^3/fad)	**P level (kg P_2O_5 / fad)**				**Response equations**	**$\hat{Y}$ max**	**X max (kg P_2O_5/fad)**
	Check	**15.5**	**31.0**	**46.5**	**$\hat{Y} = a + bx - cx^2$**		
	Plant height (cm)						
	D	C	B	A			
Without	66.60 b	83.63 b	90.96 b	97.38 b	$\hat{Y} = 67.04 + 17.93^{**}x - 2.65^{*}x^2$	97.37	52.4
	C	B	A	A			
30	91.66 a	106.50 a	124.07 a	123.12 a	$\hat{Y} = 90.60 + 23.05^{**}x - 3.95^{*}x^2$	124.23	45.2
	Number of branches / plant						
	D	C	B	A			
Without	2.62 b	2.99 b	3.35 b	3.71 b	$\hat{Y} = 2.62 + 0.37^{*}x$	--	--
	D	C	B	A			
30	3.01 a	3.58 a	3.92 a	4.11 a	$\hat{Y} = 3.02 + 0.65^{**}x - 0.09^{*}x^2$	4.19	56.0
	Leaf area index						
	D	C	B	A			
Without	2.99 b	3.31 b	4.39 b	4.64 b	$\hat{Y} = 2.91 + 0.66^{*}x$	--	--
	C	B	A	A			
30	3.60 a	4.16 a	5.41 a	5.54 a	$\hat{Y} = 3.51 + 1.04^{**}x - 0.11^{*}x^2$	5.97	73.3

the manured plants was more effective than for the un-manured ones. This was, also, observed in the number of seeds / pod and seed index but with lower magnitudes (Table 6).

This interaction confirmed the complementary role between irrigation and manuring in improving faba bean plant growth and yield.

The irrigation interval x P level interaction affected significantly seed yield / plant and / fad as well as the number of seeds / pod and seed index(Tables 4 and 5).

The seed yield / plant was significantly increased due to the addition of the first and second P increments whereas the seed yield / fad continued to increase significantly with each P increment, but with different magnitudes for the two irrigation intervals. The response equations showed diminishing increase in seed yield with greater magnitude for the frequently irrigated plants than for the less frequently irrigated ones (Table 7). It is quite evident that a higher maximum seed yield / fad could have been obtained (11.22 ardab) if the level of P was increased to 52.9 kg P_2O_5 / fad for the formers compared with a lower maximum yield of only 10.07 ardab / fad which could have been obtained if the P level was increased to 102.8 kg P_2O_5 / fad for the latter.

These results clearly indicate that frequent irrigation, saved the need for more phosphorus. This probably could be attributed to the more available P in the frequently than in the less frequently irrigated plots. Similar interaction effect was observed in the seed yield / plant as well as in the number of seeds / pod and seed index but with lower magnitudes (Table7).

The organic manuring x P level interaction affected significantly the seed yield / plant and / fad as well as the number of pods / plant, number of seeds / pod and seed index (Table 8). The harvest index was also affected by this interaction (tables 4 and 5).

It is evident from Table (8) that the seed yield / plant showed linear increase due to the increase of P level for the un-manured plants. This response was diminishing for the manured plants where the predicted maximum yield / plant could be obtained due to the addition of 54.87 kg P_2O_5 / fad. The seed yield / fad showed, also, different quadratic responses to the increase of P level by the manured and un-manured faba bean plants where the increase was diminishing, but of greater magnitude by the manured than by the un-manured ones. It is evident from Table (8) the each P increment secured a seed yield of 3.75 ardab / fad in the manured plots compared with only 1.86 ardab / fad in the un-manured ones. Therefore, the predicted

Table (4): Number of pods / plant, No. of seeds / pod and seed index of faba bean as affected by irrigation interval, farmyard manure and P and K fertilization levels and their interactions in the two seasons and their combined.

Main effects and interactions	Number of pods / plant			Number of seeds / pod			Seed index (gm)		
	1st	2nd	Comb.	1st	2nd	Comb.	1st	2nd	Comb.
Irrigation interval effect : (I)									
Every 10 days	6.65	6.88	6.77	2.43	2.55	2.49	75.08	78.25	76.67
Every 7 days	7.02	7.14	7.08	3.14	3.21	3.18	85.78	85.10	85.44
F test	**	**	**	**	**	**	**	**	**
Difference (%)			**4.6**			**27.7**			**11.4**
Farmyard manure effect: (M)									
Without	6.32	6.35	6.34	2.42	2.50	2.46	78.38	80.20	79.29
30 m^3 / fad	7.35	7.67	7.51	3.15	3.26	3.21	82.48	83.15	82.82
F test	**	**	**	**	**	**	**	**	**
Difference (%)			**18.5**			**30.5**			**4.5**
Phosphorus level effect : (P)									
Zero (Check)	5.37 d	5.62 d	5.49 d	2.34 c	2.53 c	2.44 c	74.29 c	75.01 d	74.65 c
15.5 kg P_2O_5 / fad	6.46 c	6.41 c	6.44 c	2.70 b	2.75 b	2.72 b	78.18 b	78.36 c	78.27 b
31.0 kg P_2O_5 / fad	7.67 b	7.84 b	7.76 b	3.01 a	3.09 a	3.05 a	85.43 a	85.67 b	85.55 a
46.5 kg P_2O_5 / fad	7.83 a	8.17 a	8.00 a	3.09 a	3.14 a	3.11 a	83.81 a	87.65 a	85.73 a
F test	**	**	**	**	**		**	**	**
Difference (%)			**45.7**			**27.5**			**14.8**
Potassium level effect : (K)									
24.0 kg K_2O / fad	6.74	6.93	6.84	2.77	2.85	2.81	80.44	81.10	80.77
48.0 kg K_2O / fad	6.93	7.09	7.01	2.80	2.91	2.86	80.42	82.25	81.34
F test	**	**	**	N.S.	**	**	N.S.	**	N.S.
Difference (%)			**2.5**			**1.8**			--
Interaction effects :									
I x M	N.S.	N.S.	N.S.	**	**	** (Table 6)	**	**	** (Table 6)
I x P	N.S.	N.S.	N.S.	**	**	** (Table 7)	**	**	** (Table 7)
I x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
M x P	**	**	** (Table 8)	**	N.S.	** (Table 8)	**	**	** (Table 8)
M x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
P x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	*	*	N.S.

*, ** and N.S indicate significant at 0.05, 0.01 and insignificant, respectively.

Table (5): Seed yield / plant, seed yield / fad (ardab) and harvest index of faba bean as affected by irrigation interval, farmyard manure and P and K fertilization levels and their interactions in the two seasons and their combined.

Main effects and interactions	Seed yield / plant (gm)			Seed yield / fad (ardab)			Harvest index (%)		
	1st	2nd	Comb.	1st	2nd	Comb.	1st	2nd	Comb.
Irrigation interval effect : (I)									
Every 10 days	12.48	14.03	13.26	5.42	6.43	5.93	48.16	52.22	50.19
Every 7 days	20.01	20.59	20.30	8.44	8.85	8.64	49.19	54.39	51.79
F test	**	**	**	**	**	**	**	**	**
Difference (%)			**53.1**			**45.7**			**3.2**
Farmyard manure effect: (M)									
Without	12.34	13.06	12.70	5.29	5.94	5.61	47.23	50.31	48.77
30 m^3 / fad	20.15	21.56	20.86	8.57	9.34	8.96	50.12	56.30	53.21
F test	**	**	**	**	**	**	**	**	**
Difference (%)			**64.3**			**59.7**			**9.1**
Phosphorus level effect : (P)									
Zero (Check)	9.62 c	10.87 d	10.25 d	4.14 c	4.69 d	4.42 d	46.25 c	50.67 c	48.46 d
15.5 kg P_2O_5 / fad	14.16 b	14.13 c	14.15 c	6.05 b	6.44 c	6.25 c	47.99 b	51.89 c	49.94 c
31.0 kg P_2O_5 / fad	20.48 a	21.24 b	20.86 b	8.67 a	9.31 b	8.99 b	50.24 a	54.16 b	52.20 b
46.5 kg P_2O_5 / fad	20.73 a	22.99 a	21.86 a	8.85 a	10.10 a	9.48 a	50.20 a	56.50 a	53.35 a
F test	**	**	**	**	**	**	*	**	**
Difference (%)			**113.3**			**114.5**			**10.1**
Potassium level effect : (K)									
24.0 kg K_2O / fad	15.94	16.82	16.38	6.80	7.40	7.10	49.01	52.29	50.65
48.0 kg K_2O / fad	16.55	17.80	17.18	7.06	7.88	7.47	48.34	54.32	51.33
F test	*	**	**	**	**	**	N.S.	*	*
Difference (%)			**4.9**			**5.2**			**1.3**
Interaction effects :									
I x M	**	**	** (Table 6)	**	**	** (Table 6)	N.S.	N.S.	N.S.
I x P	**	**	** (Table 7)	**	**	** (Table 7)	N.S.	N.S.	N.S.
I x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
M x P	**	**	** (Table 8)	**	**	** (Table 8)	N.S.	*	* (Table 8)
M x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
P x K	N.S.	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

*, ** and N.S indicate significant at 0.05, 0.01 and insignificant, respectively.

Table (6): Seed yield / fad and some seed yield attributes of faba bean as affected by irrigation interval x farmyard manure interaction (Comb.).

Irrigation interval	Farmyard manure (m^3 / fad)		Difference (%)
	Without	30	
	Number of seeds / pod		
	B	A	
Every 10 days	2.41 b	2.57 b	**6.6**
	B	A	
Every 7 days	2.51 a	3.84 a	**53.0**
Difference (%)	**4.2**	**49.4**	
	Seed index (gm)		
	A	A	
Every 10 days	76.87 b	76.46 b	--
	B	A	
Every 7 days	81.55 a	89.17 a	**9.3**
Difference (%)	**6.1**	**16.6**	
	Seed yield / plant (gm)		
	B	A	
Every 10 days	11.66 b	14.85 b	**27.4**
	B	A	
Every 7 days	13.74 a	26.85 a	**95.4**
Difference (%)	**17.8**	**80.8**	
	Seed yield / fad (ardab)		
	B	A	
Every 10 days	5.27 b	6.58 b	**24.9**
	B	A	
Every 7 days	5.96 a	11.32 a	**89.9**
Difference (%)	**13.1**	**72.0**	

Table (7): Seed yield / fad and some seed yield attributes of faba bean as affected by irrigation interval x P level interaction and the response equations , as well as, predicted maximum ($\hat{Y}$ max) and P level (X max) (Comb.).

Irrigation interval	P level (kg P_2O_5 / fad) Check	15.5	31.0	46.5	Response equations $\hat{Y} = a + bx - cx^2$	$\hat{Y}$ max	X max (kg P_2O_5/fad)
			Number of seeds / pod				
	C	B	A	A			
Every 10 days	2.17 b	2.36 b	2.68 b	2.75 b	$\hat{Y} = 2.02+0.30^{**}x-0.03^{*}x^2$	2.77	77.5
	C	B	A	A			
Every 7 days	2.70 a	3.09 a	3.42 a	3.48 a	$\hat{Y} = 2.69 +0.51^{**}x-0.08^{*}x^2$	3.50	49.4
			Seed index (gm)				
	C	B	A	A			
Every 10 days	72.63 b	74.65 b	79.25 b	80.14 b	$\hat{Y}= 72.32 + 3.56^{**}x$	--	--
	C	B	A	A			
Every 7 days	76.67 a	81.90 a	91.54 a	91.33 a	$\hat{Y} = 75.96 + 9.44^{**}x-1.36^{**}x^2$	92.34	53.8
			Seed yield / plant (gm)				
	D	C	AB	A			
Every 10 days	8.36 b	11.03 b	16.15 b	17.47 b	$\hat{Y} = 8.05+4.26^{**}x-0.34^{*}x^2$	26.59	97.1
	D	C	AB	A			
Every 7 days	12.12 a	17.26 a	25.56 a	26.24 a	$\hat{Y} = 11.59 +8.41^{**}x-1.12^{**}x^2$	27.38	58.2
			Seed yield / fad (ardab)				
	D	C	B	A			
Every 10 days	3.61 b	4.88 b	7.27 b	7.94 b	$\hat{Y}= 3.47+1.99^{**}x-0.15^{*}x^2$	10.07	102.8
	D	C	B	A			
Every 7 days	5.22 a	7.61 a	10.72 a	11.01 a	$\hat{Y} =5.04 +3.62^{**}x-0.53^{**}x^2$	11.22	52.9

Table (8): Seed yield / fad and some seed yield attributes of faba bean as affected by farmyard manure x P level interaction and the response equations , as well as, predicted maximum ($\hat{Y}$ max) and P level (X max) (Comb.).

Farmyard manure (m^3/fad)	P level (kg P_2O_5 / fad) Check	15.5	31.0	46.5	Response equations $\hat{Y} = a + bx - cx^2$	$\hat{Y}$ max	X max (kg P_2O_5/fad)
			Number of pods/ plant				
	D	C	B	A			
Without	5.12 b	5.79 b	7.11 b	7.30 b	$\hat{Y}= 5.03+1.15^{**}x-0.12^{*}x^2$	7.79	74.3
	D	C	B	A			
30	5.86 a	7.08 a	8.40 a	8.69 a	$\hat{Y} = 5.81+1.68^{**}x-0.23^{**}x^2$	8.88	56.6
			Number of seeds / pod				
	D	C	B	A			
Without	2.10 b	2.31 b	2.64 b	2.78 b	$\hat{Y}= 2.09 + 0.29^{*}x$	--	--
	C	B	A	A			
30	2.77 a	3.14 a	3.46 a	3.44 a	$\hat{Y} = 2.75 +0.53^{**}x-0.10^{*}x^2$	3.45	41.1
			Seed index (gm)				
	C	B	A	A			
Without	73.91 b	77.29 b	82.45 b	83.18 b	$\hat{Y} = 73.60+5.29^{**}x-0.66^{*}x^2$	84.20	62.1
	C	B	A	A			
30	75.39 a	79.25 a	88.34 a	88.29 a	$\hat{Y}= 74.67+7.72^{**}x-0.98^{*}x^2$	89.87	61.1
			Seed yield / plant (gm)				
	D	C	B	A			
Without	8.01 b	10.33 b	15.47 b	16.98 b	$\hat{Y}= 7.69+3.81^{**}x$	--	--
	D	C	B	A			
30	12.47 a	17.95 a	26.24 a	26.74 a	$\hat{Y} = 11.94+8.85^{**}x-1.25^{**}x^2$	27.60	54.9
			Seed yield / fad (ardab)				
	D	C	B	A			
Without	3.46 b	4.52 b	6.98 b	7.50 b	$\hat{Y}= 3.30 + 1.86^{**}x-0.14^{*}x^2$	9.48	103.0
	D	C	B	A			
30	5.37 a	7.97 a	11.01 a	11.44 a	$\hat{Y} = 5.22 +3.75^{**}x-0.54^{**}x^2$	11.73	53.8
			Harvest index				
	C	C	B	A			
Without	46.17 b	47.14 b	50.07 b	51.69 b	$\hat{Y} = 46.01+1.46^{**}x$	--	--
	D	C	B	A			
30	50.75 a	52.75 a	54.33 a	55.00 a	$\hat{Y}= 50.73+2.43^{**}x$	--	--

maximum seed yield amounted to 11.73 ardab / fad produced due to the increase of P level to 53.8 kg P_2O_5 / fad in the manured plots compared with only 9.48 ardab / fad produced by a higher addition of 103.0 kg P_2O_5 / fad in the un-manured ones. This interaction reflected its effect on seed yield components as observed, also, in Table (8) where lower maximum averages could have been obtained if the level of P was maximized to a higher level in the un-manured plots than in the manured ones. These results ascertain the view that organic manuring increased the availability of added phosphorus and hence lower P levels were needed in the manured than in the un-manured plots.

According to these interactions, it could be concluded that both narrowing of the irrigation interval or addition of FYM played a complementary role in maximizing the response of faba bean plants to added phosphorus, where lower P levels were needed to maximize the seed yield / fad and all of its components to higher averages in the frequently irrigated or manured plots than in the less frequently irrigated or un-manured ones.

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تأثير فترة الري،التسميد العضوي ومستوى التسميد الفوسفاتي والبوتاسي على مؤشرات تكوين العقد الجذرية ، نمو ومحصول الفول البلدي تحت ظروف الأراضي الرملية

أحمد أنور عبد الجليل*- صابر عبد الحميد موافى*- عبد الرحمن السيد عمر*- تامر صلاح مختار**

*قسم المحاصيل- كلية الزراعة- جامعة الزقازيق

**وزارة التضامن الاجتماعي

أجريت هذه الدراسة لموسمين (٢٠٠٤/٢٠٠٥ و٢٠٠٥/٢٠٠٦) بأرض رملية بالمزرعة التجريبية الزراعية بالخطارة التابعة لكلية الزراعة- جامعة الزقازيق وذلك لدراسة استجابة الفول البلدي(صنف نوبارية ١) لفترتي ري (سبعة أو عشرة أيام بين الريات)، التسميد العضوي(إضافة ٣٠م^{3}/ف بالمقارنة بعدم الإضافة)، أربعة مستويات من الفوسفور(صفر،١٥,٥ ، ٣١ و٤٦,٥كجم فو$_{2}$أ$_{5}$ / فدان) ومستويين من البوتاسيوم (٢٤و٤٨ كجم بو$_{2}$أ/ فدان) ، وتم تتبع تأثير المعاملات تحت الدراسة على أعداد وأوزان العقد الجذرية ونسبة أوزانها إلي وزن الجذر بالإضافة إلي محصول البذور ومؤشراته . ويمكن تلخيص أهم النتائج التي تم الحصول عليها كما يلي :

أدىتضييق الفترة بين الريات أو إضافة السماد العضوي إلي زيادة أعداد وأوزان العقد الجذرية ونسبة أوزانها إلي وزن المجموع الجذري، ارتفاع النبات، عدد الأفرع/ نبات، دليل مساحة الأوراق، عدد القرون/ النبات، عدد بذور القرن، دليل البذرة، وزن بذور النبات، محصول البذور للفدان ودليل الحصاد.

أدت زيادة مستوي التسميد من أي من الفوسفور أو البوتاسيوم إلي زيادة مؤشرات تكوين ونمو العقد الجذرية، محصول البذور/ فدان ومعظم مؤشراته في حين لم يتأثر كل من الوزن الجاف للعقد / النبات ونسبة أوزانها إلي الوزن الكلي للجذر، دليل مساحة الأوراق ودليل البذرة بإضافة السماد البوتاسي وذلك طبقاً للتحليل التجميعي للموسمين.

لوحظ تداخل فعل معنوي بين عوامل الدراسة وكان الأكثر أهمية بين مستويات التسميد الفوسفاتي وبين كل من فترة الري والتسميد العضوي، وكانت استجابة الفول البلدي للتسميد الفوسفاتي أعلي عند تضييق الفترة بين الريات أو إضافة التسميد العضوي؛ حيث أوضحت معادلات استجابة محصول البذور/الفدان إمكانية تعظيم المحصول إلي ١١,٢٢أردب / فدان بزيادة معدل التسميد الفوسفاتي إلي٥٢,٩كجم فو$_{2}$أ$_{5}$ مع تنظيم الري كل سبعة أيام وكذلك تعظيمه إلي ١١,٧٣ أردب / فدان بزيادة معدل التسميد الفوسفاتي إلي ٥٣,٨ كجم فو$_{2}$أ$_{5}$/ فدان مع إضافة السماد العضوي؛ وبناء عليه فأن هذه الدراسة توصي بزيادة معدل التسميد الفوسفاتي إلي ٥٤ كجم فو$_{2}$أ$_{5}$/فدان مع تنظيم الري كل أسبوع وإضافة السماد العضوي بمعدل ٣٠م^{3}/ فدان عند إعداد الأرض للزراعة تحت ظروف الأراضي الرملية.