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Effect of Different Levels of Nitrogen and Phosphorus on Yield and Yield Components of Faba bean (*Vicia faba* L.) in Calcareous Soil from Kurdistan Region of Iraq

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Research Article

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Abstract

To evaluate the effect of different levels of nitrogen and phosphorus fertilization on some growth characteristics of faba bean (*Vicia faba* L.) a field experiment was conducted at a Randomized Complet Block Design (RCBD)with four treatments and three replications at the Research Farm of the Faculty of Agriculture, University of Sulaimani, Kurdistan Region of Iraqin 2014. Results indicate that the nitrogen and phosphorus fertilizers had not asignificant effect of most studied growth characteristics of faba bean except for the plant height.The greatest plant height was observed from the application of 78 kg N ha^{-1} and 200 kg P_2O_5 ha^{-1} fertilizers. Chlorophyll content index (CCI) was not affected by the nitrogen and phosphorus fertilizer application; the highest chlorophyll content index was found in the application of 98 kg N ha^{-1} and 250 kg P_2O_5 ha^{-1} to the soil. The N and P fertilizer application had not significant effect statistically on the value of harvest index, the highest value of harvest index 43.933% was shown from the application of 98 kg N ha^{-1} and 250 kg P_2O_5 ha^{-1}. Phosphorus application had no significant effect on PUE.The lower phosphorus use efficiency (PUE)was seen at highest P rates application, the maximum PUE (86.400) was observed at T_2, and it decreased at higher P rate application to (61.223).

Keywords: Faba bean; Nitrogen; Phosphorus fertilizers

Abbreviations: RCBD: Randomized Complet Block Design; CCI: Chlorophyll Content Index; PUE: Phosphorus Use Efficiency; DAP: Diammonium Phosphate; HI: Harvest Index; EC_e: Electrical Conductivity; OM: Organic Matter; CEC: Cation Exchange Capacity; M: Molarity; AECC: Active Equivalent Calcium Carbonate.

Introduction

Faba bean (*Vicia faba* L.) is one of the major winter-sown legume crops grown in the world and has considerable importance as low-cost food rich inproteins and carbohydrates [1]. Faba bean has four main functions in agro-ecosystems: (1) providing food and feed that is

rich in protein; (2) increasing soil fertility by supplying N to agroecosystems by symbiotic N_2 fixation with Rhizobium; (3) diversifying the crop system to reduce constraints on growth and yield by the other crops in the rotation; and (4) reducing fossil energy consumption for crop production [2]. Nitrogen isa plant nutrient required in comparatively larger amounts than other elements for plant growth. Nitrogen is an essential component of many compounds of the plant, such as chlorophyll, nucleotides, proteins, alkaloids, enzymes, hormones and vitamins [3]. Nitrogen supply must be in sufficient amount to plant for an optimal yield. Nitrogen deficiency generally results in stunted growth, chlorotic leaves because the lack of N limits the synthesis of proteins and chlorophyll [4]. Phosphorus is one of the most important elements that are significantly affecting plant growth and metabolism. It is, along with N, a major yield-limiting nutrient in many regions of the world, legumes require high amounts of P due to the involvement of P in energy transfer rate that must take place in the nodule [5]. Richards et al. [6] pointed out that the increase in solubility of phosphorus in soil solution causes an increase in iron uptake by the plant which contributes in increasing nitrogen fixation by legumes then increase in protein content and seed quality.

In spite of the considerable addition of phosphorus to soil, the available amount of phosphorus for plants is usually low because its availability to plants is limited by different chemical reactions especially in arid and semi-arid soils [7]. Phosphorus plays a significant role in several physiological and biochemical plant activities like photosynthesis, the transformation of sugar to starch and transporting of the genetic traits [8]. Phosphorus has positive effects on nodule formation and nitrogen fixation in legume crops and plays a vital role in the structure of nucleus and cell membrane [1,9].

Koleand Hajra [10] reported that no significant differences between Ca superphosphate or rock phosphate were detected on growth and yield of abroad bean plant. Rakha and El-Said [11] found that the application of phosphorus fertilizers in two forms generally had anon-significant effect on the most plant growth characters of broad bean.

Some chemical properties of calcareous soil effects on availability of phosphorus for plants, a number of researchers in the field of soil chemistry and fertility indicated that the chemical factors (soil $CaCO_3$ content, soil pH, soil organic matter content, type of clay minerals) play an important role in the availability of phosphorus for plants [6,12-14]. The soils of Kurdistan region of Iraq were classified as calcareous soil, depending on the high $CaCO_3$ content, which has the slightly alkaline soil reaction (pH), this may cause decreases in the availability of phosphorus for plants due to chemical and physical fixation of (70-90%) of applied phosphorus fertilizers [15]. Amsalu et al. [16] found that variations in grain and biomass yield of faba beans were largely due to the difference in PUE. Hence the aims of this investigation were to evaluate the effect of different levels of nitrogen and phosphorus fertilizers on some growth characteristics of faba bean (Vicia faba L.) and phosphorus use efficiency in calcareous soil.

Materials and Methods

Experimental Design

This study was conducted at the Faculty of Agricultural Research Farm, University of Sulaimani, Bakrajo, Kurdistan Region of Iraq. (45°32' 5'' E and 35°32'' 05'' N) During winter growing season of 2014, the soil was uniform and calcareous ($CaCO_3$> 5) in nature. Nitrogen and phosphorus application to the soil were from Diammonium Phosphate (DAP) fertilizer which has the fertilizer formula (18:46), or DAP fertilizer contain 18% N and 46% P_2O_5. The treatments including T_1 = 0 N: 0 P_2O_5, T_2=58 N: 150 P_2O_2, T_3 = 78 N: 200 P_2O_5 and T_4= 98 N: 250 P_2O_5 kg ha^{-1} were applied to the soil at the time of sowing. The field experiment was arranged as Randomized Complete Block Design (RCBD) with three replicates; net plot size was $6m^2$ (2 x 3m), and the distance between the experiment units was one meter while the distance between blocks was two meters. Each plot was contained eight row and spacing 25 cm between the plants. The seed of regional faba bean was planted at a depth of 5 cm during the winter season on 23rd December 2014. The potassium fertilizer was applied at the rate of 150kg K_2O ha^{-1} as potassium sulfate to each experimental unit. The potassium fertilizer was applied at the time of sowing for all treatments, weeds were controlled manually. The crop was harvested at maturity on 29th April 2015.

Sample Collection and Physicochemical analysis

Soil samples were taken from (0 -30 cm) of the soil used in the field experiment and were prepared for some physical and chemical analysis. Soil particle size distribution was determined by the pipette method according to Gee and Bauder [17]. The Electrical conductivity (EC_e) and soil reaction (pH) were measured for the soil saturation extract with an EC meter, model (HI 2314) and pH meter (HANA), model (HI 83141), respectively. Some cations and anions in the soil

saturation extract were determined according to the soil analysis methods described by Page et al. [18]. The organic matter (O.M.) content was determined by dichromate oxidation (Walkley and Black procedure) as described by Nelson and Sommer [19]. Cation exchange capacity (CEC) of the soil particles was obtained by saturation the soil samplewith 1M ammonium acetate (NH_4OAc) at pH 8.1 asan extraction solution according to the method described by Suarez [20]. Total calcium carbonate ($CaCO_3$) in the soil, was determined by a rapid titration method according to Rayment and Higginson [21]. The active lime or active equivalent $CaCO_3$ (AECC), which is a fine particle size calcite, was estimated by the 0.5 M NH_4-oxalate method as described by Drouimeau [22]. The available phosphorus concentration from the soil samples was determined by extracting the samples with 0.5 M $NaHCO_3$ [23]. Some soil properties are present in Table (1).

Properties		Location
Particle Size Distribution(PSD) g kg^{-1}		Bakrajo
	Sand	75.4
	Silt	518.4
	Clay	406.2
Texture Class		Silty Clay
pH		7.52
ECe dS m^{-1} at 25°C		0.33
Soluble ions mmol L^{-1}	Ca^{2+}	2.2
	Mg^{2+}	0.58
	Na^{+}	0.49
	K^{+}	0.09
	HCO_3^{-}	2.34
	Cl^{-}	0.4
	SO_4^{2-}	0.88
O. M. g kg^{-1}		19
CEC $cmol_c$ kg^{-1}		47
Available P mg L^{-1}		36.55
CaCO3 equivalent g kg^{-1}	Total	327
	Active	117

Table 1: Some physical and chemical properties of soil used in a field experiment.

After harvesting, the plant samples were dried at 70°C; the dried samples were ground and after grinding the samples were mixed thoroughly and stored for analysis. Grinding apparatus were cleaned after grinding each sample using a brush or vacuum system [24].

Wet digestion was used for destruction of organic matter, acids that have been used in these procedures include sulfuric (H_2SO_4), and Hydrogen peroxide (H_2O_2) is also used to enhance reaction speed and to complete the digestion.

Measurement Parameters

The measurement parameters comprise most of the yield components of faba bean such as plant height (cm), seed yield (ton ha^{-1}), biological yield (ton ha^{-1}), the number pods per plant, the number of seeds per pod, seed yield, and 100 seed weight (g).

Harvest Index (HI%)

Harvest index (HI)(%) was calculated by using following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain Yield}}{\text{Biological Yield}} \text{ x } 100 \quad (1)$$

Phosphorus Use Efficiency (PUE)

The phosphorus use efficiency (PUE): The efficiency of phosphorus was calculated according to the equation described by Dobramann [25].

$$\text{Phosphorus Use Efficiency (PUE)} = \frac{\text{faba bean grain yield(kg ha}^{-1})}{\text{Fertilizer applied (kgP}_2\text{O}_5\text{ha}^{-1})} \quad (2)$$

Chlorophyll content index (CCI)

At flowering stage, three plants in three different rows were randomly selected, and chlorophyll content index (CCI) of upper, middle and lower leaves was measured by a chlorophyll meter (CCM-200, Opti-Science, USA). Also, to determine the biological yield, three plants were randomly selected in the three different rows, then the mean of plant weight was multiplied by the number of plants at each plot.

Statistical Analysis of data

Statistical data analysis like pair-wise comparison (Duncan's multiple range tests) was performed by XLSTAT software version 7.5 [26].

Results and Discussion

As a measure of yield, total above-ground biological yield, seed yield and 100 seed weight measured at maturity, pods per plant and seeds per pod were measured as yield components and plant height at maturity is measured as yield attribute.

The results of variance analysis and mean comparison indicated that total above biological yield (kg ha^{-1}), seed yield (kg ha^{-1}) 100 seed weight (g), number of pods per plant and number of seeds per pod were not influenced by the application rates of nitrogen and phosphorus to the soil and the results were not significant at 0.05 level of probability (Table 2), these maybe due to the high $CaCO_3$ content of Kurdistan soil (Table 1).

Treatments	Plant height (cm)	Biological yield (kg ha^{-1})	Seed yield (kg ha-1)	100 seed weight (g)	No. of pods $plant^{-1}$	No. of seeds pod^{-1}
T_1	55.353[b]	38613.090[a]	15537.827[a]	416.000[a]	10.33[a]	4.667[a]
T_2	61.363[a]	32371.303[a]	12960.043[a]	400.667[a]	10.667[a]	5.000[a]
T_3	63.900[a]	35264.110[a]	15452.493[a]	440.333[a]	10.667[a]	4.333[a]
T_4	59.420[ab]	32514.237[a]	14286.267[a]	424.000[a]	9.667[a]	4.333[a]

Values with the same letter are not significant by Duncan's multiple range test at the ($P<0.05$).
Table 2: Effect of different nitrogen and phosphorus levels on yield and yield components of faba bean (*Viciafaba* L.).

These results are in disagreement with those obtained by Yirga et al. & Esmail and Miran [27, 28]. They found that the application of phosphorus fertilization had a significant influence on yield and yield components of faba bean. While the results are matching with the results of Salem and El-Nakakhlawy [29], they, found that application of 80 kg ha^{-1} P_2O_5 to the soil did not affect yield component of faba bean. Similar results were reported by Rakha and El-Said [11], who found the two forms of phosphorus fertilizers application generally had a no significant effect on the most plant growth characters of faba bean.

Plant height (cm)

Plant height was affected by various nitrogen and phosphorus rates, statistical analysis of data present in Table 2 indicated that there was a significant difference between T_1 and both of T_2 and T_3 at 0.05 level of probability. These results are in harmony with the results obtained by Yirga et al. and Rouhollah et al. [27, 30], as they found that the chemical fertilizer at a rate of 50 kg urea ha^{-1} and 150kg ha^{-1} of triple super phosphate had a significant effect on plant height of faba bean. The high availability of nutrients, especially nitrogen, effects the growth and increase the length of internodes through the increased plant height [30]. While the results are not matching with the results of Nikfarjam and Aminpanah [2], who found that the P application had not significant effect on plant height.

Chlorophyll Content Index (CCI) in the Leaf

The statistical analysis of variance of the data indicated that the application of nitrogen and phosphorus fertilizers had not significant effecton chlorophyll content in the leaf of faba bean (Table 3).

Treatments	Chlorophyll content index(CCI)	Harvest index (HI%)	PUE (kg grain kg^{-1} P_2O_5)
T_1	33.537[a]	40.483[a]	0.000[a]
T_2	31.330[a]	40.227[a]	86.400[a]
T_3	31.783[a]	43.813[a]	77.260[a]
T_4	38.230[a]	43.933[a]	61.223[a]

Values with the same letter are not significant by Duncan's multiple range test at the ($P<0.05$).
Table 3: Effect of different nitrogen and phosphorus levels on Chlorophyll content index (CCI), Harvest index (Hi%) and PUE of faba bean (*Viciafaba* L.).

The results disagreed withthe finding of Rouhollah et al. [30], who found that faba bean leaf chlorophyll content is significantly affected by nitrogen and phosphorus fertilizer application to the soil.

Harvest Index (HI%)

Statistical analysis of data presented in Table 3 shows that the P and N fertilizer applications had not significant effect on the value of harvest index. The highest value of harvest index was 43.933% from T_4, 98 N:250 P_2O_5 and the lowest value was 40.483% fromthe control. All the treatments showed more or less similar behavior for HI. These results are in harmonic with the results found by Amsalu et al. [16], as they found that P application rates had non-significant effects for harvest index (HI%) of faba beans. While the results are not matching with the results

obtained by some researchers Bozorgi HR, Ashoori JNM [31,32], who reported that there was a significant difference in (P≤0.05) of the interaction between treatments of biological phosphorus, mineral phosphorus and nitrogen on harvest index.

Phosphorus Use Efficiency (PUE)

Data of Phosphorus use efficiency (PUE) of faba bean are given in Table 3. PUE was calculated regarding faba bean seeds yield per unit of P fertilizer application. The results indicated that P application had no significant effect on PUE, the lower PUE was seen at higher P rates application. The maximum PUE of 86.400 was observed at T_2, and it decreased significantly at higher Prates application. These results were in agreement with finding by Amsalu et al. [16], who found that P application had no significant effect on PUE of faba bean and decreased at higher Phosphorus rate.

Conclusion

From the present study it was possible to conclude that nitrogen and phosphorus fertilization has brought a significant effect on yield attributes. The plant height as a yield attribute increased with increases in nitrogen and phosphorus fertilizer. Finally, application of the proper amount of nitrogen and phosphorus can cause to increase of chlorophyll content index (CCI) in the leaf and harvest index (HI%) percent of fababeans plant.

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