

The Effects of Phosphorus and Farmyard Manure on Nodulation and Growth Attributes of Common Bean (*Phaseolus vulgaris* L.) in Shambat Soil under Irrigation

^{1,2}Saad A. Sulieman and ¹Tageldin E.M. Hago

¹Department of Agronomy, Faculty of Agriculture, University of Khartoum, Shambat, 13314, Sudan

²Department of Crop Sciences, Plant Nutrition, Georg-August-University Goettingen, Carl-Sprengel-Weg 1, D-37075 Goettingen, Germany

Abstract: A field experiment was conducted in the Experimental Farm of the Faculty of Agriculture, University of Khartoum at Shambat in order to study the response of common bean (*Phaseolus vulgaris* L.) to phosphorus as influenced by farmyard manure (FYM). The treatments consisted of two rates of FYM (0 and 2.5 ton ha⁻¹) and five levels of phosphorus (0, 50, 100, 150 and 200 kg P₂O₅ ha⁻¹). Triple superphosphate (48% P₂O₅) was used as a source of phosphorus in the experiment. The experiment was laid out in Split-plot design with four replicates. FYM treatments were allocated to the main-plots, whereas the phosphorus levels were allotted to the sub-plots. Seeds of common bean (cultivar Shendi) were inoculated with *Rhizobium phaseoli* strain USDA 2669 as a basic treatment. The results showed that, application of phosphorus and FYM increased all the parameters that were examined during the experiment but the increase was not significant. Phosphorus effects were sometimes erratic and inconsistent. In addition, there was a significant effect of the interaction between phosphorus and FYM on the shoot dry weight after ten weeks from sowing.

Key words: Phosphorus, farmyard manure, *Phaseolus vulgaris* L., calcareous clay soil, Sudan

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is one of the most important food legumes in Latin America and Africa^[8,15]. It is high in protein, phosphorus, iron, vitamin B₁, fiber, and is free of cholesterol. Beans are an attractive crop for farmers, because of its adaptability to different cropping systems and short growing cycle. Common bean suffers from several biotic and a biotic production constraints. The major a biotic constraints include nitrogen and phosphorus deficiency, low pH complex and drought. Bean productivity is limited by soil fertility especially phosphorus and nitrogen^[12,16]. An improved symbiotic nitrogen fixation capacity in bean combined with efficient rhizobial strains is a pre-requisite for high productivity.

Introduced to the eastern Africa coast by Portuguese traders in the sixteenth century, common bean quickly became established as a food crop in many parts of Africa. Presently, it is the second most important source of human dietary protein and the third most important source of calories for over a 100 million people in rural and poor urban communities in Africa. Its protein is cheaper than the animal protein,

making it highly competitive and important in dietary regimes of poor people in Africa. Many plant parts are used, such as leaves, green pods, green seed, but dry grain is the most important product.

The failure to establish effective nodulation is often considered the main reason for poor N₂ fixation by common bean in the field, but the cultivars may be genetically predisposed to poor fixation because of ineffective symbiosis and the short vegetative fixation period^[11,12,23]. Most studies on adaptation of beans to low phosphorus availability were carried out under conditions of combined nitrogen, and studies to ensure that tolerance to low phosphorus is compatible with N₂ fixation are needed, since attempts to select bean genotypes tolerant to low phosphorus are likely to be affected by the symbiosis established with rhizobia. Since the information on various aspects of improved agronomic practices is scanty for the area, the present report was undertaken to study the effect of phosphorus and farmyard manure application on common bean.

MATERIALS AND METHODS

A field experiment was carried out in the Experimental Farm of the Faculty of Agriculture at

Shambat (latitude 15° 40' N and longitude 32° 32' E) in order to study the effect of phosphorus and FYM on growth and yield of common bean (*Phaseolus vulgaris* L.). Some of the physical and chemical characteristics of the soil at the experimental site are shown in Table 1. The local white seeded cultivar 'Shendi' was used in the experiment. Seeds were inoculated with *Rhizobium phaseoli* (USDA 2669) that was obtained from the National Research Centre in Khartoum. The technique of inoculation used was Peat-based inoculant^[6] in which the *Rhizobium* was applied directly to the seed before planting. The treatments consisted of five phosphorus levels (0, 50, 100, 150 and 200 kg P₂O₅ ha⁻¹) and two FYM rates (0 and 2.5 ton ha⁻¹). The experiment was laid out in a Split-plot design with four replications. Farmyard manure treatments were allocated to the main-plots, and the phosphorus levels to the sub-plots. The land was prepared according to the standard procedure followed in the Faculty Experimental Farm. Cattle manure, which was obtained from the University of Khartoum Top Farm at Shambat was broadcast on the designated main-plots followed by pre-watering and land preparation. The chemical composition of FYM used in the trial is shown in Table 2. Seeds were sown on the eastern side of the ridge in plots 5 × 5 m in size and at the rate of three seeds per hole and a spacing of 20 cm and 70 cm between holes and ridges respectively. Each plot contained six ridges. A basic N dose of 43 kg N ha⁻¹ was applied to all plots at sowing. Triple superphosphate (48% P₂O₅) and urea (46% N) were used as sources of P and N respectively. The chemical fertilizers were applied at sowing in bands on one side of the ridge and at a depth of 5 cm. The plots were irrigated immediately after sowing and subsequently at 7-10 days intervals. Resowing was done after 14 days for holes, which failed to germinate. Thinning to two seedlings per hole was carried out after 21 days from sowing. Two hand weedings were done at appropriate periods during the trial. Number of nodules/plant, leaf area index (LAI) and shoot dry weight were measured at weekly intervals starting after one month from sowing until maturity. Plant height and number of branches/plant were determined once at flowering. Vegetative growth and flowering parameters were studied on three random plants taken from the central three ridges. The data were subjected to the analysis of variance (ANOVA), and means were separated by using the Duncan's Multiple Range Test^[10].

RESULTS AND DISCUSSION

Nodulation: Although all of the seeds used were inoculated with *Rhizobium*, the results showed insignificant response of nodulation of common bean plants to FYM and phosphorus. The nodulation of the

plants provided with manure was much better than those not supplied with manure (Table 3). As compared with the control (0 kg P₂O₅ ha⁻¹), increasing phosphorus levels increased the number of nodules per plant (Table 3). The poor ability of the crop to form nodules may be attributed to the partial failure of the plants to establish effective symbiosis in the field as well as genetic variability and the general variable growing conditions^[2,8]. The starter dose of nitrogen (43 kg N ha⁻¹) which was applied at sowing may be another cause of nodulation failure. Similar effects were reported by Gobara^[9] who found that, this N rate consistently depressed nodulation. Moreover, Abaidoo^[11] stated that, common bean appears to be one of the most sensitive grain legumes in the response of its nodulation to nitrogen supply. Lack of response to phosphorus in common bean had been reported by many workers^[5,21]. Nodulation failure could be attributed to the low phosphorus availability in the alkaline soils at the experimental site. This is in line with the finding of Graham^[11] and Graham *et al*^[12] who showed that, phosphorus is the most important factor limiting N₂ fixation in common bean plants. The lack of response by nodulation to FYM could be due to unfavorable changes in the soil environment such as increased salinity, pH and/or change in the soil microorganism populations, which could interfere with the infection process. This is supported by the findings of Nitta^[19,20] who showed that, the diversity of root microflora was increased by FYM application. Moreover, increase in the soil temperature resulting from decomposition of FYM might have adversely affected the nodulating bacteria.

Vegetative Attributes: Phosphorus and FYM insignificantly increased LAI, shoot and root dry matter accumulation, number of branches/plant and plant height. The effect of the two factors on these parameters is depicted in tables (4,5,6&7) respectively. The lack of response to phosphorus may be due to the low mobility and solubility of phosphorus in the soil^[22]. Similar findings were reported by Bakur^[4]. On the other hand, the negative response of phosphorus may be attributed to the alkaline nature of Shambat soil (Table 1). Mengel and Kirkby^[18] reported that phosphate uptake declined rapidly with high increasing pH. In the present study, the insignificant response to FYM may possibly be attributed to the inherently low N content of manure due to the failure for saving the liquid portion of the manure. Additionally, losses of active N substances due to volatilization or locking up as microbial protein by bacteria might have reduced the quality of the manure^[13]. Moreover, the slow acting form of N in the organic matter (OM) may also delay the rapid response to manure. Supporting evidence was reported by

Anderson^[3] who showed that, two thirds of N in the manure is in slow acting forms. On the other hand, the feeding stuffs (cereal fodder) provided to the animals from which manure was obtained is inherently low in N and has high C/N ratio, which makes the resulting manure slow to decompose. This was in harmony with the findings of Harmsen and Van Schreven^[14] who reported that, the narrower the C/N ratio, the higher the effect of manure on crop growth. Interaction of FYM and phosphorus tended to cause a significant increase in the shoot dry weight at the latest stage of plant growth (10th week from sowing) [Table 8]. The greatest effect was achieved by the combination of FYM with 100 kg P₂O₅ ha⁻¹. This might possibly be due to the beneficial effect of FYM application on the availability of phosphorus to the plants. Similar results were reported by Meek *et al*^[17] who pointed out that, the rapid fixation of phosphorus in calcareous soil could be reduced by applying organic phosphorus sources.

Reproductive Attributes: The results show that neither phosphorus nor FYM significantly affected number of flowers/plant, start of flowering and days to 50% flowering. The effects of the two experimental variables on these reproductive attributes are presented in table 9. The lack of response to phosphorus was explained by Fracis^[7] as being mainly due to the capacity of calcareous soils for promptly converting the fertilizer into insoluble forms, which are not available to plants. Similar results were reported by many workers in Sudan and other regions of similar soil properties^[5,21]. The lack of response to FYM may be attributed to the fact that, manure is not a well-balanced fertilizer being rather low in phosphorus and relatively high in nitrogen and potash. This result is in conformity with the findings of Anderson^[3]. In addition to that, FYM deteriorates rapidly in nutritive value when not probably managed.

Table 1: Physical and chemical properties of the topsoil (0-20 cm) and subsoil (20-40 cm) used in the field experimental sites in Shambat

Soil depth [cm]	pH [paste]	EC _e [dS m ⁻¹]	ESP	CaCO ₃ [%]	N _t [%]	P [mg kg ⁻¹ soil]	K [mg kg ⁻¹ soil]	Particle size distribution [%]		
								Sand	Silt	Clay
0-20	8.1	1.5	21.5	3.5	0.02	0.3	0.5	37	24	39
20-40	8.5	1.9	42.1	8.6	0.02	0.5	2.5	30	26	42

N_t: total nitrogen

Table 2: The chemical composition of the farmyard manure (FYM) used in the experiment

Na [mg kg ⁻¹]	Ca [mg kg ⁻¹]	Mg [mg kg ⁻¹]	K [mg kg ⁻¹]	N [%]	P [%]	Crude fiber [%]	Cellulose [%]	Starch [%]
60.1	385	120	462.5	1.2	1.0	22.6	27.5	0.17

Table 3: Effects of P-supply and FYM application on the nodule number per plant of common bean plants grown for 10 week. NS represents not significant. Data are means of four replicates.

	Weeks after sowing				
	5 th	6 th	7 th	8 th	9 th
P supply (Kg P ₂ O ₅ ha ⁻¹)					
0	4.00	3.25	2.38	0.88	1.25
50	1.38	1.50	2.75	0.75	1.63
100	3.13	2.63	1.88	3.00	3.25
150	2.00	5.00	2.75	0.75	0.25
200	4.13	2.63	4.88	2.13	2.63
Significance level	NS	NS	NS	NS	NS
SE ±	1.78	1.96	1.63	1.57	1.40
C.V%	21.8	30.7	11.5	29.8	56.1
FYM (ton ha ⁻¹)					
0	1.10	2.55	2.30	1.40	1.05
2.5	4.75	3.45	3.55	1.60	2.55

Table 3: Continue

Significance level	NS	NS	NS	NS	NS
SE ±	1.58	1.03	0.97	0.41	1.44
C.V%	70.8	18.4	14.8	86.9	22.8
P X FYM interaction					
Significance level	NS	NS	NS	NS	NS

Table 4: Effects of P-supply and FYM application on the leaf area index (LAI) of common bean plants grown for 10 week. NS represents not significant. Data are means of four replicates.

	Weeks after sowing					
	5 th	6 th	7 th	8 th	9 th	10 th
P supply (Kg P ₂ O ₅ ha ⁻¹)						
0	2.94	2.51	2.61	3.43	4.10	2.99
50	3.31	2.08	2.25	2.71	4.64	3.09
100	3.33	1.83	3.25	3.39	4.14	2.86
150	2.58	1.86	2.24	2.99	3.81	2.75
200	3.13	1.89	2.58	2.99	4.26	1.96
Significance level	NS	NS	NS	NS	NS	NS
SE ±	0.75	0.42	0.67	0.73	0.92	0.78
C.V%	49.4	41.8	51.8	46.9	44.0	57.3
FYM (ton ha ⁻¹)						
0	3.12	1.90	2.88	3.03	4.32	2.71
2.5	3.00	2.17	2.30	3.17	4.06	2.76
Significance level	NS	NS	NS	NS	NS	NS
SE ±	0.25	0.36	0.36	0.19	0.80	0.54
C.V%	26.4	56.0	44.5	19.1	60.6	63.0
P X FYM interaction						
Significance level	NS	NS	NS	NS	NS	NS

Table 5: Effects of P-supply and FYM application on the shoot dry matter accumulation (g) of common bean plants grown for 10 week. NS, * represent not significant and significant at $P \leq 0.05$ level respectively. Data are means of four replicates.

	Weeks after sowing					
	5 th	6 th	7 th	8 th	9 th	10 th
P supply (Kg P ₂ O ₅ ha ⁻¹)						
0	4.30	9.05	10.94	19.05	20.09	22.63
50	5.20	8.60	11.69	17.54	25.44	25.47
100	4.85	6.48	12.98	18.80	19.16	26.63
150	4.59	8.53	12.29	18.54	19.00	27.79
200	5.23	7.66	13.61	17.68	20.55	22.67
Significance level	NS	NS	NS	NS	NS	NS
SE ±	0.53	1.16	2.09	2.62	3.34	4.20
C.V%	22.0	28.6	33.9	28.7	32.1	33.6
FYM (ton ha ⁻¹)						
0	4.69	7.35	12.24	16.69	19.10	26.49

Table 5: Continue

2.5	4.98	8.78	12.36	19.96	22.60	23.58
Significance level	NS	NS	NS	NS	NS	NS
SE ±	0.48	0.92	0.47	1.90	1.80	5.63
C.V%	31.7	35.9	12.0	32.8	27.3	71.1
P X FYM interaction						
Significance level	NS	NS	NS	NS	NS	0

Table 6: Effect of farmyard manure × phosphorus interaction on shoot dry weight (g) in the 6th sample.

Treatments	P supply (Kg P ₂ O ₅ ha ⁻¹)					FYM-Mean
	0	50	100	150	200	
FYM (ton ha ⁻¹)						
0	30.10 a	30.15 a	21.00 ab	26.00 ab	25.18 ab	26.49
2.5	15.15 b	20.78 ab	32.25 a	29.58 a	20.15 ab	23.58
P-Mean	22.63	25.47	26.63	27.79	22.67	

S.E. = 5.94

Means followed by the same letters are not significantly different at the 0.05 level of probability according to (DMRT).

Table 7: Effects of P-supply and FYM application on the root dry matter accumulation (g) of common bean plants grown for 10 week. NS represents not significant. Data are means of four replicates.

	Weeks after sowing					
	5 th	6 th	7 th	8 th	9 th	10 th
P supply (Kg P ₂ O ₅ ha ⁻¹)						
0	0.26	0.37	0.50	0.65	1.06	0.77
50	0.28	0.36	0.50	0.72	1.19	1.00
100	0.30	0.32	0.58	0.71	1.05	0.79
150	0.33	0.42	0.53	0.65	1.11	1.03
200	0.31	0.36	0.61	0.69	1.09	0.84
Significance level	NS	NS	NS	NS	NS	NS
SE ±	0.04	0.04	0.07	0.10	0.09	0.12
C.V%	28.1	21.5	26.2	29.4	15.8	27.5
FYM (ton ha ⁻¹)						
0	0.29	0.35	0.54	0.68	1.08	0.94
2.5	0.31	0.38	0.55	0.68	1.11	0.83
Significance level	NS	NS	NS	NS	NS	NS
SE ±	0.01	0.03	0.05	0.04	0.07	0.13
C.V%	8.9	27.8	32.1	20.8	20.3	44.9
P X FYM interaction						
Significance level	NS	NS	NS	NS	NS	NS

Table 8: Effects of P-supply and FYM application on the plant height (cm) and branches number per plant of common bean plants at maturity. NS represents not significant. Data are means of four replicates.

	Plant height (cm)	Branches number plant ⁻¹
P supply (Kg P ₂ O ₅ ha ⁻¹)		
0	68.45	6.75
50	61.84	5.38
100	59.62	5.50

Table 8: Continue

150	64.10	6.25
200	73.24	4.88
Significance level	NS	NS
SE ±	7.22	0.72
C.V%	22.1	25.1
FYM (ton ha ⁻¹)		
0	68.75	5.85
2.5	62.15	5.65
Significance level	NS	NS
SE ±	6.40	0.50
C.V%	30.9	27.3
P X FYM interaction		
Significance level	NS	NS

Table 9: Effects of P-supply and FYM application on some reproductive attributes of common bean plants grown in the field. NS represents not significant. Data are means of four replicates.

	Flower number plant ⁻¹	Start of flowering plot ⁻¹ (day)	Days to 50% flowering
P supply (Kg P ₂ O ₃ ha ⁻¹)			
0	30.63	35.25	39.24
50	24.13	35.13	39.17
100	26.25	36.00	42.00
150	26.75	35.00	41.33
200	29.38	35.00	40.17
Significance level	NS	NS	NS
SE ±	4.23	0.86	1.89
C.V%	30.9	4.9	8.2
FYM (ton ha ⁻¹)			
0	26.85	36.25	38.93
2.5	28.00	34.30	41.83
Significance level	NS	NS	NS
SE ±	1.62	1.52	1.58
C.V%	18.6	13.6	10.8
P X FYM interaction			
Significance level	NS	NS	NS

Conclusions:(1) The beneficial effects of phosphorus to the plants that are grown in Shambat soil are little, due to its heavy clay alkaline nature.

(2) Both nodulation and nitrogen fixation of common bean plants grown in the field are highly sensitive to surrounding environmental conditions.

(3) The lack of response or negative response to FYM may be related to time of application. Thus to avoid possible adverse effects of FYM on nodulation and/or plant growth (e.g., presence of other microorganisms in the FYM or high temperature of decomposition), the FYM should better be applied some time before sowing.

(4) The present study indicated the importance of future studies on common bean nutrition in order to elucidate certain aspects such as nodulation in heavy clay alkaline soils and the question of balanced nutrition.

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