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Growth of Snap Bean (Phaseolus Vulgaris L.) as Affected by N and P Fertilizer Rates at Jimma, Southwestern Ethiopia

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Abstract **– Despite its very recent history of cultivation in Ethiopia, snap bean is one of the potential legume crops that contribute to the efforts for the realization of food security in the country and to earn foreign currency. However, the scientific information available with regards agronomy of snap bean especially the response of snap bean to N and P fertilizers for its optimum production at Jimma is very limited. Therefore, a field experiment was conducted at Jimma, Southwestern Ethiopia to study the growth response of snap bean as affected by different rates of N and P fertilizer rates. Five levels of N (0, 41, 82, 123, and 164 kg ha^{-1}) and four levels of P (0, 46, 92 and 138 kg ha^{-1}) were laid down in a randomized complete block design with three replications. N was applied in two equal splits (50% at the time of sowing and 50% during flowering) as urea and the entire dose of P was applied basal as triple super phosphate at sowing. The main effects of N and P fertilizer levels showed significant differences ($P \leq 0.05$) for all growth parameters studied. The interaction effects of N by P were significant only for root volume. The optimum total pod yield was obtained by the application of N and P at the rates of 82 N kg and 46 kg P_2O_5 ha^{-1}, respectively and beyond those rates there is a non-significant yield increment. Thus, the application of N and P at optimum rates (82 N kg and 46 kg P_2O_5 ha^{-1}) increases the growth and consequently increases the total pod yield of snap bean. However, repeating the experiment for more seasons and similar location would help us draw sound conclusion and recommendations. Hence, future studies should look in to these factors to develop fertilizer recommendation for optimum growth and yield of snap bean in Jimma and similar agro ecology area.**

Keywords **– Growth, N and P Fertilizers, Snap Bean and Total Pod Yield.**

I. Introduction

Snap bean (*Phaseolus vulgaris* L.) is belongs to the e family *Fabaceae*, tribe *Phaseoleae*, subfamily *Papilionoideae* [17], [24], [33]. It was assumed to have originated in North America and Europe [38]. It is a strain of common bean which is developed for succulent pods having little fiber through breeding and selection [7]. It is usually called garden, green, wax or string bean and all are grown for their immature pods. It is used as vegetable and serve as an important source of protein [3], fiber, micronutrients such as Fe and Zn and vitamin A [44].

In 2014 world total production of green beans is 21,720,588 tons from total area of about 1,527,613 ha. In Africa, the productions of snap bean were 695,249 and 72,853 tons, respectively. In Ethiopia the production obtained from green bean was 6,486 tones with the average productivity of 4.12 ton ha^{-1} [15].

Nowadays, snap bean is one of the most important leguminous crops cultivated for direct human consumption and forging currency boosting income in Ethiopia [6]. However, the national average yield of the crop in 2014 is 4.12 ton ha^{-1} which is very low as compared to world average productivity of 14.22 ton ha^{-1} [15]. This problem may be attributed to its production is taking place on smallholder farms with a little utilization of input [10], [16]. On the other hand, soil fertility problems related to soil acidity are common features of the Jimma areas [30], [41]. The major problems associated with soil acidity are toxicity of Aluminum (Al) and Manganese (Mn) and poor availability of essential plant nutrients such as P and N [20].

Generally, in Ethiopia and particularly in Jimma application of fertilizer by smallholder farmers for snap bean is mainly depends on the blanket recommendation (i.e. 82 kg N and 92 kg P_2O_5) and its application is regardless of production area, soil type and fertility status of the soil [27]. Thus, the national central statistical agency (CSA) [9] report of 2013 showed that the grain yield productivity of snap bean in Jimma Zone is low (903 kg ha^{-1}) and even lower than the average national yield (1,262 kg ha^{-1}). This is due to low availability of N and P in the soil and their consequent low uptake by the snap bean and also farmers use the experience of other leguminous families' fertilizer recommendation. In addition, the crop capacity to fix atmospheric N is weak compared to other legumes [32]. Therefore, this experiment was conducted to investigate the effects of N and P fertilizer rates on growth and total pod yield of snap bean at Jimma southwestern Ethiopia.

II. Materials and Methods

Description of the Study Area

The experiment was conducted at Jimma University, College of Agriculture and Veterinary Medicine (JUCAVM) horticulture and plant science research field during 2016/17 cropping season using irrigation. The area is suited at Oromyia regional state, Jimma zone of Southwestern part of Ethiopia which is located at 7^0 33' and 36^0 57' longitude and at altitude of 1710 m.a.s.l. The area receives annual rainfall of 1500 mm. The maximum and minimum temperature of the area is 26.8^{O}C and 11.4 ^{O}C, respectively. The soil of the area was characteristically reddish brown clay soil with p^H from 5.07 to 6.0 [5].

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Composite soil sample was collected from the experiment field to analyze the physicochemical properties of the soil before the experiment was conducted. The analyses were carried out at Jimma University College of Agriculture and Veterinary Medicine, Soil Laboratory. Physical and chemical properties of the top soil (0-30 cm) used in the field experimental site before sowing and after harvest are presented in Table 1.

Table 1. Physicochemical properties soil at experimental site

Soil depth (cm)	pH	Organic carbon (%)	Total nitrogen	Available phosphorus (mg/Kg)	CEC (Cmol (+)/Kg)	Clay	Silt	Sand	Texture group	Remark
0-30	5.71	0.68	0.059	3.95	20	38.66	44	17.34	Silt-clay	Before sowing
0-30	5.94		0.15	13.44						After harvest

Experimental Treatments, Design and Procedures

The fertilizer treatments considered in the study consisted of five levels of N fertilizer (0, 41, 82, 123 and 164 kg N ha^{-1}) and four levels of P fertilizer (0, 46, 92 and 138 kg P_2O_5 ha^{-1}) and their complete factorial combinations. The experiment was then conducted using a factorial experiment laid out in a randomized complete block design with three replications consisting of a total of 20 treatments. The field was plowed with tractor and harrowed to make fine seed bed. The size of each experimental unit was 2.4 m X 1.5 m (3.6 m^2) having six rows, each contains 15 plants. A distance of 0.5 m and 1.5 m were left between plots and blocks, respectively. Snap bean variety B.C. 4.4 seeds were used and two seeds per hole were sown at the recommended planting depth of 6 cm with plant spacing of 40 cm between rows and 10 cm between plants. Triple Superphosphate (TSP) (46% P_2O_5) was used as a source of P and full doses which varied depending on treatments were applied as side banding at sowing time. Urea [CO $(NH_2)_2$] (46% N) was used as source of N and it was applied in two split applications (which is at sowing time and at the time of flowering). Thinning of one seedling per hole was carried out after 15 days from sowing. Other agronomic practices were kept uniform for all treatments as recommended and adopted for the snap bean [27].

III. Results and Discussion

Data depicted on Table 2 showed that there is a significant difference ($P \leq 0.05$) due to the main effects of the levels of N and P application for the means of most of the growth parameters except for root volume in N application. In addition, the magnitudes of the mean squares for the effect of N for each crop parameters were different to that of the corresponding mean squares of P. The mean squares due to N by P interactions were significant only for root volume at P = 0.05.

Table 2. Mean square values for growth and yield of snap bean.

Parameters studied	Mean squares for sources of variation			
	N (4)	P (3)	N X P (12)	Error (40)
Days to 50% flowering	2.31*	6.37***	0.44^{ns}	0.66
Plant height (cm)	124.00***	74.89**	25.59^{ns}	15.47
Leaf area (cm^2/plant)	899965.64**	584345.33**	208173.35^{ns}	134602.60
Number of nodules per plant	1773.84**	2074.33**	466.88ns	319.52
Root volume (ml per plant)	44.56^{ns}	462.60**	122.39*	56.00
Total pod yield (ton ha^{-1})	65.00***	21.29**	4.90^{ns}	3.44

Figures in parentheses = Degrees of freedom; * = Significant at P = 0.05; ** = Significant at P = 0.01; ns = Non-significant.

Days to 50% Flowering

Days to 50% flowering was significantly (P<0.05) affected by the application of different levels of N fertilizer (Table 2). Data presented on Table 3 showed that the longest days to 50% flowering from the application of 164 kg N ha^{-1} which was statistically at par with 41, 82 and 123 kg N ha^{-1} while the shortest days to 50% flowering was recorded from the control (0 N ha^{-1}) treatment. This might be due to the fact that the increased rate of N supply may be attributed to positive role that plays in promoting vegetative growth thereby delayed flowering. This result is in line with finding of [46], reported that the application of N at the highest rate (160 kg N ha^{-1}) in green bean plant delayed days to 50% flowering by five days compared to the control treatment. In the contrary, the lower application of N leads the plant to poor assimilate formation and results in premature flowering, shortening of the growth cycle and reduced yield [19], [22].

On the other hand, days to 50% flowering was highly significantly (P<0.01) affected by the application of different levels of P fertilizer (Table 2). Data depicted on Table 3 showed that the longest days for 50% flowering was recorded from the control (0 kg P_2O_5 ha^{-1}) while the shortest days to 50% flowering was recorded from the application of 138 kg P_2O_5 ha^{-1}. This could be due to P is playing a great role on physiology and biochemistry of plants. This result is in agreement with this finding [23], [39] reported that the application of different rates of P reduced days to flowering in beans.

Table 3. Effect of N and P on days to 50% flowering, leaf area and number of nodules per plant of snap bean

N (Kg N/ha)	Growth attributes DF (Days)	TLA (cm^2/plant)	Number of nodules $plant^{-1}$
0	56.25^b	2898.1^c	128.58^a
41	56.92^{ab}	3202.6^b	123.67^{ab}
82	57.17^a	3511.6^a	110.97^{bc}
123	57.25^a	3571.0^a	107.81^c
164	57.33^a	3412.2^{ab}	98.58^c
LSD (0.05)	**0.67**	**303.21**	**16.03**
P (kg P_2O_5/ha)			
0	57.87^a	3080.1^c	96.80^b
46	57.07^b	3388.0^{ab}	117.11^a
92	56.60^{bc}	3546.5^a	123.58^a
138	56.40^c	3262.0^{bc}	118.20^a
LSD (0.05)	**0.60**	**271.20**	**13.21**
CV (%)	**1.43**	**11.05**	**15.69**

Means within a column followed by the same letter (s) are not significantly different at P = 0.05. DF = Days to 50% Flowering; LA = Total leaf Area (cm^2/plant).

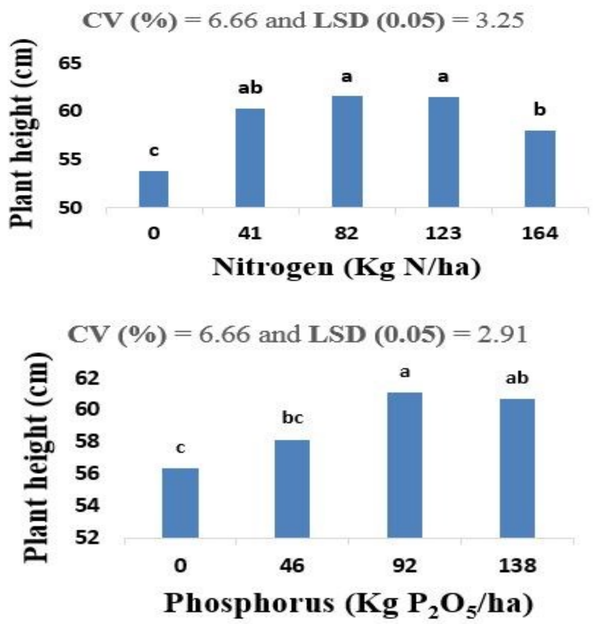
Total Leaf Area per Plant (cm^2 $Plant^{-1}$)

Total leaf area per plant responded significantly and positively to the increasing application levels of both N and P fertilizers at p = 0.01 (Table 2). Data reported in Table 3 showed that the highest total leaf area per plant was obtained at the application of 123 kg N ha^{-1} which is statistically similar with 82 and 164 kg N ha^{-1} whereas the lowest total leaf area per plant was obtained from the control treatment (0 kg N ha^{-1}). This could be due to N promotes the higher photosynthetic activity and vegetative growth and as a result leaf area was increased. Similar result was reported by [4], [22], [46] were also indicated that the highest leaf area as a result of higher rate of N application may be due to N is essential for chlorophyll and protoplasm formation.

Total leaf area per plant responded significantly and positively to the increasing application levels of both N and P fertilizers at p = 0.01 (Table 2). Based on the result the maximum and minimum total leaf area per plant was found from the highest (92 kg P_2O_5 ha^{-1}) and lowest (0 kg P_2O_5 ha^{-1}) rates of P fertilizer applications, respectively (Table 3). The total leaf area obtained at P rate 92 kg P_2O_5 ha^{-1} was statistically similar with 46 kg P_2O_5 ha^{-1}. Hence, the significant effect of P application on leaf area might be due to unique bonding properties of P that make it critical in nucleotide-based metabolic processes and direct involvement of the nutrient in generation of high energy compound such as ATP, which is essential for establishing enzymatic machinery for energy storage and transfer, thereby playing a pivotal role in the synthesis of cellulose and hemicelluloses in leaves. The current result is in agreement with [37], [43], [45] was also reported that with successive increment in P application a significant higher leaf area resulted over the control.

Plant Height (cm)

Plant height was highly significantly (P<0.01) affected by the application of different levels of N fertilizer (Table 2). In this experiment increasing the levels of N up to 82 kg increased plant height from 53.88 cm in the 0 kg N ha^{-1} to 61.55 cm with the application of 82 kg N ha^{-1}. However, the response in plant height obtained at 82 kg N ha^{-1} was statistically at par with 41 and 123 kg N ha^{-1} (Fig 1). The promotion of plant height due to the application of N fertilizer is apparent as N is essential for plant growth since it is a constituent of all proteins and nucleic acids. Similar result was reported by [14], [28], [34] bean plants height was increased due to the application of N fertilization.



Means followed by the same letter(s) are not different at P = 0.05

Figure 1. Effects of N and P rates on plant height of snap bean.

Plant height was highly significantly (P<0.01) affected by the application of different levels of P fertilizer (Table 2). The result showed in Fig 1 indicated that the highest plant height was observed with the application P at the rate of 92 kg P_2O_5 ha^{-1} which was not statistically different from 138 kg P_2O_5 ha^{-1}. While, the lowest plant height was observed from control treatment (0 kg P_2O_5). The promotion of plant height due to application of P could be P is essential for the production and transfer of energy in plants. This finding is in line with [35], [36], who reported that increases in bean plant height due to increasing P fertilizer application rates. In contrast, [43] reported that P rate had no significant effect on plant height in common bean.

Number of Nodules per Plant

Number of nodules per plant was highly significantly (P<0.01) affected by the application of different levels of N fertilizer (Table 2). Result presented in Table 3 showed that the highest value was obtained from the control (0 kg N ha^{-1}) which was statistically similar with 41 kg N ha^{-1} and the lowest value was obtained from the highest N application (164 kg N ha^{-1}) which was statistically similar with 123 kg N ha^{-1}. The possible reason could be the increased in N application increased the availability of N for the plant and this inhibit nodulation development by the native *rhizobia* bacteria. This finding is in line with the finding of [3] who reported that number of nodule per plant suppressed by N application.

On the other hand, applied P was also affect nodulation on snap bean. Based on the result presented in Table 3 the highest number of nodules was obtained from the application of 92 kg P_2O_5 ha^{-1} which was statistically similar with 46 and 138 kg P_2O_5 ha^{-1} and the lowest number of nodule was obtained from the control treatment (0 kg P_2O_5 ha^{-1}). This is due to P have a positive influence in survival and efficiency of *Rhizobium* bacteria which are responsible for fixing atmospheric N in legumes. In line with this work [21], [31], [47] also reported with increasing the application of P the number of nodules was also increased. In contrast, P deficiency is a chief contributing factor limiting BNF in legumes in which it reduces number of nodules [18], [40].

Root Volume (Ml Plant^{-1})

Result showed in Table 2 indicated that there is a significant (P<0.05) effect in root volume due to the combined interaction effect of N and P fertilizers. The highest root volume was obtained from the combined application of N and P at the rate of control (0) kg N ha^{-1} with 138 kg P_2O_5 ha^{-1} which was statistically similar with a combined application of 0 kg N ha^{-1} with 46 and 92 kg P_2O_5 ha^{-1}; 41 kg N ha^{-1} with 0, 46, and 92 kg P_2O_5 ha^{-1}; 82 kg N ha^{-1} with 0 kg P_2O_5 ha^{-1}; 123 kg N ha^{-1} with 46,92 and 138 kg P_2O_5 ha^{-1}; 164 kg N ha^{-1} with 0, 46, 92 and 138 kg P_2O_5 ha^{-1} (Table 4) while the lowest root volume was observed at control treatment (0 kg N with 0 kg P_2O_5 ha^{-1}). The combined application of 0 kg N ha^{-1} with 138 kg P_2O_5 ha^{-1} gave 35 per cent increment on root volume over the control treatments (0 kg N with 0 kg P_2O_5 ha^{-1}). This may be due to applications of N and P fertilizers is apparent as N is essential for root growth and development since it is a constituent of all proteins and nucleic acids whereas P is essential for the production and transfer of energy in plants. [8], [46] were also observed enhanced bean plants root volume due to N fertilization. Similarly, [2], [42] also reported as P has an effect in stimulating root and plant growth.

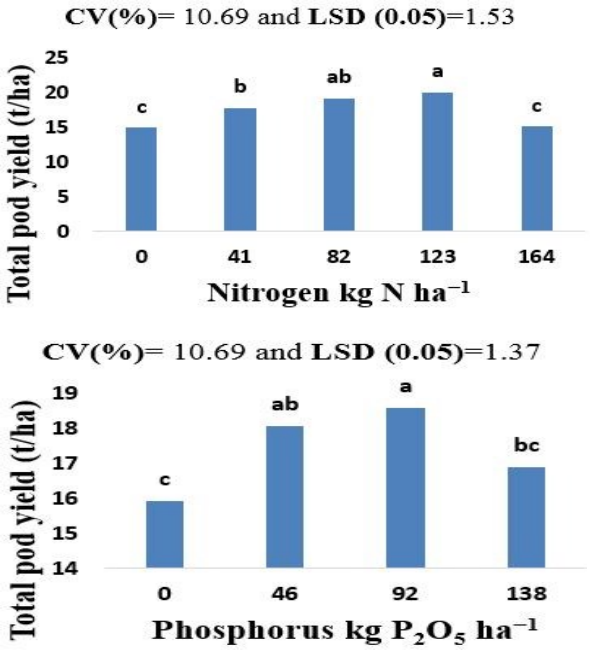
Table 4. Interaction effect of N and P application on root volume of snap bean.

Root Volume (Ml Plant^{-1})					
N (Kg N/ha)	**P (Kg P_2O_5/ha)***				**Mean**
	0	**46**	**92**	**138**	
0	54.57^{c}	66.51^{ab}	67.87^{ab}	73.65^{a}	**54.57**
41	68.50^{ab}	70.69^{ab}	66.88^{ab}	63.07^{bc}	**68.5**
82	67.87^{ab}	63.85^{b}	64.01^{b}	63.07^{bc}	**67.87**
123	63.64^{bc}	70.79^{ab}	65.16^{ab}	67.82^{ab}	**63.64**
164	65.31^{ab}	67.30^{ab}	67.40^{ab}	66.98^{ab}	**65.31**
Mean	**63.98**	**63.98**	**63.98**	**63.98**	**63.98**

* Means across all rows and columns followed by the same letter (s) are not different at P = 0.05; LSD (0.05) = 9.21; CV (%) = 5.71

Total Pod Yield (ton Ha^{-1})

Total pod yield responded highly significantly (P<0.01) to the increasing application levels of both N and P fertilizers (Table 2). The highest total pod yield was obtained from the application of 123 kg N ha^{-1} which was statistically at par with that at 82 kg N ha^{-1} whereas the lowest total pod yield was obtained from control treatment (0 kg N ha^{-1}) which was statistically at par with 164. Kg N ha^{-1}. This shows that further increase in applied N levels beyond the optimum rate resulted in reduction of total pod yield (Fig 2). This could be due to the optimum supply of N plays a great role in almost all plant metabolic processes, increased rate of photosynthesis and vigorous vegetative growth in which it contributes for higher pod yield. The result is in line with the results obtained by [11], [12], [14], [25], [34], who reported with increasing the rates of N yield increased significantly in bean.



Means followed by the same letter(s) are not different at P= 0.05

Figure 2. Effects of N and P rates on total pod yield of snap bean.

In P rates, with increasing the levels up to 92 kg P_2O_5 ha^{-1} increased total pod yield highly significantly (P ≤ 0.01) from 15.93 ton ha^{-1} in the control treatment (0 kg P_2O_5 ha^{-1}) to 18.58 ton ha^{-1} with the application of 92 kg P_2O_5 ha^{-1} (Fig 2). However, the response in total pod yield obtained at 92 kg P_2O_5 ha^{-1} was statistically at par with 46 kg P_2O_5 ha^{-1}. The increase in pod yield might be attributed to overall improvement in growth attributes such as leaf area per plant, plant height and number of primary branch. Similarly, [1], [28], [29] were also reported the increased in pod yield of bean plant by increased application of P fertilizer.

IV. Conclusion

It can be concluded that different fertilizer levels did significantly (p<0.05) influenced most of the growth attributes of the snap bean. Maximum days to flowering (57.33) were recorded at 164 kg N ha^{-1} whereas the maximum number of nodules was recorded from the control

(0 kg N). The total leaf area per plant and plant height were recorded the maximum value for plants subjected to highest dose of applied N fertilizer viz., 123 kg ha^{-1}, in which it was statistically at par with applied 82 kg N ha^{-1}. On the other hand, response toward added P fertilizer rates also indicated that the minimum days to 50% flowering (56.40) was recorded at 138 kg P_2O_5 ha^{-1} whereas the maximum number of nodule was recorded at the application of 92 kg P_2O_5 ha^{-1} in which it was statistically similar with 41 and 138 kg P_2O_5 ha^{-1}. In case of plant height (61.05 cm) and number of leaves $plant^{-1}$ (4.89) the maximum resulted for plants subjected to highest dose of applied P fertilizer viz., 92 kg P_2O_5 ha^{-1}, in which it was statistically at par with applied 46 kg P_2O_5 ha^{-1}. Likewise, total pod yield showed a significant effect on the application of N and P independently and the highest values were recorded at rates of 123 kg N (20-ton ha^{-1}) and 92 kg P_2O_5 ha^{-1} (18.58 ton ha^{-1}) in which it was statistically at par with application of 82 kg N ha^{-1} (19.17 ton ha^{-1}) and 46 kg P_2O_5 ha^{-1} (18.06 ton ha^{-1}), respectively. This indicated that increasing the rates of both N and P fertilizer beyond 82 kg N and 46 kg P_2O_5 ha^{-1}, respectively resulted in a non-significant yield increment. Hence, the application of N and P at the optimum rates (82 N kg and 46 kg P_2O_5 ha^{-1}) resulted in increase the growth attributes of snap bean and consequently increases the total pod yield. However, repeating the experiment for more seasons and similar location would help us draw sound conclusion and recommendations. Hence, future studies should look in to these factors to develop fertilizer recommendation for optimum growth and yield of snap bean in Jimma and similar agro ecology area.

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