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Full Length Research

Elucidating the Role of Phosphorous on Growth Performance and Yield components of Haricot bean *(Phaseolus vulgaris L.)* at Arba Minch, Southern, Ethiopia

[*1]Azmera Walche and [2]Pellegrino Conte.

[1]Horticulture department , College of Agricultural Sciences, Arba Minch University, Ethiopia
P.Box number: 21 Arba Minch
[2]Department of Agriculture and Forestry Science, University of Palermo, viale delle Scienze ed. 4, 90128 Palermo, Italy

Corresponding Author' E-mail: *Email: azmeralove@yahoo.com, Email: pellegrino.conte@unipa.it

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Haricot bean (*Phaseolus vulgaris L.*) is an important cash crop for many farmers and source of protein in many parts of Ethiopia. However, its production is prominently affected by deficiency of phosphorus. Therefore, a field experiment was conducted at Arba Minch University demonstration farm during March-July 2015 cropping season in order to evaluate the response of haricot bean to different doses of phosphorus amendment and its role on growth, dry matter yield and yield components of the crop. Five doses of phosphorous (0, 10, 20, 30 and 40kgha^{-1}) have been applied. Experiment was laid out in randomized complete block design (RCBD) with three replication. Haricot bean variety dinknesh was used as planting material. Phosphorus amendment significantly increased leaf area, dry matter, and crop yield whereas plant height, number of branches per plant , number of pods per plant, number of seeds per plant were not significantly affected. From our statistical findings apparent from the table and figures, we conclude that phosphorous fertilizer rates of 20 kgha^{-1}. is the optimum dose to enhance the yield in haricot bean. Moreover, we recommend 20 kgha^{-1}dosage of phosphorous fertilizer to haricot bean producing farmers. Furthermore, the recommendation is specific to the farm lands that share similar physical, chemical, biological properties to the soil in Arba Minch University demonstration farm, Southeren, Ethiopia.

Keywords: Haricot beans, Diammonium phosphate, dry matter, phosphorus and yield.

INTRODUCTION

Background and Justification

Haricot bean (*PhaseolusVulagris*L), locally known as 'Boleqe' also referred to as dry bean, common bean, kidney bean and field bean is a very important legume crop grown worldwide. It is an annual crop which belongs to the family *Fabaceae*. It grows best in warm climate at temperature of 18 to 24^{o}C(Teshale et al., 2005). Haricot bean was probably first cultivated with maize, and it seems likely that the two crops evolved together in a cereal-Legume farming system in much the same way as cowpeas and sorghum in West Africa (CACC, 2002). It is widely cultivated throughout different parts of Ethiopia. It is produced in four major agro-ecological zones, including central, eastern, southern and western zones. Additionally farmers also grow the bean to use as forage for livestock and mulching. It can be used in intercropping system with maize and between young trees until canopy closure.

In Ethiopia, Haricot bean is grown predominantly under smallholder producers as an important food crop and source of cash. It is one of the fast expanding legume crops that provide an essential part of the daily diet and foreign earnings for most Ethiopians (Girma, 2009). The major haricot bean producing areas of Ethiopia are central, eastern and southern parts of the country (CSA, 2011). The crop grows well between 1400 and 2000 m above sea level (Fikru, 2007). In 2011/12, total Haricot bean production in the country was about 3,878,023.01 quintals (1.77% of the grain production) on approximately 331,708.15 hectares of land (2.74% of the grain crop area) (CSA, 2011).

Yield of legumes in farmers' field is usually less than 0.65tha^{-1} against the potential yield of 1.2 t ha^{-1}thereby suggesting a large yield gap (CACC, 2002). Low yield potential of legumes has made them less competitive with cereals and other high value crops. The average national productivity of haricot bean is 0.72t ha^{-1} (CACC, 2002) and its regional productivity is 0.81 t ha^{-1}.As source of food, it is extensively consumed in traditional meals, and being part of the diet of the farming households, it serves as a source of protein to supplement the protein deficient main dishes like maize and enset in the southern parts of our country. Besides, the farmers also grow the bean to use the straw as forage for livestock, source of fuel, mulching, bedding, and covering material for houses of poor farmers(Journal of Biology, Agriculture and Healthcare www.iiste.org, 2014).

Despite all these advantages, little effort was made to improve its productivity and the yield is comparatively low because of depletion of nutrients as a result of erosion and crop mining, lack of optimum fertilizer rate, etc. Haricot bean has high nitrogen requirement for expressing their genetic potential. However, as bean has the ability to fix and use atmospheric nitrogen with regards to soil fertility and mineral nutrition requirement, phosphorus is considered as the first and nitrogen as the second limiting plant nutrient for bean yield in the tropical zone of cultivation. Moreover, phosphorus plays an important role in biological nitrogen fixation. For the symbiotic fixation of nitrogen to occur, the roots have to interact with compatible rhizobia in the soil and factors that affect root growth or the activity of the host plant would affect nodulation Bacterial growth, nodule formation, and the biological nitrogen fixation activity itself are processes that are dependent on the energy supplied from the sugars that need to be transacted down ward from the host plant shoots. Therefore, phosphorus is the basis for the formation of useful energy, which is essential for sugar formation and translocation. Haricot bean crop dependent on nitrogen fixation needs more inorganic phosphorus than the same crop provided with mineral nitrogen. Haricot beans are therefore typically susceptible to low soil phosphorus when accompanied by low soil.

Phosphorus unavailability in soil is a major constraint to haricot bean production in the tropics. Among the essential plant nutrients, nitrogen and phosphorus are often deficient in many soils of tropical Africa as well as in many Ethiopian soils. In the tropics, the amount of available phosphorus in soils is largely insufficient to meet the demand of legumes and thus phosphorus deficiency is prevalent in pulse crops (*World Journal of Agricultural Research*, 2014).

Statement of the Problems

Haricot bean is nowadays widely grown in several areas of the country and have high economic importance. However, in the tropics, the amount of available phosphorus in soils is largely insufficient to meet the demand of legumes and, thus, phosphorus deficiency is prevalent in pulse crops. One of the solutions to alleviate such problem can be application of P fertilizers from external sources based on recommended crop specifics doses. In order to make site specific recommendation of P for Haricot bean production, characterization of the soil at the experimental site, and nutrient rate experiment was found vital. So far, no studies are conducted on determination of optimum phosphorus fertilizer rate for production of Haricot bean at Arba Minch, Ethiopia. Therefore, this study was conducted in order to fill this gap and to know optimum rate of fertilizers in the study area.

Objective of the Study

General Objectives

This study was initiated with general objectives to elucidate responses of haricot bean to rates of phosphorous fertilizer

Specific Objectives

- To evaluate the role of different rates of phosphorus on the growth characteristics of haricot bean.
- To evaluate the response of haricot bean to different rates of Phosphorous
- To characterizes the soil of the experimental site,
- To evaluate rates of phosphorous fertilizer on growth performance and yield.
- Acquire of information on influences of phosphorus in growth, dry matter and yield component of haricot bean.
- Evaluate the role of phosphorous on the growth and yield parameters of haricot bean

- To identify optimum level of phosphorous at experimental area.

MATERIALS AND METHODS

Experimental Site Description

The experiment was conducted at Arba Minch University, production and demonstration farm. Arba Minch University is located 495 km south of Addis Ababa. It has an altitude of 1218 m.a.s.l, longitude of 37.36°E and 6.04°N. In Arba Minch, there are two months where rain fall is abundant. They are April and May where 161.8mm and 151.2 mm of rain fall is recorded respectively and the lowest rain fall in January and February which is 32 mm and 9 mm respectively. The mean annual rainfall is recorded 500-1100 mm, the annual average air temperature is 17-39°C and the mean soil temperature is 22-35 °C in different depth of soils.

Experimental Material and Method

The area intended for the experiment was prepared by manually.. The prepared land was divided in to three blocks and block was divided in to five plots. The spacing between plots and blocks was 1m and 1.20m respectively. The haricot bean dinkinesh seed was planted according the standard planting depth 5cm and the spacing between rows and between plants was 40cm and 10cm respectively. The application of phosphorous fertilizer for each plot was applied as side-dressing during sowing time. After sowing and watering was conducted immediately by using furrow irrigation method. Then all other agronomic practices were conducted following the standard procedure.

Experimental Design and Treatment

The experiment was laid out in Randomized Complete block Design (RCBD) with five treatments and 3 blocks. The Di-ammonium phosphate (DAP) was used as source of phosphorus for this experiment. The level of P that was used for total area of the experiment conducted was 129.6gram. The applied level for each treatment was 0, 10, 20, 30, and 40kgha^{-1}, respectively. The total area of the experiment was124.8 m^2, 7.8 m width and 16 m length. The plot had a width of 1.8 m and length of 2.4 m. The area of a single plot was 4.32 m^2 and the area of a single block was 25.2 m^2. The number of plants with in each plot was 85 in number. The number of plants within each block was 425 and the total number of plants with the experiment was 1275.

Soil Sample Collection and Laboratory Analysis

Soil samples, 0-30 cm depth, was collected from representative spots of the entire experimental field by using diagonal sampling method before planting and the composite sample was obtained. The soil was air dried and grounded fine by using mortar and pestle. The fined soil was sieved through 2 mm sieve size. pH and EC were determined in Arba Minch university soil Laboratory. The pH of the soil was measured using pH-Meter 3510Jenway. The electrical conductivity of the soil was analyzed by using EC meter 4510 Jenway.The soil texture was analyzed by using Bouyoucos hydrometer method and the textural class was determined by using the soil textural triangle. The soil moisture was analyzed by gravimetric sampling method. Determination of organic matter and total organic carbon was analyzed by using Muffle furnace at 440^{0}C in chemistry laboratory. Determination of Available $PO_4^{-3}$was done by Mehlich I-Extractable Method and the absorbance of the standards and samples was recorded at 882nmwavelength by using Uv-Visible spectrophotometer. Determination of Total Phosphorus was done by perchloric acid digestion. Total Nitrogen was determined by Kjeldhal Method. Estimation of available nitrogen of soil sample was determined by Alkaline potassium permagnate method (Subhaiah and Asija, 1956).Total potassium and available potassium was analyzed by elemental analysis of soil samples using atomic absorption spectrophotometer.

Agronomic Data Collection

Data on plant height, leaf area, number of branches per plant, number of pods per plant, number of seed per pod, dry matter and yield was collected from five pre tagged plants of each two middle rows to reduce error due to boarder effect. The plant height was measured from the base of the plant to the apical bud of plant and expressed in centimeters. Leaf area was measured by using a leaf area meter 211(sq.cm). The number of branches per plant was recorded by counting branches from each five pre tagged plants and the mean was calculated. Pods from pre tagged plants were counted and were recorded as number of pods per plant. Seeds per pod was counted from five representative pre tagged plants and mean value was recorded as number of seeds per pod. Dry matter was analyzed from the representative five plants by cutting above ground part and air dried. The samples were air dried and weighed using sensitive beam balance. The mean was recorded as dry matter of the plant (g).

Method of Data Analysis

Data on plant height, leaf area, number of branches per plant, number of pods per plant, number seed per pod, dry matter and yield was statically analyzed using the SAS version 9.1 software and significant means were separated using Least significant difference(LSD) at a probability level of 5%.

RESULTS AND DISCUSSION

Physical and Chemical Properties of top Soil (0-30cm depth) Before Sowing and After Harvesting of Haricot Bean Crops.

Table1: Chemical and physical properties of top soil (0-30cm depth) of experimental sites before sowing

S.No.	Nutrient content and textural class	Analytical and textural results of soil
1	Available PO_4^{3-} in ppm(gkg^{-1} soil)	0.323 ± 0.009
2	Available Nitrogen in ppm(gkg^{-1} soil)	0.27 ± 0.04
3	Available potassium in ppm(gkg^{-1})	12.20 ± 0.07
4	Total Phosphorous (%)	0.389 ± 0.007
5	Total Nitrogen (%)	0.304 ± 0.004
6	Total Potassium (%)	20.1 ± 0.8
7	Organic Matter (%)	6.8 ± 0.2
8	Total Organic Carbon (%)	2.30 ± 0.08
9	EC($mscm^{-1}$)	0.22 ± 0.007
10	Ph	7.6 ± 0.014
11	Moisture content (%)	35 ± 4
12	Sand (%)	62 ± 1
13	Clay (%)	4 ± 1
14	Silt (%)	33 ± 1
15	Textural classification	sandy loam soil

Table 2: Chemical and physical properties of soil (0-30cm) of experimental sites after harvesting

S.No.	Nutrient content and textural class	Analytical and textural results soil
1	Available PO4-3 in ppm(gkg^{-1} soil)	0.378 ± 0.008
2	Available Nitrogen in ppm(gkg^{-1} soil)	0.292 ± 0.006
3	Available potassium in ppm (gkg^{-1} soil)	13.25 ± 0.08
4	Total Phosphorous (%)	0.457 ± 0.008
5	Total Nitrogen (%)	0.4360 ± 0.0007
6	Total Potassium (%)	22.9 ± 0.3
7	Organic Matter (%)	7.2 ± 0.3
8	Total Organic Carbon (%)	2.4 ± 0.1
9	EC($mscm^{-1)}$	0.22 ± 0.007
10	pH	7.6 ± 0.01
11	Moisture content (%)	35 ± 4
12	Sand(%)	62 ± 1
13	Clay(%)	4 ± 1
14	Silt(%)	33 ± 1
15	Textural classification	sandy loam soil

The available phosphorus of the experimental sites was higher after harvesting than before planting (Tables 1 and 2). The difference in Available phosphorous concentration in soil might be resulted from changes in biological and geochemical processes at different activities after human disturbances.

Table 3: Influences of phosphorous nutrient on Growth performance, yield and yield components of Haricot bean

P kg/ha	plant height/plant	leaf area/plant	Number of branch/plant	Number of pods/plant	Number of seed/pod	Dry matter in gram/plant	Yield q/ha
0.00	100±13[a]	56±6[c]	5±2[a]	43±4[a]	6.1±0.2[a]	67±13[b]	58±2[b]
10.00	113±14[a]	58±8[bc]	5±1[a]	46±13[a]	6.3±0.4[a]	81±15[b]	77±9[b]
20.00	121±15[a]	66±5[abc]	4±1[a]	54±16[a]	6±1[a]	119±9[a]	104±11[a]
30.00	122±14[a]	68±2[ab]	4.9±0.4[a]	50±11[a]	6.3±0.6[a]	83±23[b]	75±17[b]
40.00	108±5[a]	69±4[a]	4.5±0.8[a]	41±5[a]	6.2±0.4[a]	79±19[b]	69±8[b]
Grand mean	113±14	64±7	5±1	47±10	6.2±0.4	86±23	77±18
CV	11.3	8.63	28.1	23.1	7.7	19.1	13.7
LSD	1.61ns	3.51*	0.23ns	0.72ns	0.29ns	4.30*	4.30*

Means with the same letter in the same column are not significantly different.
Ns- Statistically not significant, * significant at $P<0.05$

Application of P might have contributed in releasing some amount of fixed P to be available for crop. This also indicates that deficiency of P cannot be replaced other atoms. As result in soil which are deficient in Organic Matter, Total Organic Carbon, Available phosphorous, Available Nitrogen, Available potassium, Total Phosphorous, Total Nitrogen, Total Potassium are important to apply P together with nutrients to increase crop production. Soil analysis of the experimental location before sowing and after harvesting showed that similar PH and EC values. Textural analysis showed that the same textural class before and after planting was sandy loam soil.

Plant Height

The application of P fertilizer had no significant role on plant at $P<0.05$. The high plant height (122 cm) was recorded on application rate of 30kg ha^{-1}. Moreover, application of 20kgha^{-1} has showed high plant height (121cm) next to P 30 kg ha^{-1}. On the other hand, there was no significant difference on plant height. This result is inagreement to that reported by Birhan (2006) where he found a non-significant response of plant height to P application on haricot bean. The least plant height (100 cm) was recorded with the control (0kg P ha-^{1}). The highest rate of P application at the study not resulted significant difference on plant height. This may be due to high dose of phosphorous fertilizer tends to flowering, fruiting, seed formation, nutrient interaction and may affect the availability of other nutrients which are important for vegetative growth of the haricot bean.

Leaf Area

The phosphorous application at all rates resulted in a significant higher leaf area compared to the control (Table 3). The highest leaf area (69.02cm^2) and (68.06 cm^2) were recorded at rate application of 40kg pha^{-1} and 30kg p ha^{-1} respectively. There was significant difference among means of applied fertilizer rates. Significant increase in leaf area was observed with increment in P application from 10 to 40 kg ha^{-1}. Similarly, significant increase in application from 25 to 75kgha^{-1}(Veeresh, 2003). The lower leaf area was recorded at control treatment. This might be due to deficiency of available P at the study site which does not provide fast and vigorous growth of haricot bean. The leaf area of haricot bean decreased at control.

Number of Branches per Plant

The application of P fertilizer did not significantly affect the number of branches per plant (Table 3). The number of branches per plant decreased with increasing phosphorus doses. The highest number of branches per plant was recorded at control. This is in contrast with the result reported by Shubhshree, (2007), where significantly higher number of branches per plant was recorded with 75kg $P_2O_5ha^{-1}$. The mean of P fertilizer applied revealed higher number of branches per plant at control. The least number of branches per plant (4.53) was recorded at 40 P kg ha^{-1}.

Number of Pods per Plant

The application of P fertilizer had not significantly increased the number of pods per plant (Table 3). The higher number of pod per plant (53.93) was recorded with P rates of 20kgha^{-1}. The same result were reported by (Meseret, 2014). All P fertilizer rates increased pods per plant over the control except at P 40kgha^{-1}. The

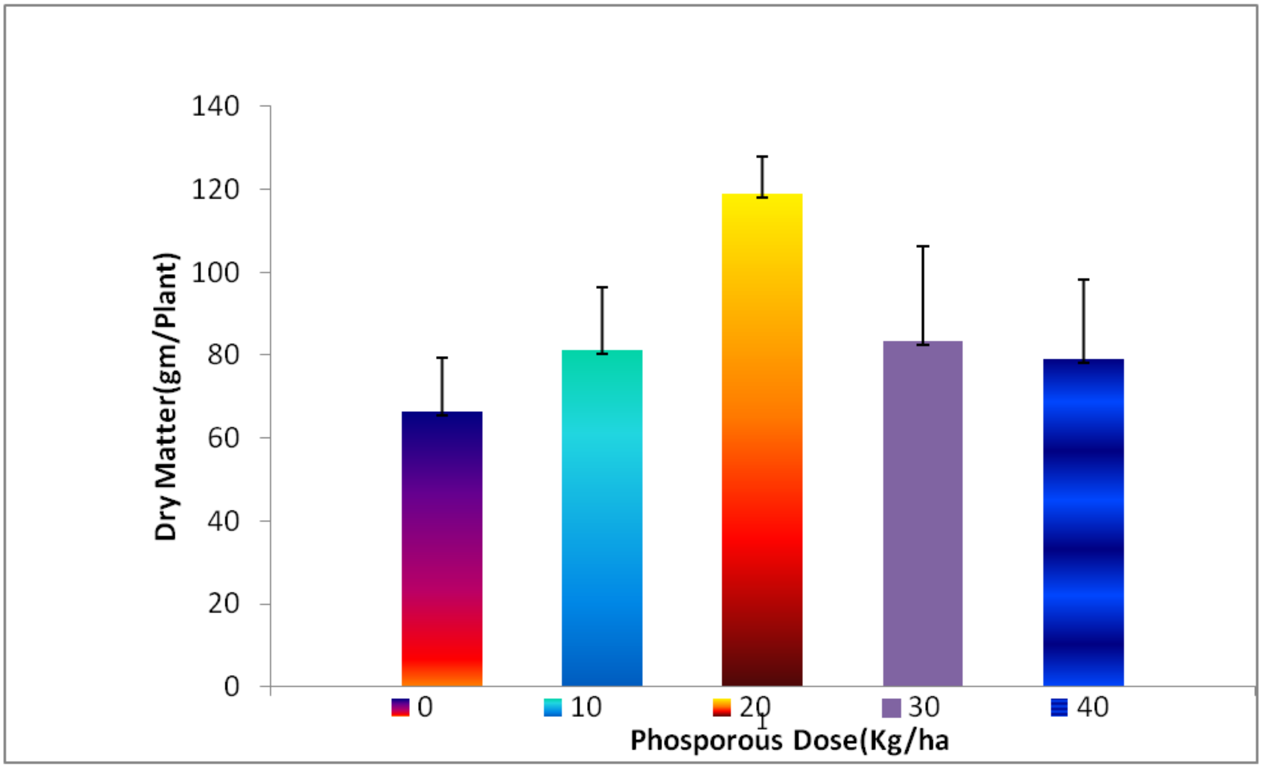

Figure 1: The role of Phosphorus on the dry Matter of Haricot bean (Mean± standard deviation**)**

lowest pods per plant (41.13) were recorded at P 40kgha^{-1}. The result is similar to (Shubhashree, 2007), which reported that application of different rates of phosphorous fertilizer influences number of pods per plant and significantly revealed that more number of pods per plant of common bean 75kg P_2O_5ha^{-1}(Veeresh N.K, 2003). Similar result was revealed in number of pods per plant, due to increased P application (Singh A. and Singh S.S, 2000). Also increase in number pods per plant with increasing P fertilizer rates (Meseret, 2014). Thus the increment of number pods per plant due to application of P fertilizer confirms with P fertilizer promotes the formation of nodes and pods in legumes (Buttry B.R, 1969).

Number of Seeds per Pod

Phosphorus fertilizer application has no significant response to different rates of P application on number of seeds per pods. The highest (6.32seed/pod) of seed per pod was recorded at rates of 30 P kgha^{-1}where as the lowest (5.97seed/pod) was recorded at rates of 20 p kgha^{-1}. The result of the study were in agreement with findings of (Shubhashree, 2007), who reported that number of seeds per pod increased significantly to increased level of phosphorous fertilizer. Similarly, increment of seed per pod with increasing P fertilizer application to optimum level might be due to formation of P fertilizer for nodule formation, protein synthesis (Meseret, 2014). Increasing of seeds per pod with increasing P fertilizer application to correct level among the more significant function and qualities of plant on which phosphorous has important effects for photosynthesis, nitrogen fixation, flowering and fruiting, seed formation and root developments.

Dry Matter

The application rates of P fertilizer have significantly increased the dry matter yield of haricot bean at the $p<5\%$. There was a significant difference among the five levels of P nutrient rates (Figure 1). The maximum 119gplant^{-1} dry matter yield was recorded at application of P 20kgha^{-1}, whereas the minimum (67gplant^{-1} was recorded at control. This result was in agreement to Shubhashree, (2007) where he reported dry matter accumulation increases with application of phosphorus rates. Similarly, the increment in dry matter with application of P fertilizer might be due to the adequate supply of could be attributed to an increase in number of branches per plant, and leaf area (Mesert, 2014). This is compatible to Veeresh, (2003) who reported significant and linear increase in total dry matter production of common bean plant was observed due to increased

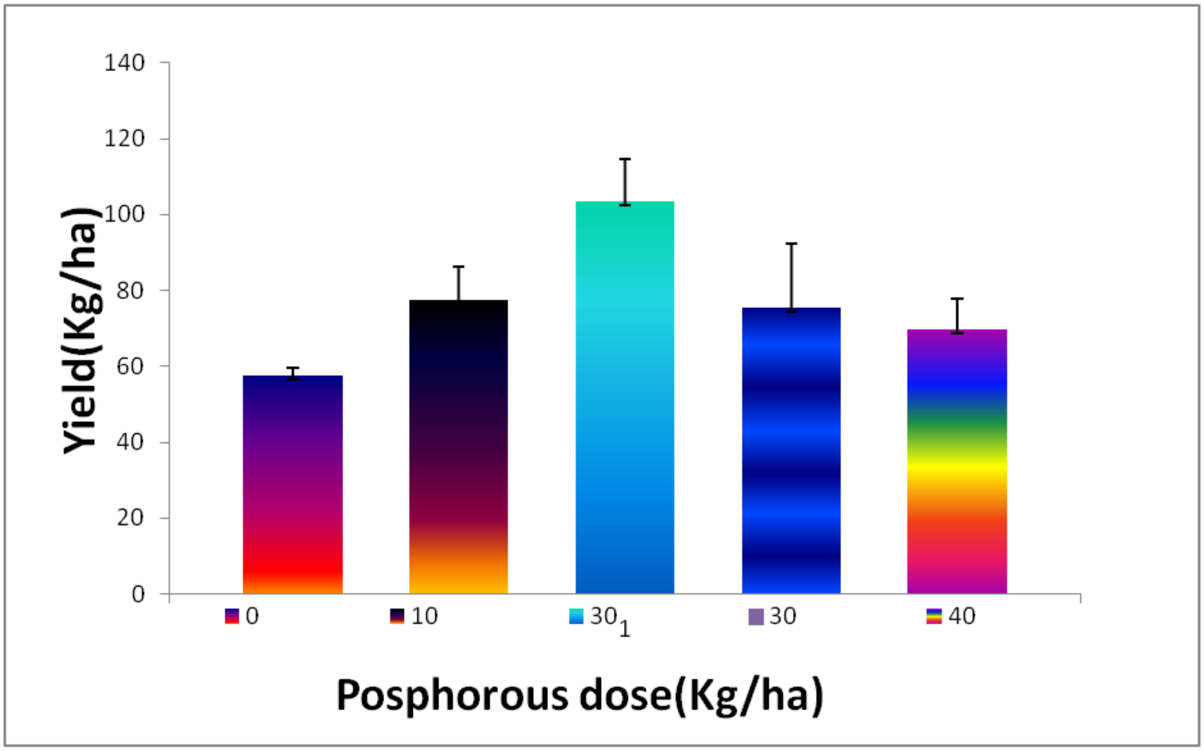

Figure 2: The role of Phosphorus on the yield of Haricot bean((Mean± standard deviation**)**

phosphorous. Also similarly, this is in agreement with the study conducted on soybean indicated that increasing the phosphorus concentration in the soil increased the whole dry matter accumulation and total leaf area (Jennifer D.C, 2000).

The increment in dry matter with increasing application of P fertilize might be due to the adequate supply of P could be characterized to an increase plant height, leaf area and number of pods per plant. This increment in dry matter is related to the function of P. P is involved in many vital plant growth processes. The most essential function is energy storage and transfer. Adenosine di- and triphosphates (ADP and ATP) act as "energy currency" within plants. Since energy obtained from photosynthesis and metabolism of carbohydrates is stored in phosphate compounds for subsequent use in growth and reproductive processes, the increment in dry matter with application of P fertilizer. This revealed increase number of seeds per pods, number of pods per plant and photosynthetic area, which determines a strong direct correlation with dry matter accumulation and yield.

Yield

There was significant variation among the different doses on yield of haricot bean at the probability level of 0.05. The maximum (104qha^{-1}) yield was recorded at application of P 20 kgha^{-1} whereas the minimum (58qha^{-1}) was recorded at control. There was significant variation among the five levels of P fertilizer rates (figure 2). This result was similar to Mesfin Kassa, (2014) who reported that P improves availability of P for crops and also external P application improved crop yield performance. The result may be attributed to the fact that application of phosphorous fertilizer increases crop growth and yield on soil which is naturally low in P and in soils that have been depleted (Mullins, 2001). The application of P fertilizer had positive effect on yield because fertilized plots gave better yield compared to control plot (P 0kgha^{-1}). The optimum application P fertilizer revealed at P application of 20kgha^{-1}in Arbaminch SNNPRS, Ethiopia. Grain yield was generally higher at fertilized plot compared to control.

CONCLUSION AND RECOMMENDATION

Application of the optimum level of fertilizer is necessary to achieve maximum yield of haricot bean crop. The present study was initiated to assess the elucidating the role of phosphorus on growth performance, dry matter and yield component of haricot bean. The applied P fertilizer levels were revealed a significant difference on leaf area, dry matter and yield of haricot bean. The application P 20 kg ha^{-1}has significantly increased leaf area, dry matter and yield of haricot bean. While, application of 40 kg P ha^{-1} was declined number of branch per plant and number of pods per plant as compared to control. There was a significant increase on growth parameters of haricot bean crop as rates of P fertilizer increased. Maximum values of leaf area, dry matter and yield were recorded at application rates of 20kg P ha^{-1} on haricot bean at experimental location. Based on the result obtained, it is possible to conclude and recommend that phosphorus fertilizer rate of 20kgha^{-1} was optimum to increase yield of haricot bean in Arba Minch Southern, Ethiopia and similar agro-ecological zones which have the same physiochemical properties of soils.

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