Journal of Agriculture and Crops
ISSN(e): 2412-6381, ISSN(p): 2413-886X
Vol. 5, Issue. 9, pp: 151-157, 2019
URL: https://arpgweb.com/journal/journal/14
DOI: https://doi.org/10.32861/jac.59.151.157

Academic Research Publishing Group

Original Research Open Access

Quality of Snap Bean (*Phaseolus Vulgaris L.*) as influenced by N and P Fertilizer Rates at Jimma Southwestern Ethiopia

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Abstract

Snap bean is a warm-season crop harvested for its immature seed pods. In Ethiopia its production increased from time to time for both export and local markets. A field experiment was conducted at the research field of JUCAVM, during 2017 cropping season using irrigation aiming to improve the quality of snap bean. 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 planting and 50% during flowering) as Urea and the entire dose of P was applied basal as triple super phosphate at sowing. In this experiment pod length, pod diameter, pod protein concentration, pod straightness and marketable pod yield were measured as quality parameters. The results revealed that the main effects of N and P fertilizer rates showed significant differences ($P \leq 0.05$) for all quality parameters except for percentage of pod protein concentration and straightness of pod. Accordingly, the interaction effects of N and P were significant for percent of pod protein concentration and straightness of pod. Considering the major quality parameters and marketable pod yield applying 82 kg N ha $^{-1}$ and 46 kg P2O5 ha^{-1} gave better result to increase the quality of snap bean in Jimma area. However, repeating the experiment for more seasons and similar location would help us draw sound conclusion and recommendations.

Keywords: N and P fertilizer; Protein concentration; Pod yield; Quality and snap bean.

1. Introduction

Snap bean (*Phaseolus Vulgaris* L.) is cultivated and growing in over continents of the world except Antarctica [1]. Global and Africa production of snap bean in the year 2017 is nearly 24.2 and 0.76 million metric tons of fresh pods yield. In Ethiopia its production was nearly 7384 tons with average productivity of 4.1 t ha^{-1} in which it is very low compared to world and Africa average productivity of 15.3 and 9.37 ton ha^{-1} respectively [2]. It has been among the most important and highly prioritized crops as a means of foreign currency earning in Ethiopia [3]. As a vegetable, snap bean is high in protein and soluble fiber and low in calories. Snap beans are an excellent source of vitamin K and are a very good source of manganese, vitamin C, dietary fiber, vitamin B2, copper, vitamin B1, chromium, magnesium, calcium, potassium, phosphorus, choline, vitamin A (in the form of carotenoids), niacin, protein, omega-3 fatty acids, iron, vitamin B6, vitamin E, and contains valuable quantities in absorbable form of the mineral silicon [4].

Snap bean is grown as cash crop by large- and small-scale farmers in East Africa [5]. The immature pods and seeds are produced and marketed fresh, canned or frozen products [6]. Its Production and productivity determined by its genetic potential and environment to which the crop is exposed. Improving one or combination of potentially yield limiting factors may lead to an increase in its productivity [7]. In Africa, specifically in Ethiopia Snap bean has low yield and quality due to both biotic and abiotic factors. Factors associated to biotic factors includes disease and pests, varieties with low yield potential and susceptibility to disease and pests whereas abiotic factors are associated with soil related problems and N and P deficiency from the soil are the most common problems [8, 9].

Soil studies in Jimma area indicated that about 88 % of the soil had available P below the critical level (10-15 ppm) and also the total nitrogen was found as one of the limited plant nutrient in this area. The reason for the decline of total N in cropped fields can be N leaching problem as the area receives high rainfall and farmers have a limited cultural practice to integrate leguminous plants on their farmlands [10, 11]. According to Tantawy, *et al.* [12], Abdel-Mawgoud, *et al.* [13], yield and quality of snap bean were significantly improved by applying macro and micro nutrient mainly N and P. The imbalance supply of these nutrients results in poor plant growth, cell division, crop quality and yield, reduction in pest and diseases resistance and exposure to different physiological disorder [14]. Therefore, efficient use of N and P nutrients are required by snap bean growers.

In Ethiopia the application of nutrients 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 [15]. Whereas, different studies have suggested the response of snap bean to N and P application is site specific and agro-ecology dependent [16-18]. This calls for further studies in Jimma area where information is scares and the crop has growing well.

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2. Materials and Methods

2.1. 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 located at Oromyia regional state, Jimma zone of Southwestern part of Ethiopia which is located at 70 33' and 360 57' longitude and at an altitude of 1710 m.a.s.l. The area receives average annual rainfall of 1624 mm. The mean maximum and minimum temperature of the area is 26.7^{O}C and 11.2^{O}C, respectively [19]. The soil of the area was characteristically reddish-brown clay soil with pH from 5.07 to 6.0 [15]. 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 JUCAVM, soil laboratory. Physicochemical properties of the soil (0-30 cm) used in the field experimental site both before sowing and after harvest for soil analysis of the experimental site (Table 1).

Table-1. The physicochemical properties of a soil of the 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 (Moderately Acidic)	0.06 (Very low)	0.005 (Very low)	3.95 (Very low)	20	59.34	23.33	17.33	clay	Before sowing
0-30	5.9 (Moderately Acidic)		0.15 (Medium)	23.3 (Medium)		59.34	23.33	17.33	clay	After sowing

2.2. Experimental Treatments, Design and Crop Management

The treatment was 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}) in a factorial combination. The experiment was laid out in a randomized complete block design with three replications. 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 contain 15 plants, 0.5 m and 1.5 m distance 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 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 (50% at sowing time and 50% at the time of flowering). Thinning of one seedling per hole was carried out after 15 days from sowing. Other agronomic practices like land preparation, weeding, watering, cultivation and pest control were kept uniform for all treatments as recommended and adopted for the snap bean [15].

2.3. Data Collection

Marketable pod yield (t/ha): The pods were sorted based on visual observations and measurement; and pods which are free from insect and disease damage, uniform in color, slightly curved and straight, pod length (12-16cm) and pod diameter (8-12mm) was considered as marketable and finally the marketable yield per plot was converted to tons per hectare [20].

Fibreless nature: Fiber content determined as snap ability was assessed by breaking the pod and observed visually. It was rated on a scale of 1 to 3 where (1= fibrous nature, 2= moderately fibrous and 3= fibreless nature) and this was done on 25 randomly selected pods per plot [21].

Pod Straightness: Twenty-five randomly selected pods per plot were taken and separated based on their straightness. The result was recorded on the basis of 1 to 3 scale (1 = curved, 2 = moderately straight and 3 = straight) [21].

Pod length (cm): The average pod length was measured from the mean of 25 randomly selected pods per plot using ruler [20].

Pod diameter (cm): The average pod diameter was measured at the point of maximum diameter from 25 randomly selected pods per plot by using a digital caliper (Fowler Us Patented USA) [20].

Pod protein concentration (%): Total N in green pods of snap bean were measured by a sulfuric acid-hydrogen peroxide digestion using a temperature-controlled digestion block [22], followed by determination of total N concentration in the digest using automated colorimetry [23, 24]. Protein concentration was estimated by multiplying the N value by 6.25 [25].

2.4. Method of Analysis

2.4.1. Soil Analysis

Samples were randomly collected from the experimental field using an auger with soil depth of 30 cm in a zigzag pattern before planting and the composite sample was taken for further analysis. The soil was air dried and ground using mortar and pestle to pass through 2mm sieve. Soil textural class, pH, available soil organic carbon (SOC), N and P and cation exchange capacity (CEC) of the sample were determined at JUCAVM soil laboratory (Table 1). The pH (1:25 solid: liquid ratio) of the soil was measured in water using pH meter. The soil texture was analyzed by Bouyoucos hydrometer method [26] and the textural class was determined by using the soil textural triangle. Available P was determined by Bray I method using ammonium fluoride as an extractant and measuring the concentration of the nutrient at 880 nm [27]. Soil organic carbon was determined by the wet digestion method [28]. Total N was determined by the wet oxidation procedure of the Kjeldhal method [29].

2.4.2. Experimental Analysis

Before analysis all the data's collected were checked for its normality and the data for pod straightness and fibreless nature were transformed using Arcsine transformation method before analysis. Then the data collected on two-way were subjected to Analysis of Variance (ANOVA) using SAS statistical software version 9.2 [30]. For parameters showing significant differences, mean separation was carried out using least significant difference (LSD) test at 5% probability level [31].

3. Result and Discussion

In this study the application of N and P nutrient for Snap bean plant shows significant effect on the quality of fresh pod yield, Results depicted on Table 2 showed that there is a significant ($P \leq 0.05$) interaction effect of N and P fertilizers on percent of pod protein concentration and pod straightness nature. However, results for marketable pod yield and pod length of quality parameters showed a significant ($P \leq 0.05$) difference due to the main effects of N and P application. On the other hand, pod diameter and pod fibreless nature were significant only for P application.

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

Parameters studied	Mean squares for sources of variation			
	N	P	N X P	Error
Marketable pod yield (t/ha)	64.75***	33.78**	6.66ns	4.67
Pod length (cm)	8.44***	2.84*	1.28ns	1.37
Pod diameter (cm)	0.01**	0.0003ns	0.002ns	0.002
Pod protein concentration (%)	5.59**	4.17*	3.31*	1.45
Pod straightness	0.01ns	0.06ns	0.07*	0.03
Pod fibreless	1.20***	0.07ns	0.06ns	0.11

** = Significant at P= 0.05; ** = Significant at P= 0.01; ***= Significant at P= 0.001; ns= Non-significant*

3.1. Pod Length (cm)

Pod length was very highly significantly ($P \leq 0.001$) affected by the application of N fertilizer (Table 2). The results in Table 3 showed that with the application of different N rates increases pod length up to 15% from the control and the highest value for pod length was recorded from 164 kg N ha^{-1}, which was statistically at par with 123 kg N ha^{-1}. This could be because of the increased supply of N fertilizer, which resulted in more foliage, leaf area and higher supply of photosynthesis that have induced formation of longer pods. This result in coherent with the finding of Rahman, *et al.* [32], and El-Tohamy, *et al.* [33], that pod length has showed a significant increment with successive application of N fertilizer rate.

Similarly, the application of P showed a significance ($P \leq 0.05$) effect in pod length. The application of P at different rates increases pod length up to 8.03% from the control and maximum value of pod length was found from 92 kg P_2O_5 ha^{-1}, which was statistically similar with 138 kg P_2O_5 ha^{-1} (Table 3). This might be resulted with successive increment in the application of P up to optimum level and the maximum number of foliage and leaf area as well as root volume and length increases with increasing level of P. The finding is at par with the work of Rafat and Sharifi [34], who reported the application P increased pod length with increasing rates of P fertilizer up to optimum level in green bean.

Table-3. Effects of different rates of N and P on pod quality parameters of snap bean

	Quality parameters*		
N (Kg N/ha)	**PL**	**PD**	**PFN**
0	**11.93^{d}**	**0.88^{c}**	**1.71^{d}**
41	13.16^{c}	0.92^{bc}	2.09^{c}
82	13.23^{bc}	**0.96^{a}**	2.22^{bc}
123	13.93^{ab}	0.93^{ab}	2.42^{ab}
164	**14.02^{a}**	0.94^{ab}	**2.55^{a}**
LSD (0.05)	**0.76**	**0.04**	**0.27**
P (Kg P_2O_5/ha)			
0	**12.82^{b}**	0.92	2.10
46	13.10^{b}	0.92	2.18
92	**13.85^{a}**	0.93	2.25
138	13.24^{ab}	0.92	2.24
LSD (0.05)	**0.68**	**0.03**	**0.23**
CV (%)	**6.94**	**4.8**	**14.98**

** Means within a column followed by the same letter(s) are not significantly different at P=0.05. PL= Pod length (cm); PD= Pod diameter (cm); PFN= Pod fibreless nature (Scale)*

3.2. Pod Diameter (cm)

Pod diameter doesn't show significant effect by applying P and combined application of N & P whereas applying N fertilizer highly significantly ($P \leq 0.01$) increased pod diameter (Table 2). The result in this study showed that by applying different rates of N fertilizer pod diameter increases up to 9.1% from the control and the widest pod diameter was recorded from 82 kg N ha^{-1}, which was at par with 123 and 164 kg N ha^{-1} (Table 3). The possible reasons for the maximum pod diameter obtained from the highest N application could be due to increased supply of N fertilizer that might have resulted in more foliage, leaf area and higher supply of photosynthesis which might induce formation of higher pod diameter. In conformity with this result, Wondemagegn [18] and El-Tohamy, *et al.* [33] also reported an increment in pod diameter was due increased rates of N fertilizer up to optimum level on snap bean.

3.3. Pod Fibreless Nature

The present study shows that pod fibreless nature was very highly significantly ($P \leq 0.001$) affected by applying N fertilizer whereas there is no any significant effect by applying P fertilizer and the combined application of N and P fertilizers (Table 2). With regards to nitrogen fertilizer application, the highest fiber content was recorded from the control and the lowest value was recorded in response to application of 164 kg N ha^{-1} which was statistically at par with 123 kg N ha^{-1} (Table 3). The result showed that application different rates of nitrogen minimizes the fiber content of fresh pods up to 49 % from the control. The probable reason could be the supply of high N favors the conversion of carbohydrate into protein and as a result pods contained lower fiber. The current result is in agreement with Wondemagegn [18] and Salinas, *et al.* [35] reported that fiber content reduced when the application of N increased on snap bean.

3.4. Pod Straightness

In the present study, there were significant ($P \leq 0.05$) interaction effects of N and P fertilization on pod straightness of snap bean (Table 2). The results depicted in Table 4 showed that the maximum value was observed with the combined application of N and P at the rate of 82 kg N with 92 kg P_2O_5 ha^{-1}, which was not statistically different from control (0 N) with 46, 92 and 138 kg P_2O_5 ha^{-1}; 41 kg N with 0, 46 and 92 kg P_2O_5 ha^{-1}; 82 kg N with control (0 P) and 46 P_2O_5 ha^{-1}; 123 kg N with 46, 92 and 138 kg P_2O_5 ha^{-1} and 164 kg N with 0, 46, 92 and 138 kg P_2O_5 ha^{-1}; while, the minimum value for pod straightness was observed from control treatment (zero N and P). The combined application of 82 kg N with 92 kg P_2O_5 ha^{-1} gave 37.01 % increment on pod straightness over the control treatments. This could be due to the application of N and P fertilizers are apparent as N is essential for plant growth and development since it is a constituent of all proteins and nucleic acids and P is essential for the production and transfer of energy in plants.

Table-4. Interaction effect of N and P on pod straightness nature

N (Kg N/ha)	**P (Kg P_2O_5/ha)***				**Mean**
	0	**46**	92	138	
0	**1.70^{c}**	2.07^{ab}	2.12^{ab}	2.33^{ab}	
41	2.14^{ab}	2.20^{ab}	2.09^{ab}	1.97^{bc}	
82	2.12^{ab}	1.99^{abc}	**2.33^{a}**	1.97^{bc}	
123	1.98^{bc}	2.12^{ab}	2.03^{abc}	2.12^{ab}	
164	2.04^{abc}	2.10^{ab}	2.10^{ab}	2.09^{ab}	
LSD (0.05)			**0.34**		
CV (%)			**8.84**		

Means followed by the same letter(s) within a column in a treatment are not significantly different at P= 0.05;

3.5. Pod Protein Concentration (%)

Nitrogen and P fertilization and their interaction significantly ($P \leq 0.05$) affected pod protein concentration (Table 2). The results presented in Table 5 indicated that the maximum value was observed with the combined application of N and P at the rate of 82 kg N ha^{-1} with 138 kg P_2O_5 ha^{-1}, which was not statistically different from control with 92 and 138 kg P_2O_5 ha^{-1}; 41 kg N with 46, 92 and 138 kg P_2O_5 ha^{-1}; 82 kg N with 0, 46 and 92 P_2O_5 ha^{-1}; 123 kg N with 0, 46 and 138 kg P_2O_5 ha^{-1} and 164 kg N with 46 P_2O_5 ha^{-1} while the minimum pod protein concentration was observed from control treatment for both N and P application. The combined application of 82 kg N ha^{-1} with 138 kg P_2O_5 ha^{-1} gave 43.44 % increment on pod protein concentration over the control treatment. This could be due to the application of N is essential for plant growth and development since it is a constituent of all proteins and nucleic acids as well as N supply favors the conversion of carbohydrate into protein. On the other hand, P is essential for the production and transfer of energy in plants and as a result protein concentration increased. In line with this result El-Tohamy, *et al.* [33] and Dwivedi and Bapat [36] reported that increase in rate of N applications significantly increased protein content on bean plants.

Table-5. Interaction effect of N and P on and % protein concentration of snap bean

N (Kg N/ha)	P (Kg P_2O_5/ha)*				Mean
	0	**46**	92	138	
0	**13.49^{d}**	16.49^{c}	17.85^{abc}	17.55^{abc}	
41	16.97^{bc}	17.39^{abc}	18.61^{ab}	17.41^{abc}	
82	17.69^{abc}	17.65^{abc}	18.19^{abc}	**19.35^{a}**	
123	17.95^{abc}	17.91^{abc}	16.69^{bc}	17.55^{abc}	
164	16.94^{bc}	18.17^{abc}	16.93^{bc}	16.97^{bc}	
LSD (0.05)				**1.97**	
CV (%)				**6.92**	

Means followed by the same letter(s) within a column in a treatment are not significantly different at P= 0.05;

3.6. Marketable Pod Yield (t ha^{-1})

Marketable pod yield was very highly significantly ($P \leq 0.001$) affected by the application of N fertilizer (Table 2). Results depicted in Table 6 revealed that the highest marketable pod yield was recorded from 123 kg N ha^{-1} application which was statistically at par with the application of 82 kg N ha^{-1} while the lowest marketable pod yield was recorded from the control treatment (zero N). The application of 82 and 123 kg N ha^{-1} increased marketable pod yield by 63.32 and 63.55% compared to the control (zero N), respectively. The possible reasons for the highest marketable pod yield observed from the higher N application was related with the increase in the N fertilizer rate that resulted in better vegetative growth, which in turn enables the crop to produce greater photo-assimilate in the pods. Similar result also stated by Beshir [37]; Rahman, *et al.* [32]; El-Tohamy, *et al.* [33]; Mahmoud, *et al.* [38]; El-Awadi, *et al.* [39] reported that increasing N fertilizer application rate increased marketable pod yield.

Table-6. Effects of N and P rates on marketable pod yield (MPY)

N (Kg N/ha)	MPY
0	**8.36^{c}**
41	11.63^{b}
82	13.98^{a}
123	**14.00^{a}**
164	10.58^{b}
LSD (0.05)	**1.79**
P (Kg P_2O_5/ha)	
0	**10.20^{b}**
46	12.46^{a}
92	**13.49^{a}**
138	10.85^{b}
LSD (0.05)	**1.60**
CV (%)	**18.39**

Means within a column followed by the same letter(s) are not significantly different at P=0.05; MPY= Marketable pod yield (tha^{-1})

Marketable pod yield was highly significantly ($P \leq 0.01$) affected by the application of P fertilizer (Table 2). The result depicted in Table 6 indicated that the application P at different rates has shown variation on marketable pod yield and the maximum value was recorded from the 92 kg P_2O_5 ha^{-1} which was statistically at par with 46 kg P_2O_5 ha^{-1} application while the minimum value was recorded from the control which was statistically similar with 138 kg P_2O_5 ha^{-1}. This may be because of the application of P improves flower formation and fruits expansion and increases the marketable pod yield. This work is in line with Dauda, *et al.* [40] and Ranjbar-Moghaddam and Aminpanah [41] who reported the marketable pod yield increment due to applying P fertilizer up to optimum rate.

4. Summery and Conclusion

It can be concluded that different fertilizer levels did significantly ($p<0.05$) influenced most of the quality attributes of the snap bean. In the case of pod quality parameters, the highest value for pod percent protein concentration and pod straightness nature was observed from the combined effect of N and P while pod length, pod diameter and pod fibreless nature produced the maximum value due to the main effects of N and P. The result obtained in this study revealed that a combined application of N and P on different combined application rates including 82 kg N with 46 kg P_2O_5 ha^{-1} gave optimum straightness nature and percent protein concentration. On the other hand, the highest pod length obtained due to main effects of N and P at the rates of 164 kg N and 92 kg P_2O_5 ha^{-1}, respectively. But pod diameter and pod fibreless nature showed significant effect only due to the main effect of N is produced the highest value at the rates of 82 and 164 kg N ha^{-1}, respectively. Whereas, the optimum rates of 82 kg N and 46 kg P_2O_5 ha^{-1} helps for snap bean growth and development which contributes for optimum marketable pod yields. Hence, the application of N and Pat the optimum rates (82 N kg and 46 kg P_2O_5 ha^{-1}) resulted in increase the quality attributes of snap bean as well as the marketable pod yield will be tentatively recommended. However, repeating the experiment for more seasons and similar location would help us draw sound conclusion and recommendations. Therefore, future studies should look in to these factors to develop fertilizer recommendation for optimum quality and marketable pod yield of snap bean in Jimma and similar agro-ecology area.

Acknowledgement

We are grateful to Jimma University College of Agriculture and Veterinary Medicine, for providing horticultural research field for this study. We also appreciate and highly acknowledge the Ministry of Agriculture for financial support that has made my studies possible. In addition, USAIDMASHAV-MoANR, SHP project for financial support to accomplish our final research works and soil analysis.

Reference

[1] Gepts, P., 1998. "Origin and evolution of common bean: past events and recent trends." *Hort Science,* vol. 33, pp. 1124–1130.

[2] FAOSTAT, 2019. "Food and Agriculture organizations of the United Nations." *Statistics Division,* Available: www.fao.org

[3] Gezahegne, A. and Dawit, A., 2006. "Food and forage legumens of Ethiopia." In *progress and prospect proceedings of the work shop on food and forage legume, 22- 26 September 2003. Addis Ababa, Ethiopia.*

[4] FAO, 2018. *Post-harvest management of snap bean for quality and safety assurance: Guidance for horticultural supply chain stakeholders*. Rome, Italy: FAO. p. 4.

[5] CIAT, 2006. "Highlights ciat in africa: Snap bean for income generation by small farmers in East Africa." Available: http://ciat-library.ciat.cgiar.org/articulos_ciat/highlight31.pdf

[6] Abate, G., 2006. "The market for fresh snap beans. Working paper, the strategic marketing institute." pp. 6-8. Available: https://www.canr.msu.edu/productcenter/uploads/files/the%20market%20for%20fresh%20snap%20beans2.pdf

[7] Dessalegn, L., 2003. *Snap bean production and research status (phasiolus vulgaris) in Ethiopia*. Nazret, Ethiopia: Melkasa Agricultural Research Center (MARC).

[8] Okello, J. J., Narrod, C., and Roy, D., 2007. *Food safety requirements in African green bean exports and their impact on small farmers. Markets, trade and institutions division*. Washington, Dc. USA: International Food Policy Research Institute. p. 56.

[9] Katungi, F., Mutuoki, E. A. T., Setegn, G., Karanja, D., A., F., Sperling, L., Beebe, S., Rubyogo, J. C., and Buruchara, R., 2010. "Improving common bean productivity: An analysis of socioeconomic factors in ethiopia and eastern kenya. Baseline report tropical legumes ii. Centro internacional de agricultura tropical - ciat. Cali, colombia." Available: https://www.academia.edu/1909600/IMPROVING_COMMON_BEAN_PRODUCTIVITY_AN_ANALYSIS_OF_SOCIO-ECONOMIC_FACTORS_IN_ETHIOPIA_AND_EASTERN_KENYA

[10] Nigussie, A., Ambaw, G. M., and Kissi, E., 2013. "Fertility status of eutric nitisol and fertilizer recommendation using numass in the selected areas of jimma zone, Southwestern Ethiopia." *Tropical and Subtropical Agroecosystems,* vol. 16, pp. 487-495.

[11] Tisdale, S. L., Nelson, W. L., Beaton, J. D., and Havlin, J. L., 1993. *Soil fertility and fertilizers*. 5th ed. NY: Macmillan Publishing Co. p. 634.

[12] Tantawy, A. S., Abdel-Mawgoud, A. M. R., Habib, H. A. M., and Hafez, M. M., 2009. "Growth, productivity and pod quality responses of green bean plants phaseolus vulgaris to foliar application of nutrients and pollen extracts." *J. of Agri. and Bio. Sci.,* vol. 5, pp. 1032-1038.

[13] Abdel-Mawgoud, A. M. R., El-Bassiouny, A. M., Ghoname, A., and Abou-Hussein, S. D., 2011. "Foliar application of amino acids and micronutrients enhance performance of green bean crop under newly reclaimed land conditions." *Aust. J. Basic Appl. Sci.,* vol. 5, pp. 87-95.

[14] Aticho, A. and Elias, E., 2011. "Soil nutrient stock evaluation under different land use types in the smallholder farming system of jimma zone, Ethiopia." *Int. J. Agri. Res.,* vol. 6, pp. 707-713.

[15] MoANR, 2016. "Major vegetable crops production system." presented at the Efficient use of irrigation water and improved agronomic practices of irrigated crops. A working manual, Small Scale Irrigation Development Directorate, MoANR.

[16] Negash, F. and Rezene, Y., 2015. "N and phosphorus fertilizers rate as affecting common bean production at areka, Ethiopia." *Journal of Agriculture and Crops,* vol. 1, pp. 33-37.

[17] Turuko, M. and Mohammed, A., 2014. "Effect of different p fertilizer rates on growth, dry matter yield and yield components of common bean (phaseolus vulgaris l.)." *World Journal of Agricultural Research,* vol. 3, pp. 88-92.

[18] Wondemagegn, N. H., 2012. *Effect of n rate on growth, yield and quality of green bean (phaseolus vulgaris l.) varieties at bishoftu, Central Ethiopia*. An M.Sc. Thesis Submitted to the School of Graduate Studies Jimma University, pp. 25-49.

[19] Available: https://en.climate-data.org/africa/ethiopia/oromia/jimma-927063/

[20] IDEA, 2001. *Fresh green beans. Adc commercialization bulletin*. Kololo, Kampala, Uganda: Agribusiness Development Centre. p. 12.

[21] Getachew, E., 2012. *Determination of appropriate sowing date and plant spacing for green bean (Phaseolus vulgaris L.) candidate varieties under Jimma condition*. An MSc Thesis presented to the School of Graduate Studies of Jimma University, p. 105.

[22] Thomas, R., Sheard, R. W., and Moyer, I. P., 1967. "Comparison of conventional and automated procedures for nitrogen, phosphorus and potassium analysis of plant material using a single digest." *Agron. J.*, vol. 99, pp. 240–243.

[23] Wall, L. L., Gehrke, C. W., Neuner, T. E., Cathey, R. D., and Rexnord, P. R., 1975. "Cereal protein nitrogen: Evaluation and comparison of four different methods." *J. Assoc. Off. Anal. Chem.*, vol. 58, pp. 811–817.

[24] Watanabe, F. S. and Olsen, S. R., 1965. "Test of an ascorbic acid method for determining phosphorus in water and NaHCO3 extracts from soil." *Soil Sci. Soc. Am. Proc.*, vol. 29, pp. 677–678.

[25] Imran, M., Khan, H., Hassan, S. S., and Khan, R., 2008. "Physicochemical characteristics of various milk samples available in Pakistan." *J. Zhejiang Univ. Sci. B.*, vol. 9, pp. 546–551.

[26] Bouyoucos, G. H., 1951. "Reclamation of hydrometer for making mechanical Analysis of soils." *Agronomy Journal*, vol. 43, pp. 434–438.

[27] Bray, R. H. and Kurtz, L. T., 1945. "Determination of total organic and available phosphorus in soils." *Soil Science Journal*, vol. 59, pp. 39-45.

[28] Walkley, A. and Black, C. A., 1934. "An experimentation of Degtjareff method for determining soil organic matter and the proposed modification of the chromic acid titration method." *Soil Sci.*, vol. 37, pp. 29-38.

[29] Dewis, J. and Freitas, P., 1970. *Physical and chemical methods of soil analysis*. Rome, Italy: FAO Bulletin No. 10., p. 275.

[30] SAS Institute, I., 2009. *JMP. Version 1*. Cary, North Carolina.

[31] Gomez, K. A. and Gomez, A. A., 1984. *Statistical procedures for Agricultural Research*. 2nd ed. New York: John wily and Sons.

[32] Rahman, M. A., Hoque, A. K. M. S., Rahman, M. N., Talukadar, M. B., and Islam, M. S., 2007. "Effects of N and phosphorous on growth and yield of French bean." *J. Soil N.*, vol. 1, pp. 30-34.

[33] El-Tohamy, W. A., Ghoname, A. A., Riad, G. S., and Abou-Hussein, S. D., 2009. "The influence of slow release fertilizer on bean plants (Phaseolus Vulgaris L.) grown in sandy soils." *Australian Journal of Basic and Applied Sciences*, vol. 3, pp. 966-969.

[34] Rafat, M. and Sharifi, P., 2015. "The effect of p on yield and yield components of green bean." *J. Soil Nature*, vol. 8, pp. 9-13.

[35] Salinas, R. N., Escalante, E. J., Rodríguez, G. M., and Sosa, M. E., 2011. "Yield and nutritional quality of snap bean in terms of biofertilization." *Trop. Subtrop. Agroecosys.*, vol. 13, p. 347–355.

[36] Dwivedi, A. K. and Bapat, P. N., 1998. "Sulphur-P interaction on the synthesis of Nous fraction and oil in soybean." *J. Indi. Soc. Soil Sci.*, vol. 46, pp. 254-257.

[37] Beshir, M. H., 2015. *Improving snap bean (phaseolus vulgaris l.) production under reduced input systems*. A Ph.D. Thesis submitted to University of Saskatchewan, Canada, pp. 24-72.

[38] Mahmoud, A. S., EL-Desuki, M., and Abdel-Mouty, M. M., 2010. "Response of snap bean plants to bio-fertilizer and N level application." *Inter. J. of Aca. Res.*, vol. 2, pp. 179-183.

[39] El-Awadi, M. E., El-Bassiony, A. M., Fawzy, Z. F., and El-Nemr, M. A., 2011. "Response of snap bean (Phaseolus vulgaris L) plants to N fertilizer and foliar application with methionine and tryptophan." *Nature and Science*, vol. 9, pp. 87-94.

[40] Dauda, S. N., Ndor, E., Azagaku, E. D., Isa, A. S., and Onuk, E. G., 2016. "Production and economic returns of green bean (phaseolus vulgaris l) varieties under rates of n and p." *Application in Sudan Savanna of Nigeria, PAT*, vol. 12, pp. 211-219.

[41] Ranjbar-Moghaddam, F. and Aminpanah, H., 2015. "Green bean (phaseolus vulgaris l.) growth and yield as affected by chemical p fertilizer and phosphate bio-fertilizer." *IDESIA (Chile)*, vol. 33, pp. 77-85.