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Research Article

Improving Yield and Pod Quality of Green Bean (*Phaseolus vulgaris* L.) through Application of Nitrogen and Boron Fertilizers in the Central Rift Valley of Ethiopia

[1]Meaza Abebe, [2]Husssien Mohammed Beshir and [2]Amsalu Gobena

[1]Department of Dugda Woreda Agriculture and Natural Resource, Ethiopia
[2]Hawassa University College of Agriculture, School of Plant and Horticultural Sciences, P.O. Box 05 Hawassa University, Hawassa, Ethiopia

Abstract

Background and Objective: Green beans are economically very important vegetable crops in Ethiopia for both small scale and large commercial producers. However, its productivity and pod quality are constrained by lack of proper crop management mainly fertilizer application including nitrogen (N) and boron (B). To determine optimum amount of N and B application for growth, yield and pod quality of green bean with economically feasible way. **Materials and Methods:** This field experiment was conducted in Ethiopia at Dugda district (Meki) during the 2018 dry season (January-March) under irrigation. The experiment was conducted using split plot arrangement of four levels of nitrogen as main plot factor (0, 50,100 and 150 kg ha^{-1}) and four levels of boron as sub plot factor (0, 2, 4 and 6 kg ha^{-1}) in randomized complete block design (RCBD) with three replications. Data on phenology, growth yield and pod quality of green bean were recorded. **Results:** It was found that application of N and B resulted in significant impact on phenology, growth, yield and pod quality of green bean under Dugda conditions. Generally, delayed flowering and maturity, surplus vegetative growth, higher yield and good pod quality of green beans were observed under combinations of higher rates of N and B. However, the effect of B was more pronounced at the higher rates of N. **Conclusion:** It can be concluded that combined application of 100-150 kg ha^{-1} N and 2 kg ha^{-1} B resulted in better yield and pod quality of green bean and economically feasible for green bean producers in the study area.

Key words: Pod quality, nitrogen, boron, yield

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Corresponding Author: Husssien Mohammed Beshir, Hawassa University College of Agriculture, School of Plant and Horticultural Sciences, P.O. Box 05 Hawassa University, Hawassa, Ethiopia Tel: +25191194706

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Green bean (*Pharsealus vulgaris* L.) is one of the most important legume vegetable crops cultivated since long years ago. Green bean is a group of common bean that has been selected for succulent pods which primarily grown for its young fleshly flavorful pods. The immature pods and seeds are produced and marketed fresh, canned or frozen products[1]. The crop is widely cultivated due to its good source of fiber. Its immature edible pod and unripe seeds contain protein, carbohydrate, fat, fiber, thiamine, riboflavin, calcium and iron[2]. Green bean has been among the most important vegetable crops as a means of foreign currency earning in Ethiopia[3]. Recently, it is becoming a high value commodity which has the potential for improving the incomes and livelihoods of smallholder farmers in Ethiopia and diversifying agricultural production and increasing export exchange earnings[1]. At the same time the local demand and consumption of green bean in Ethiopia have increased. Green beans production in Ethiopia during 2003-2013 increased by 76.5 and 77.1%, respectively[4].

The average productivity of green bean in Ethiopia was 4.06 t ha^{-1} and it is very low as compared to the world average production[5] of 13.2 t ha^{-1}. Experience shows that, the major reasons for the low productivity and quality of green bean are low nutrient status of the soil in most of the bean growing areas of the country and inadequate application of fertilizers, lack of adequate suitable varieties for specific or wider production locations, poor cultural practices and the prevalence of diseases and insect pests in production areas.

Green beans are very delicate crops that poor management of the crop in terms of nutrition and other cultural practices affect their productivity and pod quality. In the past, Ethiopian smallholder farmers were limited to use dia ammonium sulphate (DAP) and urea fertilizers that provided nitrogen and phosphorus nutrients only. Crop yields in Ethiopia have been constrained by very limited set of imported fertilizer and ultimately affect the main crop production and productivity of the country. Soil tests showed that Ethiopian crop lands lack essential macro nutrients and micro nutrients such as sulfur, boron, potassium, zinc and copper. Boron is a micro-nutrient needed by plants. It is closely associated with calcium and calcium transport, cell wall production, cell division in plant growing points, sugar transport in plants, flower and fruit development and plant hormone regulation[6]. Vegetables vary in their boron requirements. In boron-deficient pea (*Pisum sativum* L.) leaves, although, the concentration of sugars and starch increased, there was a negative effect on bean seeds quality and productivity[6].

The study on the effect of Boron concentration on growth and nitrogen fixation of soybean plant indicated that, plant grown on soil without Boron resulted significantly low dry weight of the whole plant and lower nodule as compared to plant fertilized with Boron fertilizer[7]. Moreover, Beet root fresh leaf analysis result indicated that there was significantly higher nitrate reductase enzyme activity and enhanced assimilation of NO^{-3} in leaves treated with optimum amount of boron concentration than plant not fertilized with boron fertilize[8].

Higher productivity and better quality of green bean pods were produced due to applied nitrogen[9]. Owing to its importance in improving productivity and pod quality, application of nitrogen fertilizer is very critical for green bean production. However, from its nature of leachability and mobility to the environment, its adverse impact to the environment and its cost implications, proper amount of nitrogen should be determined for specific locations. Therefore, this study was designed to determine optimum area specific fertilizer (N and B) recommendation for growth, yield and pod quality of green bean with economical feasibility.

MATERIALS AND METHODS

Description of the study area: The field experiment was conducted at *Dugda* district (Meki) during the 2018 dry season (January-March) under irrigation. The site is situated in major green bean growing belts in the central Rift valley of Ethiopia. It is located at 135 km to south east of Addis Ababa. The site is found at a latitude of about 8°08'00"N and longitude of 38°48'59.99"E and with an elevation of 1636 m above sea level. The site receives average annual rainfall of 720 mm and with a mean annual temperature of 18°C. The mean maximum and minimum temperature during the experiment period were 27.7 and 14.14°C, respectively. It is categorized with semiarid climate and Andosol soil type with sandy loam soil texture[10].

The soil analysis result for the study area showed that the soil had low level of total nitrogen (0.134%), low level of organic carbon (0.81%), medium level of available phosphorus (10.02 ppm), low level of available boron (<0.0004 mg kg^{-1} ppm) and medium CEC (25.63 meq/100 g soil) as per the criteria developed by Murphy[11] for Ethiopian soils.

Experimental materials: Green bean variety plate which was released in 2016 by Melkassa Agricultural Research Center was used for the study. The seed of green beans plate variety was obtained from Melkassa Agriculture Research center (MARC). The variety was a growing potential within the altitude of 1100-1800 m.a.s.l. and takes 60-65 days to reach commercial maturity. Fertilizer source for nitrogen (N) and boron (B) were urea and Borax ($Na_2B_4O_7.10H_2O$), respectively and the recommended rate of phosphorus fertilizer (29 kg ha^{-1}) were applied during planting uniformly to all plots in the form of triple super phosphate (TSP).

Experimental design and treatments: This study was conducted using split plot arrangement of four levels of nitrogen as main plot factor (0, 50,100 and 150 kg ha^{-1}) and four levels of boron as sub plot factor (0, 2, 4 and 6 kg ha^{-1}) in randomized complete block design (RCBD) with three replications. There were a path of 1.5 m between blocks, 1 m between main plots and 0.6 m between sub plots. The plot size for each sub plot was 4 m^2 (2×2 m), main plot is 4.6×4.6 m (21.16 m^2) and total area 16.8×21.4 m (360 m^2). The green bean (plate) seed for each treatment was planted in five rows per plot. The plots were with 2 m row length and spacing between rows was 40 cm and between plants 10 cm. Two seeds per hill were planted and were thinned to one per hill upon appearance of true leaves. The nitrogen fertilizer for each treatment was divided in to three equal splits and the first was applied after 15 days of sowing and the second side dressed 4 weeks after sowing and finally the remaining amount was applied during the beginning of flowering. Boron fertilizer was divided into two equal parts and applied with nitrogen during second and third application of the nitrogen.

Analysis of the experimental soil: The soil sample was analyzed for textural classes, pH and organic matter, total nitrogen, available phosphorus, cation exchange capacity (CEC) at the Ziway soil laboratory using standard laboratory procedures and for exchangeable boron at Debre Zeit Horticoop Ethiopia (Horticulture) PLC Soil and Water Analysis Laboratory using examination standards laboratory procedures Mehlich-3. According to the soil laboratory analysis, the results indicated that the textural class of the experimental site was sandy loam. The soil of the study area had low level of total nitrogen (0.134%), low level of available boron (<0.0004 mg kg^{-1} ppm), medium level of organic carbon (0.81%), low level of available phosphorus (10.02 ppm) and medium CEC (25.63 meq/100 g soil) as per the criteria developed by Murphy[11] for Ethiopian soils. The pH (H_2O) of the soil was 7.63 showing slightly alkaline nature of the soil[12]. Reports indicated that the preferable pH for most crops and productive soils ranges from 4-8. Thus, the pH of the experimental soil was within the range for productive soils.

Data collection and measurement

Crop phenology: Days to of flowering was determined by counting the number of days from sowing to the time when 50% of the plants in a plot produce flowers through visual observation. Days to maturity was determined as the number of days from sowing to the time when 50% of the plants in the plot are ready to harvest based on visual observation. Pods which are firm and fleshy with small green immature seeds are said to be matured.

Growth parameter: Number of primary branches per plant and plant height were counted and measured, respectively, from 5-tagged plants from net plot at the harvesting stage. Number of leaves per plant was determined by taking 5-tagged plants from net plot and counted for their leaves at flowering and it was averaged per plant. The leaf areas of four randomly selected plants were measured after flowering using leaf area meter (LI-3100, Lincoln, Nebraska USA) and it was averaged per plant.

Yield components and yield of green bean: Total pod yield was measured by harvesting total pods from all plants in three middle rows and convert to tons per hectare. Aboveground fresh and dry biomass was measured from total aboveground biomass from all plants in three middle rows after taking the fresh weight samples was dried in an oven at 70°C to constant weight and converted to m^2. Number of pods per plant was determined by counting the pods from 5 randomly pre-tagged plants from net plot area at harvest and it was averaged per plant. Harvest index was calculated by dividing pod fresh yield by the total fresh biomass yield and multiplied by 100.

Pod quality parameter for market standard: Pod length was measured from the node where the pod emerged to the tip of the pod from an average of four selected plants per plot. Pod diameter was measured on the central part of the pod by rolling tape meter. Ten randomly selected pods from four plants per plot were taken for this measurement and it was averaged per pod.

Texture and appearance of pods were scored using a visual rating scale using the method used by Beshir *et al.*[9] and which were modified from Martinez *et al.*[13] and Proulx *et al.*[14]. Five experienced individuals in the region, who study in grading and packing commercial green beans for export markets, rated pod texture and appearance. Pod texture scale consisted of:

1 = Very fine
2 = Fine
3 = Reasonably fine
4 = Coarse
5 = Very coarse surface

Pod appearance was expressed as the overall look of the pods, which is a combination of different expressions (fineness of texture, absence of defect, straightness of pods, small and immature seeds) on the pod. Pod appearance was scored as:

1 = Excellent
2 = Good
3 = Acceptable
4 = Poor
5 = Rejected

Straightness of pods was rated from 25 randomly selected pods per plot by visual rating using test panel of 5 people on the basis of 1-3 scale (1: Curved, 2: Moderately straight, 3: Straight) which was used by Getachew *et al*.[15]. Total marketable pod yield was determined by harvesting fresh marketable pod from the net plot area (three middle rows). The total harvested pods was sorted based visual observation and pods which are free from insect and diseases damage, uniform in color slightly curved and straight pod length was considered as marketable and finally the marketable yield per plot was converted to tons per hectare. Total unmarketable pod yield was determined by visual observations and pods which are bleached insect and diseases damage, curved were considered as unmarketable.

Statistical analysis: Two way analysis of variance (ANOVA) was done using GenStat Computer Software version 13.3 General linear model (GLM) was used for the analysis. Mean separations was done using least significant difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Crop phenology: The analysis of variance revealed that the different level of N and B fertilizers significantly ($p<0.001$) affected days to flowering and maturity of green bean. Additionally the interaction effect of the N and B had also significant ($p<0.05$) effect on days to flowering and maturity.

Numerically, the lowest days to flowering and maturity were recorded from the combination of N at rate of 0 kg ha^{-1} with B at rate of 2 kg ha^{-1}. All levels of B with each of no N and 50 kg N ha^{-1} resulted in similar effect on flowering and maturity of green bean. Higher levels of N fertilizer rates delayed the time to flowering and maturity as compared to no N and B fertilizers (control treatment). Numerically, the longest days to flowering and maturity were recorded from the combination of N at rate 150 kg ha^{-1} with B at rate of 6 kg ha^{-1} but this combination was not significantly different from the combination of N 150 with 2 kg B ha^{-1} (Table 1). Days to flowering and maturity were increased by 8 and 6.67 days, respectively, in response to 150 kg N ha^{-1} combined with 6 kg B ha^{-1} as compared to the treatment of no N and B. Generally, higher rate of N with the higher rate of B fertilizers delayed flowering and maturity, however, the lower rates of N with the lower rates of B fertilizers reduced days to flowering and maturity of green beans (Table 1). This might be due to the fact that as increased nitrogen fertilization results increasing the period of vegetative growth of plants due to the fact that nitrogen is an essential nutrient for plant growth, development and reproduction[16]. Nitrogen is being a part of amino acid, protein, enzymes and chlorophyll molecules, it encourages vegetative growth[17] and boron application improved the uptake of P and N[18]. Several previous studies also revealed that increased vegetative growth of green beans and dry beans were observed under increased N fertilizer[3,19,20]. Mahmoud *et al*.[21] also reported that all vegetative growth parameters of green beans were gradually and significantly increased by increasing the level of N fertilizer application that resulted in delayed flowering and maturity. This finding is in line with Beshir *et al*.[22], who declared that applied nitrogen delayed flowering and maturity of green bean as compared to Rhizobium inoculation and no applied of nitrogen. Similarly, Zahoor *et al*.[23] reported that the role of boron is to encourage vegetative growth and increase the rate of photosynthesis and gathering plant dry matter. The interaction between N and boron was increased material representation and thus provided an opportunity to reduce the flower abortion as a result of reducing the state competition, including the food product during the growth and development of these flower. Nitrogen was needed by plants in all stages of their lives because of its vital to the growth of plants and increase production[24]. Similar result is reported by Aaid[25], who declared that nitrogen increased vegetative growth and delay aging on broad bean. On the other hand, excessive available N can result in reduced and delayed yield as well as reduced dry matter content[26].

Growth parameters: The analysis of variance showed that plant height, branch number, leaf number and leaf area were significantly ($p<0.001$) affected due to the main effect of N and B fertilizers as well as the interactions of these two factors.

Table 1: Interaction effect of nitrogen and boron fertilizers on days to flowering and days to maturity of green bean at Dugda woreda (Meki)

Nitrogen (kg ha^{-1})	Boron (kg ha^{-1})	Days to 50% flowering	Days to 50% maturity
0	0	41.33^{i}	61.00^{hi}
	2	42.0^{ih}	60.67^{i}
	4	43.00^{gf}	61.0^{hi}
	6	44.00^{f}	61.33^{gh}
50	0	42.67^{gh}	62.00^{fg}
	2	43.00^{gf}	62.00^{fg}
	4	43.33^{gf}	63.33^{de}
	6	44.00^{f}	62.00^{fg}
100	0	46.00^{e}	63.00^{de}
	2	46.67^{de}	64.00^{de}
	4	47.33^{cd}	65.00^{bc}
	6	48.33^{b}	64.00^{cd}
150	0	46.00^{e}	65.67^{bc}
	2	47.00^{cd}	65.33^{bc}
	4	48.00^{b}	66.67^{ab}
	6	49.00^{a}	67.67^{a}
CV (%)		0.80	1.00

CV%: Coefficient of variance (%). Means in the same column followed by the same letter(s) are not significantly different at 5% probability level

Table 2: Interaction effect of nitrogen and boron on growth parameters of green bean planted in 2018 cropping season at Dugda woreda (Meki)

Nitrogen (kg ha^{-1})	Boron (kg ha^{-1})	Leaves number (plant^{-1})	Branch numbers (plant^{-1})	Plant height (cm)	Leaf area (cm^{2})
0	0	12.00^{i}	6.00^{h}	37.96^{g}	590.87^{g}
	2	12.74^{hi}	6.70^{hg}	39.13^{gf}	679.99^{gf}
	4	13.07^{hi}	7.40$^{f\text{-}h}$	40.01$^{e\text{-}g}$	765.52$^{e\text{-}g}$
	6	12.200^{i}	7.90$^{d\text{-}f}$	40.63$^{d\text{-}g}$	758.78$^{e\text{-}g}$
50	0	13.33$^{g\text{-}i}$	8.17$^{e\text{-}g}$	41.47$^{c\text{-}g}$	754.59$^{e\text{-}g}$
	2	14.00$^{g\text{-}i}$	8.83$^{d\text{-}f}$	40.17$^{e\text{-}g}$	812.23$^{d\text{-}g}$
	4	14.87$^{f\text{-}i}$	9.03$^{d\text{-}f}$	42.75$^{b\text{-}f}$	824.56$^{d\text{-}f}$
	6	15.47$^{e\text{-}h}$	9.50$^{c\text{-}e}$	40.50$^{d\text{-}g}$	844.94$^{d\text{-}f}$
100	0	16.23$^{e\text{-}g}$	10.17$^{b\text{-}d}$	44.17$^{b\text{-}d}$	1083.99^{bc}
	2	17.23$^{d\text{-}f}$	9.00^{edf}	46.61^{a}	1096.89^{bc}
	4	18.37^{de}	9.43$^{c\text{-}e}$	43.71$^{b\text{-}d}$	943.56$^{c\text{-}e}$
	6	19.52^{cd}	10.10$^{b\text{-}d}$	47.41^{a}	998.16$^{b\text{-}d}$
150	0	21.68^{bc}	10.90$^{a\text{-}c}$	46.27^{ab}	1108.87^{bc}
	2	23.77^{bc}	11.50^{ab}	44.55^{bc}	1222.96^{ab}
	4	25.27^{a}	11.97^{a}	46.82^{a}	1138.28^{bc}
	6	26.66^{a}	11.83^{a}	47.20^{a}	1372.23^{a}
CV (%)		5.50	5.50	2.90	8.70

CV%: Coefficient of variance (%). Means in the same column followed by the same letter(s) are not significantly different

Numerically, the tallest plant height, largest number of leaves and maximum leaf area were recorded from the combination of 150 N and 6 kg B ha^{-1}. However, branch number was numerically largest at 150 N and 4 kg B ha^{-1}. Numerically, the shortest plant height, the smallest leaf number and leaf area was recorded from the combination of N at rate of 0 kg ha^{-1} with B at rate of 0 kg ha^{-1} (control treatments). Growth parameters were increased as the levels of N increased. The combination of 150 kg N ha^{-1} with 6 kg B ha^{-1} increased plant height, leaf number, branch number and leaf area by about 19.93, 54.99, 49.87 and 56.94%, respectively as compared to the control treatment (0 kg N ha^{-1}) with (0 kg B ha^{-1}) combinations (Table 2). Generally, higher rate of N with the higher rate of B fertilizers increased growth parameters of green bean plant.

The current study showed that N vitally determined the growth parameters (height, leaf number, branch number and leaf area) of the green bean plants specially at 150 kg N ha^{-1} with 6 kg B ha^{-1} (Table 2). This might be due to nitrogen contributed to the higher rates of vegetative growth of plant. Nitrogen is thus essential nutrient for plant growth, development and reproduction because N is a major component of chlorophyll, the compound by which plants use sunlight energy to produce sugars from water and carbon dioxide (i.e., photosynthesis). It is also a major component of amino acids, the building blocks of proteins[16]. Similarly nitrogen is very important nutrient for plant growth due to being a part of amino acid, protein and enzymes and chlorophyll molecule[18]. This finding is also in agreement with the findings of Beshir *et al.*[22], who stated that growth

Table 3: Interaction effect of nitrogen and boron fertilities on pod number and total pod yield of green bean planted in 2018 cropping season at Dugda woreda (Meki)

Nitrogen (kg ha^{-1})	Boron (kg ha^{-1})	Pod number plant^{-1}	Total pod yield (t ha^{-1})
0	0	27.00^{h}	11.91^{g}
	2	29.00^{gh}	11.97^{g}
	4	30.07^{f-h}	12.66^{fg}
	6	31.21^{f-h}	12.59^{fg}
50	0	33.13^{e-g}	13.55^{fg}
	2	33.50^{ef}	14.13^{fg}
	4	33.00^{e-g}	14.25^{e-g}
	6	34.50^{ef}	14.45^{d-g}
100	0	36.50^{de}	16.84^{b-e}
	2	47.33^{a}	19.97^{a}
	4	39.80^{cd}	15.44^{c-f}
	6	39.10^{cd}	15.99^{c-f}
150	0	41.33^{bc}	17.09^{bc}
	2	39.50^{cd}	18.73^{b}
	4	45.00^{ab}	17.39^{bc}
	6	37.41^{c-e}	16.97^{bc}
CV (%)		4.20	5.90

CV%: Coefficient of Variance (%). Means with the same letter(s) are not significantly different

parameters were increased due to applied nitrogen fertilizer on green beans. Similarly Moniruzzaman *et al.*[27] indicated that application of N nutrient significantly influenced vegetative growth of green beans. It was reported that plant height was significantly increased up to 120 kg N ha^{-1} but further increase to 160 kg N ha^{-1} could not result further increase in plant height. Several other previous studies have revealed that increases in vegetative growth of green beans and dry beans due to addition of nitrogen fertilizer[18,19]. According to Chatzopoulou *et al.*[24] application of nitrogen leads to an increase in plant height, number of branches and improved photosynthetic efficiency by having larger leaf area. Generally, nitrogen was needed by plants in all stages of their lives because of its vital to the growth of plants and increase production[24]. Boron fertilizer has positive role in the transport of carbohydrate materials from the source to the sink, which gave a greater chance to reduce competition[28]. Boron treatment could improve growth by increasing IAA content and IAA/cytokinin ratio in leaves by blocking IAA oxidase inhibitors by forming complexes with these inhibitors[29]. This is may be due to the positive role of boron in the transport of carbohydrate materials from the source to the sink, which gave a greater chance to reduce competition[28]. According to Ali and Ati[30], the numbers of branches per plant was increased with increasing amount of boron applied and number of applications. This was consistent with Abd El-Monem *et al.*[31] on broad beans when sprayed boron. Our result confirmed that boron application without and with the combination of higher rates of N increased branching of green bean.

Yield components and yield of green bean

Pod number: The analysis of variance showed that pod number per plant was significantly ($p<0.001$) affected due to the main effect of N and B fertilizers as well as the interaction of these two factors ($p<0.05$).

Numerically the highest pod number per plant was obtained from the combination of 100 N and 2 kg B ha^{-1}, which was statistically par to the combination of 150 with 4 kg B ha^{-1}. The lowest pod number per plant was recorded from the combination of N at rate of 0 kg ha^{-1} with B at rate of 0 kg ha^{-1} (control treatment). This combination was no statistically different within the combination of 0 kg and 50 kg N ha^{-1} with all level of kg B ha^{-1} (Table 3). However, the combination of 100 kg N ha^{-1} with 2 kg B ha^{-1} brought about 42.95% increments in pod number per plant as compared to control treatment (0 kg N ha^{-1}) with (0 kg B ha^{-1}) treatment combinations. Generally, pod number per plant of green beans was increased as the combination of N with B fertilizers increased. The current study showed that both N and B determined the pod number per plant of the green bean particularly at 100 kg N ha^{-1} combined with 2 kg B ha^{-1} which increased pod number per plant (Table 3). This finding is in line with Beshir *et al.*[9], who declared that applied nitrogen increased the pod number per plant. In addition, this finding is in agreement with the findings of Gascho[32], who reported that yield increases when boron and nitrogen applied on soybean during reproductive development. Similarly, Oplinger *et al.*[33] observed that boron applied on soybean resulted in early flowering increased yields by 3% and Davis *et al.*[34] reported that plants receiving foliar or soil boron had higher total and marketable yields than plants no receiving boron. Previous studies have revealed that total pod yield as well as pod quality of green beans were significantly enhanced with increased levels of nitrogen[22]. As different researchers indicated that, boron is one of the essential micro-nutrients required by plant for pollen and pollen tube development[35,36]. In our study, an increase in the pod number with increasing Boron fertilization rate might be related with the role of boron on the improvement of fertilization through enhancement of pollen and pollen tube development.

Total pod yield (t ha^{-1}): The analysis of variance showed that total pod yield was significantly ($p<0.001$) affected by the main effects of N and B fertilizers as well as the interaction ($p<0.05$) effect of the two factors.

Numerically the highest total pod yield of green beans was obtained from the combination of 100 N and 2 kg B ha^{-1}. The lowest total pod yield was recorded from the combination of N at rate of 0 kg ha^{-1} with B at rate of 0 kg ha^{-1} (control treatment). This combination was no statistically different from the combination of 0 and 50 kg N ha^{-1} with all rates of kg B ha^{-1}. The combination of 100 kg N ha^{-1} with 2 kg B ha^{-1} brought about 40.36% increments in total pod yield as compared to control treatment (0 kg N ha^{-1}) with (0 kg B ha^{-1}) treatment combinations.

The current study showed that both N and B determined the total pod yield tone per hectare of the green bean particularly 100 kg N ha^{-1} with 2 kg B ha^{-1} increased total pod yield (Table 3). This finding is in line with Beshir *et al.*[9], who declared that applied N at 100 kg ha^{-1} increased the total pod yield. Srinivas and Naik[37] in which application of nitrogen fertilizer at 100 kg ha^{-1} to the vegetable green beans led to high marketable yield of all varieties obtained similar results. Similarly this finding is in line with BARI[38] which reported that application of 150 kg N ha^{-1} produced significantly higher pod yield of green beans that was at par with 200 kg N ha^{-1}. Prajapoti *et al.*[39] also recorded higher pod yield of French bean from 120 kg N ha^{-1}. Also this finding is in agreement with the findings of Gascho[32], who reported that yield increases when boron and nitrogen were applied to soybean during reproductive development. Similarly Oplinger *et al.*[33] observed that boron applied to soybean resulted in early flowering and increased yields by 3% and Davis *et al.*[34] reported that plants receiving foliar or soil boron had higher total and marketable yields than plants receiving no boron. Previous studies have revealed that total pod yield as well as pod quality of green beans were significantly enhanced with increased levels of nitrogen[35]. Ali *et al.*[40], who reported that boron treatment achieved a significant increase in the number of pods with a percentage increase of 10% compared to control. Moreover, Reddy *et al.*[41] indicated that application of micronutrients including boron significantly influenced total yield in pigeon pea through the modification of plant growth morphology and physiology. In this study we observed that an increase in pod yield might be due to inhibition of flower inhibition and pod abscission, improvement in morpho-physiological characteristic like plant height, brunch number, leaf area, pod yield and enhanced dry matter accumulation and its portioning to increase pod per plants (Table 1-3). This was consistent with Abd El-Monem *et al.*[31] on broad beans when sprayed boron resulted in higher yield. The interaction between N and boron was with a percentage increase of 56.9% compared to control. This was consistent with Shaaban *et al.*[42] that interaction of boron with nitrogen led to an increase in the number of seeds on broad bean.

Aboveground fresh biomass of green bean: The analysis of variance showed that aboveground fresh biomass of green beans such as shoot fresh weight, total aboveground fresh biomass and harvest index of green bean were significantly affected by the main effects of N ($p<0.001$) and B ($p<0.05$) fertilizers applied. The interaction effect of these two factors also significantly influenced aboveground biomass of green bean.

The highest total aboveground fresh biomass, shoot fresh weight and pod fresh weight were recorded from the applied of 150 kg N ha^{-1} and 6 kg B ha^{-1}. This combination was statistically similar to the combination of 150 kg N ha^{-1} with 2 and 4 kg B ha^{-1}. The lowest total aboveground fresh biomass, shoot fresh weight and pod fresh weight was recorded from the combination of N at rate of 0 kg ha^{-1} with B at rate of 0 kg ha^{-1} (control treatment). This combination was no statistically different from the combination of 0 and 50 kg N ha^{-1} with all rates of kg B ha^{-1} (0, 2, 4, 6 kg B ha^{-1}). The least all aboveground biomass parameters was recorded from control treatment. Total aboveground fresh biomass is was no statistically different from the combination of 0 and 50 kg N ha^{-1} with all rates of kg B ha^{-1} (0, 2, 4, 6 kg B ha^{-1}). The least all aboveground biomass parameters was recorded from control treatment. Total aboveground fresh biomass is

Table 4: Interaction effect of Nitrogen and boron fertilizer sources on aboveground fresh biomass of green bean at Dugda woreda (Meki)

Nitrogen (kg ha^{-1})	Boron (kg ha^{-1})	Shoot fresh weight (g m^{-2})	Pod fresh weight (g m^{-2})	Total aboveground fresh biomass (g m^{-2})	Harvest index (%)
0	0	1475.0^{f}	1191.0^{h}	2633.0^{g}	0.450^{f}
	2	1447.0^{f}	1197.0^{h}	2644.0^{g}	0.450^{f}
	4	1616.0^{ef}	1366.0^{f-h}	2983.0^{fg}	0.458^{d-f}
	6	1610.0^{ef}	1359.0^{f-h}	2969.0^{fg}	0.457^{ef}
50	0	1606.0^{ef}	1355.0^{f-h}	2961.0^{fg}	0.457^{d-f}
	2	1663.0^{ef}	1414.0^{f-h}	3076.0^{fg}	0.459^{c-f}
	4	1676.0^{ef}	1425.0^{e-h}	3101.0^{efg}	0.459^{c-f}
	6	1696.0^{d-f}	1452.0^{d-g}	3141.0^{d-g}	0.462^{b-e}
100	0	1935.0^{bc}	1684.0^{b-e}	3619.0^{b-e}	0.465^{a-d}
	2	1948.0^{b-d}	1699.0^{b-d}	3645.0^{b-d}	0.466^{a-c}
	4	1794.0^{c-e}	1544.0^{c-f}	3339.0^{c-f}	0.462^{b-e}
	6	1849.0^{b-e}	1598.0^{b-f}	3448.0^{bc-f}	0.464^{ab-e}
150	0	1960.0^{bc}	1709.0^{b-d}	3703.0^{bc}	0.462^{b-e}
	2	2074.0^{ab}	1823.0^{b}	3897.0^{b}	0.468^{ab}
	4	1989.0^{bc}	1739.0^{bc}	3728.0^{bc}	0.466^{a-c}
	6	2223.0^{a}	1973.0^{a}	4196.0^{a}	0.470^{a}
CV (%)		4.8	5.8	5.6	0.5

Means followed by the same letter within column are not significantly different at p<0.05 level of significance, CV: Coefficient of variation (%)

generally increased significantly with the increase in the rate of nitrogen and boron fertilizer applied (Table 4). The combination of 150 kg N ha^{-1} with 6 kg B ha^{-1} brought about 34.89% increments in shoot fresh weight gram per meter square, 39.61% in pod fresh weight gram per meter square, 37.24% in total aboveground fresh biomass and 4.26% in harvest index of green bean as compared to control treatment (0 kg N with 0 kg B ha^{-1}). This finding is in line with Beshir *et al.*[23], who declared that application of 100 kg N ha^{-1} increased fresh pod yield by 42% as compared to the control (0 N ha^{-1}). Similarly, this result related to El-Awadi *et al.*[43] stated that the application of nitrogen fertilizer at recommended dose increasing significantly the vegetative growth criteria (i.e., plant length, leaves number/plant, number of branches/plants and fresh and dry weight per plant).

Aboveground dry biomass of green bean: The analysis of variance showed that aboveground dry biomass of green beans such as shoot dry weight, pod dry weight and total aboveground dry biomass of green bean were significantly affected due to the main effect of applied N (p<0.001*)* and B (p<0.05) fertilizers. The interaction of the two main factors also significantly (p<0.05) affected aboveground dry biomass. Numerically the highest total dry biomass, shoot dry weight and pod dry weight were recorded from combined application of 150 kg N ha^{-1} and 6 kg B ha^{-1}. This combination was statistically similar to the combination of 150 kg N ha^{-1} with each of 2 and 4 kg B ha^{-1}. The lowest total dry biomass, shoot dry weight and pod dry weight were recorded from the combination of N at rate of 0 kg ha^{-1} with B at rate of 0 kg ha^{-1} (control treatment). This combination was no statistically different from the combination of 0 and 50 kg N ha^{-1} with all rates of kg B ha^{-1} (0, 2, 4 and 6 kg B ha^{-1}). Total aboveground dry biomass of green beans is increased as the rate of nitrogen and boron fertilizer applications increased (Table 5). The combination of 150 kg N ha^{-1} with 6 kg B ha^{-1} brought about 39.66% increments in pod dry weight gram per meter square, 33.15% in shoot dry weight gram per meter square, 32.25% in total aboveground dry biomass and 4.26% in harvest index of green bean as compared to control treatment (0 kg N with 0 kg B ha^{-1}). This finding of boron in line with Jasim and Obaid[44], who stated that boron treatment achieved a significant increase in pod dry weight which reaching 8.89 g with a percentage increase of 7.75% compared to control. This is due to the role of boron to encourage vegetative growth and increase the rate of photosynthesis and gathering plant dry matter[23]. This current finding is also in line with Beshir *et al.*[22], who declared that application of 100 kg N ha^{-1} resulted in the highest pod dry weight as compared to the control (0 N ha^{-1}).

Pod quality parameter for market standard

Marketable pod yield (t ha^{-1}): The analysis of variance revealed that applied N and B as main factor and their interaction significantly (p<0.001) affected marketable pod yield of green bean.

Table 5: Interaction effect of nitrogen and boron fertilizers on aboveground dry biomass (Pod dry weight, Shoot dry weight and Total aboveground dry biomass) of green bean at Dugda woreda (Meki)

Nitrogen (kg ha^{-1})	Boron (kg ha^{-1})	Pod dry weight (g m^{-2})	Shoot dry weight (g m^{-2})	Total aboveground dry biomass (g m^{-2})
0	0	238.27^{e}	288.27^{f}	526.53^{f}
	2	239.40^{e}	289.40^{f}	528.80^{f}
	4	273.20^{de}	323.20^{ef}	596.40^{ef}
	6	271.87^{de}	321.87^{ef}	593.73^{ef}
50	0	271.00^{de}	321.20^{ef}	592.20^{ef}
	2	282.53^{de}	336.03^{d-f}	618.57^{ef}
	4	285.00^{de}	335.22^{ef}	620.22^{ef}
	6	289.07^{c-e}	339.06^{d-f}	628.13^{d-f}
100	0	336.87^{bc}	386.87^{b-d}	723.73^{b-d}
	2	339.47^{bc}	392.80^{bc}	732.27^{bc}
	4	315.47^{b-d}	358.80^{c-e}	674.26^{c-e}
	6	319.73^{b-d}	369.70^{b-e}	689.47^{bc-e}
150	0	345.00^{bc}	391.87^{bc}	737.07^{bc}
	2	364.67^{b}	414.73^{b}	779.33^{b}
	4	347.70^{bc}	397.73^{bc}	745.47^{bc}
	6	394.53^{a}	444.43^{a}	839.07^{a}
CV (%)		5.80	4.90	5.30

Means followed by the same letter within column are not significantly different at p<0.05 level of significance, CV: Coefficient of variation (%)

The marketable pod yield of green beans was improved by application of both N and B fertilizers. The highest pod marketable pod yield of green beans was obtained from the combination of 100 N and 2 kg B ha^{-1} and this was statistically similar with of 150 N and 2 kg B ha^{-1}. Numerically, the lowest marketable pod yield was recorded from the combination of N at rate of 0 kg ha^{-1} with B at rate of 0 kg ha^{-1} (control treatment). The combination of 100 kg N ha^{-1} with 2 kg B ha^{-1} brought about 81% increments in marketable pod yield as compared to control treatment (0 kg N ha^{-1}) with (0 kg B ha^{-1}) treatment combinations. Generally, marketable pod yield of green beans was improved as the combination of N with B fertilizers increased. Lack of N at lower rates may limit the growth and shininess of pods that reduce its appearance and overall look for marketability. Similarly results are reported by Mahmoud *et al.*[22] that indicated, total pod yield as well as pod quality of green bean were significantly improved by increased levels of N. This finding is supported by Beshir *et al.*[9], who declared that applied nitrogen at the rate of 100 kg ha^{-1} improved marketable pod yield of green beans. Similar other results were obtained by Srinivas and Naik[37] in which applied of N fertilizer at 100 kg ha^{-1} to the vegetable green beans led to high marketable yield of all varieties. Further, this finding is in agreement with the findings of Gascho[32], who reported that yield increases when B and N were applied to soybean during reproductive development. Similarly Oplinger *et al.*[33] observed that boron applied to soybean early flowering increased yields by 3% and Davis *et al.*[34] reported that Plants receiving foliar or soil B had higher total and marketable yields than plants receiving no B.

Pod length and diameter: The analysis of variance revealed that pod length of green beans was significantly (p<0.001) affected due to the main effect of N and B fertilizer application and also the interaction (p<0.05) effect of N and B fertilizers. However, pod diameter was not affected by N and B as well as their interaction.

Numerically, the longest pod length was obtained from the combination of 150 N and 6 kg B ha^{-1}. This combination was statistically at par to the combination of 50, 100 and 150 kg N ha^{-1} with all level of B fertilizer except 50 kg N ha^{-1} with 0 kg B ha^{-1}. Numerically, the lowest pod length was recorded from the combination of N at rate of 0 kg ha^{-1} with B at rate of 0 kg ha^{-1} (control treatment). This combination was statistically same to the combination of 0 kg N ha^{-1} with 2 kg B ha^{-1} (Table 6). Application of 150 kg N ha^{-1} with 6 kg B ha^{-1} brought about 26.34% increments in pod length as compared to control treatment (0 kg N with 0 kg B ha^{-1}). Generally, pod length of green beans was increased as the combination of N with B fertilizers increased. This finding is in line with Beshir *et al.*[9], who declared that applied nitrogen at the rate of 100 kg ha^{-1} increased pod length than Rhizobium inoculation and the control treatment of no fertilizers. Similarly according to Moniruzzaman *et al.*[27], pod length increased with the increase of nitrogen up to 120 kg N ha^{-1}. Singh[45] got maximum pod length from the application of 125 kg N ha^{-1}. Optimum level of nitrogen (120 kg ha^{-1}) increases the rate of photosynthesis by chlorophyll formation and thus more photo assimilates were made and pod length increased[35]. Moreover application of Zn and B significantly increased pod length up to 4 kg Zn

Table 6: Interaction effect of Nitrogen and Boron fertilizer sources on marketable pod yield and pod length at Dugda woreda (Meki)

Nitrogen (kg ha^{-1})	Boron (kg ha^{-1})	Marketable yield (t ha^{-1})	Pod length (cm)
0	0	10.21^{g}	10.467^{f}
	2	10.72^{g}	11.17^{ef}
	4	12.44^{f}	11.967^{de}
	6	12.387^{f}	12.7^{b-d}
50	0	11.64^{fg}	12.567^{cd}
	2	12.56^{f}	13.2^{a-c}
	4	12.76^{ef}	13.23^{a-c}
	6	13.22^{ef}	13.43^{a-c}
100	0	14.87^{cd}	13.167^{a-c}
	2	18.493^{a}	13.37^{a-c}
	4	14.26^{de}	13.7^{ab}
	6	14.38^{c-e}	13.93^{a}
150	0	15.83^{b-d}	13.93^{a}
	2	16.92^{ab}	13.8^{ab}
	4	15.93^{bc}	14.07^{a}
	6	15.60^{cd}	14.20^{a}
CV (%)		7.20	2.90

Means followed by the same letter within column are not significantly different at p<0.05 level of significance, CV (%): Coefficient of variation (%)

Table 7: Interaction effect of Nitrogen and boron fertilizer sources on texture, appearance and straightness of green bean at Dugda woreda (Meki)

Nitrogen rate (kg ha^{-1})	Boron rate (kg ha^{-1})	Texture	Appearance	Straightness
0	0	2.10^{a}	2.067^{ab}	2.13^{e}
	2	1.67^{abc}	1.80^{a-e}	2.40^{de}
	4	1.93^{a}	2.13^{a}	2.53^{cd}
	6	1.73^{ab}	1.93^{abc}	2.53^{cd}
50	0	1.67^{abc}	1.867^{a-d}	2.40^{de}
	2	1.67^{abc}	1.867^{a-d}	2.40^{de}
	4	1.40^{bcd}	1.667^{b-f}	2.50^{cd}
	6	1.23^{cd}	1.467^{d-g}	2.60^{b-d}
100	0	1.33^{bcd}	1.467^{d-g}	2.60^{b-d}
	2	1.33^{bcd}	1.53^{c-g}	2.53^{cd}
	4	1.40^{cd}	1.53^{c-g}	2.67^{b-d}
	6	1.40^{cd}	1.60^{c-g}	2.80^{a-c}
150	0	1.33^{bcd}	1.40^{efg}	2.67^{b-d}
	2	1.33^{bcd}	1.33^{fg}	2.67^{b-d}
	4	1.27^{cd}	1.40^{efg}	2.867^{ab}
	6	1.00^{d}	1.20^{g}	3.067^{a}
CV (%)		10.10	8.50	3.50

Means followed by the same letter within column are not significantly different at p<0.05 level of significance, CV (%): Coefficient of variation (%)

and 1.0 kg B ha^{-1}. Optimum level of nitrogen (120 kg ha^{-1}) increases the rate of photosynthesis by chlorophyll formation and thus more photo assimilates were made and pod length increased. However when nitrogen was applied up to 160 kg ha^{-1}, nitrogen increased vegetative growth instead of pod development.

Pod texture, appearance and straightness: The result indicated that pod texture, appearance and straightness of green bean pod were significantly influenced by the main effect of N (p<0.001) and B (p<0.01) as well as by the interaction (p<0.05) of N and B.

The pod texture, appearance and straightness of green bean was improved by application of both N and B fertilizers. Fine pod texture, remarkable pod appearance and straight pods of green bean were obtained from the combination of 150 N and 6 kg B ha^{-1} (Table 7). This combination resulted in statistically similar to the combination of 50, 100 and 150 kg N ha^{-1} with all level of B fertilizer except 50 kg N ha^{-1} with 0 and 2 kg B ha^{-1}. The coarser pod texture, poor pod appearance and more curved pods were obtained from the combination of N at rate of 0 kg ha^{-1} with B at rate of 0 kg ha^{-1} (control treatment). This was statistically same to the combination of 0 and 50 kg N ha^{-1} with all rates of B

Table 8: Economic analysis due to the application of nitrogen and boron fertilizers on pod yield of variety plate green beans grown at East Shoa Zone Dugda Woreda (meki)

Nitrogen and boron rate (kg ha^{-1})	Average pod yield -----------(kg ha^{-1})----------		Gross field benefit -----------(ETB ha^{-1})-----------		Net benefit (ETB ha^{-1})	Marginal Return	Marginal rate return (%)	Benefit cost ratio
0×0	10210	1021	102100	45285	56815	-	-	1.3
50×0	10640	1064	106400	45860	60540	7.5	748	1.3
100×0	14870	1487	148700	46435	102265	33.3	3333	2.2
0×2	10720	1072	107200	46685	60515	-176.6	D	1.3
150×0	15830	1583	158300	47010	111290	240.0	24003	2.4
50×2	12560	1256	125600	47260	78340	-182.2	D	1.7
100×2	18490	1849	184900	47835	137065	154.4	15439	2.9
0×4	12440	1244	124400	48085	76315	-387.2	D	1.6
150×2	16920	1692	169200	48410	120790	259.8	25981	2.5
50×4	12760	1276	127600	48660	78940	-303.9	D	1.6
100×4	14260	1426	142600	49235	93365	30.7	3066	1.9
0×6	12390	1239	123900	49485	74415	-114.2	D	1.5
150×4	15930	1593	159300	49810	109490	177.9	17789	2.2
50×6	13220	1322	132200	50060	82140	-180.9	D	1.6
100×6	14380	1438	143800	50635	93165	40.0	3998	1.8
150×6	15600	1560	156000	51210	104790	71.9	7191	2.0

D: Dominance, During experimental period the price of urea and borax was 11.5 and 700 ETB kg^{-1}, respectively and the cost of green bean seed was 120 ETB kg^{-1}

fertilizer except 50 kg N ha^{-1} with 4 and 6 kg B ha^{-1}. Generally, pod texture, appearance and straightness of green beans were improved as the combination of N with B fertilizers increased. This finding is in line with Beshir *et al.*[9], who reported applied nitrogen at the rate of 100 kg ha^{-1} improved pod texture and appearance of green beans. Similarly the results are in agreement with that obtained by Mahmoud *et al.*[22] indicated that total pod yield as well as pod quality of green beans were significantly improved by increased levels of nitrogen.

Partial budget analysis: Partial budget is a way of calculating the total costs that vary and the net benefits of each treatment[44]. From this study, the average yields of 16 treatment combinations were obtained. According to CIMMYT[46] the average yield was adjusted down wards by 10%. This is for the reason that, researchers have assumed that using plots the same treatments the yields from the experimental and plots and farmers' fields are different, thus average yield should be adjusted down ward. Based on this, the recommended level of 10% was adjusted from all 16 treatments to get the net yield.

For the different treatment combinations the total costs and net benefits were calculated. As the rate of N and B fertilizer application increased, each additional kilogram of the fertilizer had effect on pod yield. To estimate the total costs, average current prices of urea and Borax were collected at the time of planting and the field average price of 1 kg of pod yield of green beans was taken at harvest (17 birr kg^{-1}). The cost of daily labour during the season was 80 birr per day. Then finally, adjusted yield was multiplied by field price to obtain gross field benefit of green beans. All the variable costs were subtracted from gross benefit to obtained net benefit.

The result of the economic analysis showed that the highest net benefit 120790 birr ha^{-1}, the highest marginal rate of return to 25980% and were obtained from combined application of 150 N and 2 kg B ha^{-1} (Table 8).

CONCLUSION

The results of the study showed that most of the green bean phenology, growth, yield and pod quality parameters were significantly affected by the N and B treatments. Combined applications of higher rates of N and B resulted in delay flowering and maturity of green bean. The result also indicated that higher rates of N and applied B encouraged vegetative growth leading to improve above ground biomass and pod yield of green bean. The effect of higher of N fertilizer had more influence than the levels of B. Pod quality of green bean also improved by the applications of N and B. Generally, higher rates of N considered in the current study resulted in better yield and pod quality of green bean. But 2 kg ha^{-1} of B was enough to improve green bean pod yield and quality when combined with higher rates of N (100 and 150 kg N ha^{-1}) of N. Depending on the availability of resources to buy the fertilizer, green bean producers in the study area can use 100-150 N ha^{-1} combined with 2 kg B ha^{-1}.

REFERENCES

1. Abate, G., 2006. The market for fresh green beans. Working Paper, The Strategic Marketing Institute, pp: 6-8.

2. CIAT., 2006. Highlights of CIAT in Africa: Green beans for income generation by small farmers in east Africa. Series No. 31, International Center for Tropical Agriculture, Africa.
3. Wossen, T., 2017. Determination of optimum rate of blended fertilizer for pod yield of snap bean (*Pharsalus vulgaris* L.) at Teda, North Gondar, Ethiopia. Int. J. Sci. Basic Applied Res., 32: 66-79.
4. Alemu, Y., S. Ketema, M. Hinsermu, J. Geleto and G. Tabor *et al*., 2018. Performance of snap bean (*Phaseolus vulgaris* L.) genotypes for green pod yield and quality in the central Rift valley of Ethiopia. Greener J. Plant Breed. Crop Sci., 6: 1-6.
5. FAO., 2012. FAOSTAT statistical database. Food and Agriculture Organization of the United Nations, Rome, Italy.
6. Gupta, U.C., 2007. Boron. In: Handbook of Plant Nutrition, Barker, A.V. and D.J. Pilbeam (Eds.). CRC Press, New York.
7. Yamagishi, M. and Y. Yamamoto, 1994. Effects of boron on nodule development and symbiotic nitrogen fixation in soybean plants. Soil Sci. Plant Nutr., 40: 265-274.
8. Bonilla, I., O. Cadahia, O. Carpena and V. Hernando, 1980. Effects of boron on nitrogen metabolism and sugar levels of sugar beet. Plant Soil, 57: 3-9.
9. Beshir, H.M., B. Tesfaye, R. Bueckert and B. Taran, 2015. Pod quality of snap bean as affected by Nitrogen fixation, cultivar and climate zone under dryland agriculture. Afr. J. Agric. Res., 10: 3157-3169.
10. CSA., 2014. Agricultural sample survey 2014: Volume I. Report on area and production of major crops (Private peasant holdings, meher season). Statistical Bulletin 532, Central Statistical Agency, Addis Ababa, Ethiopia.
11. Murphy, H.F., 1968. A report on fertility status and other data on some soils of Ethiopia. Experimental Station Bulletin No. 44, Hailesilassie College of Agriculture, Oklahoma State University, pp: 1-551.
12. Tekalign, T., I. Hague and E.A. Aduayi, 1991. Soil, plant, water, fertilizer, animal manure and compost analysis manual. Plant Science Division (PDS), Working Document No. B13, International Livestock Center for Africa (ILCA), Addis Ababa, Ethiopia.
13. Martinez, C., G. Ros, M.J. Periago, G. Lopez, J. Ortuno and F. Rincon, 1995. Physico-chemical and sensory quality criteria of green beans (*Phaseolus vulgaris*, L.). LWT-Food Sci. Technol., 28: 515-520.
14. Proulx, E., Y. Yagiz, M.C.N. Nunes and S. Banyal, 2010. Quality attributes limiting snap bean post harvest life at chilling and non-chilling temperatures. HortScience, 45: 1238-1249.
15. Getachew, E., A. Mohammed, A. Tesfaye and A. Nebiyu, 2014. Growth and yield response of green beans (*Phaseolus vulgaris* L.) in relation to time of sowing and plant spacing in the humid tropics of Jimma, southwest Ethiopia. Int. J. Soil Crop Sci., 2: 61-67.
16. Brady, N.C. and R.R. Weil, 2002. The Nature and Properties of Soils. 13th Edn., Prentice Hall, New Jersey, ISBN: 0130167630, Pages: 960.
17. Devlin, R.M. and F.H. Witham, 1986. Plant Physiology. 4th Edn., CBS Publishers and Distributors, Delhi, India.
18. Robertson, G.A. and B.C. Loughman, 1974. Reversible effects of boron on the absorption and incorporation of phosphate in *vicia faba* L. New Phytol., 73: 291-298.
19. Abdel-Mawgoud, M., S.R. EL-Desuki, S.D. Salman and A.M.R. Abou-Hussein, 2005. Performance of some snap bean varieties as affected by different levels of mineral fertilizers. J. Agron., 4: 242-247.
20. Otieno, P.E., J.W. Muthomi, G.N. Chemining'wa and J.H. Nderitu, 2009. Effect of rhizobia inoculation, farm yard manure and nitrogen fertilizer on nodulation and yield of food grain legumes. J. Biol. Sci., 9: 326-332.
21. Mahmoud, A.R., M. El-Desuki and M.M. Abdel-Mouty, 2010. Response of snap bean plants to bio-fertilizer and nitrogen level application. Int. J. Acad. Res., 2: 179-183.
22. Beshir, H.M., F.L. Walley, R. Bueckert and B. Tar'an, 2015. Response of snap bean cultivars to Rhizobium inoculation under dryland agriculture in Ethiopia. Agronomy, 5: 291-308.
23. Zahoor, R., S.M.A. Basra, H. Munir, M.A. Nadeem and S. Yousaf, 2011. Role of boron in improving assimilate partitioning and achene yield in sunflower. J. Agric. Soc. Sci., 7: 49-55.
24. Chatzopoulou, P.S., T.V. Koutsos and S.T. Katsiotis, 2006. Study of nitrogen fertilization rate on fennel cultivars for essential oil yield and composition. J. Veg. Sci., 12: 85-93.
25. Aaid, K.Y., 2012. The effect of three foliar fertilizers on the growth and yield of two variety broad been (*Vicia faba* L.) under the drip irrigation system. Tikrit Univ. Agric. J., 12: 131-137.
26. Kleinkopf, G.E., D.T. Westermann and R.B. Dwelle, 1981. Dry matter production and nitrogen utilization by six potato cultivars. Agron. J., 73: 799-802.
27. Moniruzzaman, M., M.R. Islam and H. Hasan, 2008. Effect of N P K S Zn and B on yield attributes and yield of French bean in South Eastern Hilly Region of Bangladesh. J. Agric. Rural Dev., 6: 75-82.
28. Barker, A.V. and D.J. Pilbeam, 2006. Handbook of Plant Nutrition. CRC Press, New York, ISBN-13: 9780824759049, Pages: 632.
29. Puzina, T.I., 2004. Effect of zinc sulfate and boric acid on the hormonal status of potato plants in relation to tuberization. Russian J. Plant Physiol., 51: 209-214.
30. Ali, N.S. and A.S. Ati, 2011. The effect of boron fertilization on faba bean (*Vicia faba* L) yield, fertilizer and water productivity. Euphrates J. Agric. Sci., 3: 81-86.
31. Abd El-Monem, M.S., I.F. Ibrahim and R.S. Mahmoud, 2009. Response of broad bean and lupin plants to foliar treatment with boron and zinc. Austr. J. Basic Applied Sci., 3: 2226-2231.

32. Gascho, G.J., 1993. Boron and Nitrogen Applications to Soybeans: Foliar and through Sprinkler Irrigation. In: Foliar Fertilization of Soybeans and Cotton, Murphy, L.S. (Ed.). Potash and Phosphate Institute, Norcross, GA., pp: 17-33.
33. Oplinger, E.S., R.G. Hoeft, J.W. Johnson and P.W. Tracy, 1993. Boron Fertilization of Soybean: A Regional Summary. In: Foliar Fertilization of Soybeans and Cotton, Murphy, L.S. (Ed.). Potash and Phosphate Institute, Norcross, GA., pp: 7-16.
34. Davis, J.M., D.C. Sanders, P.V. Nelson, L. Lengnick and W.J. Sperry, 2003. Boron improves growth, yield, quality and nutrient content of tomato. J. Am. Soc. Hortic. Sci., 128: 441-446.
35. Fageria, N.K., 2009. The Use of Nutrient in Crop Plants. CRC Press, New York, USA.
36. Hedge, D.M. and K. Srinivas, 2004. Plant water relations and nutrient uptake in French bean. J. Irrigat. Sci., 11: 51-56.
37. Srinivas, K. and L.B. Naik, 1990. Growth, yield and nitrogen uptake in vegetable French bean (*Phaseolus vulgaris* L.) as influenced by nitrogen and phosphorus fertilization. Haryana J. Hortic. Sci., 19: 160-167.
38. BARI., 2004. Annual report. Bangladesh Agricultural Research Institute, Gazipur, Bangladesh, pp: 341-342.
39. Prajapati, M.P., H.A. Patel, B.H. Prajapati and L.R. Patel, 2004. Studies of nutrient uptake and yield of frenchbean (*Phaseolus vulgaris* L.) as affected by weed control methods and nitrogen levels. Legume Res. Int. J., 27: 99-102.
40. Ali, A., M.A. Nadeem, A.T.M. Tahir and M. Hussain, 2007. Effect of different potash levels on the growth, yield and protein contents of chickpea (*Cicer arietinum* L.). Pak. J. Bot., 39: 523-527.
41. Reddy, M.M., B. Padmaja, S. Malathi and L.J. Rao, 2007. Effects of micronutrients on growth and yield of pigeonpea. J. SAT Agric. Res., 5: 3-3.
42. Mahmoud, M.S., F.E.S. Abdalla, E.A.M.A. Abou El-Nour and A.K.M. El-Saady, 2006. Boron/Nitrogen interaction effect on growth and yield of faba bean plants grown under sandy soil conditions. Int. J. Agric. Res., 1: 322-330.
43. El-Awadi, M.E., A.M. El-Bassiony, Z.F. Fawzy and M.A. El-Nemr, 2011. Response of snap bean (*Phaseolus vulgaris* L.) plants to nitrogen fertilizer and foliar application with methionine and tryptophan. Nat. Sci., 9: 87-94.
44. Jasim, A.H. and A.S. Obaid, 2014. Effect of foliar fertilizers spray, boron and their interaction on broad bean (*Vicia faba* L.) yield. Sci. Pap. Ser. B Hortic., 58: 271-276.
45. Singh, R.V., 2000. Response of frenchbean (*Phaseolus vulgaris* L.) to plant spacing and nitrogen, phosphorous fertilization. Indian J. Hortic., 57: 338-341.
46. CIMMYT., 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. CIMMYT Economics Program, Mexico, DF., ISBN-10: 9686127186, Pages: 79.