EFFECT OF NITROGEN RATE ON GROWTH, YIELD AND QUALITY OF GREEN BEAN *(Phaseolus vulgaris* L.*)* VARIETIES AT BISHOFTU, CENTRAL ETHIOPIA

MSc THESIS

BY

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Hailye Negussie Wondemagegn

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APPROVAL SHEET
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As Thesis research advisor, I herby certify that I have read and evaluated this thesis prepared, under my guidance, by Hailye Negussie, entitled "**Effect of Nitrogen Rate on Growth, Yield and Quality of Green Bean *(Phaseolus Vulgaris L.)* Varieties at Bishoftu, Central Ethiopia**". I recommend that it be submitted as fulfilling the thesis requirement.

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As members of the *Board of Examiners of the MSc Thesis Open Defense Examination*, we certify that we have read, evaluated the thesis prepared by Hailye Negussie and examined the candidate. We recommended that the thesis could be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Horticulture (Vegetable Science).

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External Examiner	Signature	Date

DEDICATION

This thesis is dedicated to my fiancé **Helina Getachew** and **to all my friends**.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my work and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment for the requirements for an MSc Degree in Horticulture with specialized in Vegetable Science at Jimma University College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made available to borrowers under the rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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Name: Hailye Negussie

Signature: ________________

Place: Jimma, Ethiopia

Date of submission: November, 2012

LIST OF ABREVIATIONS

ATVET	Agricultural Technical and Vocational Education Training
DAP	Diammonium phosphate
DZARC	Debre Zeit Agricultural Research Center
EHDA	Ethiopian Horticulture Development Agency
IDEA	Investment in Developing Export Agriculture
JUCAVM	Jimma University College of Agricultural and Veterinary Medicine
MARC	Melkassa Agricultural Research Center
N	Nitrogen
P	Phosphorous
MRR	Marginal Rate of Return
SAS	Statistical Analysis Software
TSP	Triple Super Phosphate
UAAIE	Upper Awash Agro Industry Enterprise

BIOGRAPHICAL SKETCH

Hailye Negussie was born in March 5, 1980 in Addis Ababa, Ethiopia. He attended his elementary school (1987-1995) and secondary school (1995-1999) at Sebeste Negase and Nefas Silk, respectively. He then joined Jimma College of Agriculture (now Jimma University College of Agriculture and Veterinary Medicine) in 1999 to pursue his first degree and upon successful completion; he was awarded with a BSc degree in Horticulture in the year 2003. Immediately after graduation, he was employed in the Ministry of Agriculture and Rural Development of Ethiopia as a junior instructor in the Department of Plant Science at Agarfa Agricultural Technical and Vocational Education Training (ATVET), in September 2003 and served for one and half year. Since January, 2005 he has been working in various private organization as Senior Supervisor at Dugda Floriculture Development P.L.C. (March to August, 2005), Production Manager at Joe Flowers P.L.C. (September, 2005 to May, 2009) and Farm Manager at Supreme Flora P.L.C. (June, 2009 to August 2010). On September 2010, he joined the School of Graduate Studies program of Horticulture Department at Jimma University College of Agriculture and Veterinary Medicine for his MSc degree through self sponsorship.

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TABLE OF CONTENTS

Contents **Page**

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

Table **Pages**

LIST OF FIGURES

Figure **Page**

LIST OF TABLES IN THE APPENDICES

Appendix Table **Page**

EFFECT OF NITROGEN RATE ON GROWTH, YIELD AND QUALITY OF GREEN BEAN *(Phaseolus vulgaris L.)* VARIETIES AT BISHOFTU, CENTRAL ETHIOPIA

ABSTRACT

Green beans take the highest share among the leading exportable vegetables and recently, it is becoming one of the most important vegetables in local markets as well. However, several biotic and abiotic factors are contributing to the low yields and quality. Among others, soil nitrogen content is low on most part of the bean growing areas of the country and also there is no adequate application of nitrogen fertilizer. In addition, there is lack of adequate suitable varieties for specific or wider production locations. Therefore, an experiment was conducted at Bishoftu in the year 2011/2012 with the objective of determining the optimum level of N and identifies appropriate green beans (Phaseolus vulgaris L) varieties for higher yield and quality. A 4x5 factorial experiment arranged in Randomized Complete Block Design (RCBD) with three replications was used. The treatments consisted of four bush type bobby bean varieties namely, Melka 1, Melka 3, Melka 5 and Contender blue and five levels of N (0, 40, 80, 120 and 160 kg N ha^{-1}). In view of that, data were collected pertaining to growth, yield and quality of green beans and analyzed using SAS statistical software version 9.2 (SAS Institute Inc., 2008). The results revealed that the difference between the four varieties was highly significant ($P<0.05$) for all parameters studied. Variety Melka 3 gave highest plant height (37.41cm), total leaf area (2839.28 cm^2/plant), shoot and root dry weight (31.83 g/plant), total pod yield (14.04 t/ha), marketable pod yield (11.40 t/ha), average marketable pod weight (5.70g), pod dry weight (5.86 g/plant), pod straightness value (2.81) and pod length (13.56cm). The highest pod diameter (9.93mm) and pod protein content (19.71%) was obtained from Melka 5 and in the case of 50% flowering, Contender blue required shortest time (46.40 days). Application of N had a highly significant ($P<0.05$) effect on all studied parameters except for the tap root length and pod straightness. Application of 160 kg N ha^{-1} increased plant height by 9.36 cm, total leaf area by 50.62%, shoot and root dry weight by 45.9%, pod protein content by 10% and delayed days to 50% flowering by five days over the control and also highest value for pod color (3.39) and lower pod fiber content (2.93) was observed. The application of 120 kg N ha^{-1} increased the total pod yield by 49.85%, marketable pod yield by 52.33%, number of pods per plant by 42.48%, average marketable pod weight by 19.3%, pod dry weight by 90.79%, pod length by 15.25%, pod diameter by 37.99% over the control. The application of 120 kg N ha^{-1} produced a statistically similar result with 80 kg N ha^{-1} on total and marketable pod yield. Total pod yield had significantly positive correlation with plant height ($r=0.63^{**}$), total leaf area ($r=0.62^{**}$), days to 50% flowering ($r=0.48^{**}$), number of primary branches ($r=0.27^{*}$), marketable pod yield ($r=0.96^{**}$), unmarketable pod yield ($r=0.40^{**}$), total number of pods per plant ($r=0.64^{**}$), average marketable pod weight ($r=0.57^{**}$), pod length ($r=0.61^{**}$) and pod diameter ($r=0.68^{**}$). The statistical analyses it was evident that application of 80 kg N ha^{-1} with variety Melka 3 could improve productivity and quality of green beans around the study area while on the basis of partial budget analyses has also indicated that variety Melka 3 with 40 kg N ha^{-1} produced the highest MRR (1306.67%). However, repeating the experiment for more seasons would help us draw sound conclusions and recommendations. Hence, future studies should look in to these factors to develop fertilizer recommendations for optimum yield and quality of green bean in Bishoftu area.

1. INTRODUCTION

Green bean (*Phaseolus vulgaris L.*) belong to the family Leguminaceae, and subfamily Papilionaceae (Mahajan and Gupta, 2009) and they are autogamous, diploid with chromosome number of 2n=22 and originated in Central and South America (Swiader *et al.,* 1992). According to Bose *et al.* (2002), Africa is considered to be the secondary center of diversity. There is a speculation that green bean was introduced to Ethiopia in the 16^{th} century by the Portuguese (Frew, 2002).

According to Rubatzkey and Yamagucbi (1999) green bean is one of the most cultivated leguminous vegetables in the world and it is the most important food legume. It has been considered as an important protein supplement for cereals and root crops based food habits (Lemma, 2003). Green bean is mainly used as vegetable and its edible green pods supply protein, carbohydrate, fat, fiber, thiamin, riboflavin, Ca and Fe, and the seed contains significant amount of thiamin, niacin, folic acid as well as fiber (Duke, 1983). The leaves of bush and climbing types of green bean are also used as a vegetable in some systems, and the haulms after harvest are fed to livestock as a high-protein feed in areas like Ethiopia's Rift Valley (Katungi *et al.*, 2010).

FAOSTAT (2012) reported that in 2010, annual production of green bean in the world covered an area about 1.5 million hectares with a total production of 19.8 million tons while in Ethiopia the productions occupied total area of above 1,700 hectares, with total production of 6,900 tons and from this production the quantity of exported green bean were 3160 tons and 5.47 million USD were obtained. In similar year, the top five producers in the world are China, Indonesia, Turkey, India and Thailand. The major destination of the export markets for Ethiopian green beans is United Kingdom, United Arab Emirates and the Netherlands (EHDA and EHPEA, 2011).

Currently in Africa green bean are the leading export crop from non-traditional crops; and countries in Eastern and Southern African (Kenya, Zambia, Ethiopia, and Zimbabwe) have shown recent increases in green bean exports (Okello *et al.*, 2007). Similarly, in Ethiopia green bean is the leading vegetable export to European countries with the highest share among all vegetables let alone its importance in local markets. With the growing export and local demand, a lot of private and state enterprises are becoming involved in the production and export business of green bean (Lemma, 2003). Currently, the major production areas of green bean in Ethiopia are Debrezit, Hawasa, Holeta, Koka, Meki, Sebeta, Sendafa, Upper Awash area and Zewayi. In producing area the choice of green bean variety is determined by the geophysical characteristics (soils, climate, and disease and pest prevalence), as well as the preference of the end markets and the three most common types of green beans traded on the world market are extra fine, fine and bobby beans (Okello *et al.*, 2007; Henry, 2009; Rowell and Strang, 2011).

Green bean has low yield and quality generally in Africa and several biotic and abiotic factors are contributed to their low yields and quality. Biotic constraints include diseases and pests, varieties with low yield potential, and susceptibility to diseases and pests. And from the abiotic factors the major constraints are soil related (Okello *et al.*, 2007; Katungi *et al.*, 2010) and with the order of decreasing importance, they are N and P deficiency, low exchangeable bases, and soil moisture deficits, which may occur early, mid, or late in the season (Okello *et al.*, 2007). The other reason for lower yield of green bean is due to poor agronomic practices and also farmers don’t recognize the need of proper cultural practices like timely planting, fertilizer and manure application, weeding and crop protection in the field (Katungi *et al.*, 2010)

In eastern Africa, N is low on 50% of the bean production areas (Okello *et al.*, 2007). Similarly, Chien and Menon (1995) reported that most tropical soils are deficient in N and P. According to Hofman and Cleemput (2004) all soils in a natural state are deficient in N for crop growth. Soil nutrient depletion and decreasing yields are inevitable if crops are grown and harvested without replenishment of nutrients. Soil fertility studies conducted at different locations in Ethiopia for different crops have shown good yield responses to applied N and P fertilizers, indicating low N and P status of these soils (Berga *et al.*, 1994; Yohannes, 1994). It is also important to note that fertilizer response is directly related to soil and crop types emphasizing that soils varying in fertility status and crop species respond differently to applied fertilizers. Lemma (2003) stated that genetic potential and the environment to which the crop is exposed, determine its yielding ability and improving any or combination of potentially yield limiting factors may lead to an increase in productivity.

Generally, in 2010 the average productivity of green bean in Ethiopia was 4.06 tons ha^{-1} and it was very low as compared to the world average production of 13.2 tons ha^{-1} (FAOSTAT, 2012) and some of the major reasons for the low productivity are, first the soil nitrogen content is low on most part of the bean growing areas of the country and also there is no adequate application of nitrogen fertilizer. Secondly, there is lack of adequate suitable varieties for specific or wider production locations as a result of which the yield potential and quality of green bean is not adequately tapped. Although, few green bean varieties which vary in growth habit and yielding potential are under production in the country and their fertilizer recommendation is 92 kg P ha^{-1} and 82 kg N ha^{-1} (Lemma, 2003) and the application is regardless of varieties, production area and soil type and fertility status. Currently in Ethiopia the rates of N fertilizer application differs from producer to producer and also deviate from the national recommendation and some of the N application rates are 110, 140 and 215 kg ha^{-1} by Upper Awash Agro Industry Enterprise, Jittu farm and Ethio Vegfru P.L.C., respectively. While in the case of most farmers, the N application rates are lower from recommendation. These all imply that there is a need to come up with area and varieties specific fertilizer recommendation for green bean. Hence, this study was conducted with the general objective of determining the optimum level of N and identifies appropriate green bean varieties for higher yield and quality under Bishoftu conditions. The hypothesis behind this study is that pod yield and quality in green bean is a function of varieties and N fertilizer application.

Specific objectives:

- Determine the yield and quality response of green bean varieties to different levels of N fertilizer
- Select best performing variety/ies of green bean with respect to yield and quality
- Assess whether yield and quality of green bean is affected by the interaction effect of varieties and N level.

2. LITERATURE REVIEW

2.1. Description of Green Bean

Green bean belongs to the family Leguminaceae. The Leguminaceae families are the most important plant group involved in symbiotic N fixation comprises dicotyledonous plants. There are about 10,000 species of legumes, and out of these nearly 200 are cultivated by humans and have been divided into three subfamilies, namely Papilionaceae, Caesalpinioideae and Mimosoideae. The largest of the three is Papilionaceae and in this subfamily important cultivated genus are like *Trifolium, Melilotus, Medicago, Phaseolus, Crotalaria, Pisum, Dolichos, Cajanus, Vigna, Lathyrus,* etc. is found (Mahajan and Gupta, 2009). The genus *Phaseolus* includes approximately 35 species of which four are cultivated: *P. vulgaris L.*, *P. lunatus L.*, *P. Coccineus L.* and *P. acutifolius A*. (Bose *et al.*, 2002).

Green bean is also known as snap bean, pole bean, wax bean, string bean and French bean (Duke, 1983; Tindall, 1988). They are either pole (runner and half runner) or bush types. Bush type bean form compact plants (determinate) that grow 0.3 to 0.6 m in height with a uniform pod set, while pole bean produce vines (indeterminate) that may reach 2.4 to 3 m in length and bear pods continuously. Half runners have a growth habit between bush and runner, producing vines averaging 0.9 m long. Typically, pole bean set pods over a longer period of time than bush beans. Pods of either type may have strings or be string less; they may be round or flat in shape. While green is the most common color, pods may be yellow (wax beans), purple, or streaked (Henry, 2009; Rowell and Strang, 2011).

Green bean is usually picked while still immature and the inner bean are just beginning to form in the pod and they are typically eaten the pod in fresh form. Green beans are often deep emerald green in color and come to a slight point at either end. Green bean varieties are usually selected for their great texture and flavor while still young and fresh on the plant (WHFoods, 2012). The three most common types of green bean traded on the world market are extra fine, fine and bobby beans and they are sorted according to size and fine bean should be between 10 and 13cm in length and 6-9mm in diameter. Bobby bean should be between 12 and 16cm in length and 8-12mm in diameter (Henry, 2009; Rowell and Strang, 2011).

According to Kovatch (2003), Lemma (2003) and Henry (2009) harvesting of green bean generally takes place 50-65 days from planting and 15 to 18 days following full bloom although temperatures affect this time period (Henry, 2009). Similarly, Hodges (1990) reported that green bean are ready for harvest in 48-65 days after planting, depending on the climate and variety.

As indicated in Appendix Table 1 green bean is the major direct source of proteins, vitamins, micro and macro nutrients and dietary fiber for both humans and livestock, especially in poor countries, where animal protein is expensive. Raw leaves of green bean contain (per 100 g): 36 calories, 86.8% moisture, 3.6 g protein, 0.4 g fat, 6.6 g total carbohydrate, 2.8 g fiber, 2.6 g ash, 274 mg Ca, 75 mg P, 9.2 mg Fe, 3,230 mg b-carotene equivalent, 0.18 mg thiamine, 0.06 mg riboflavin, 1.3 mg niacin and 110 mg ascorbic acid (Duke, 1983).

2.2. Green Bean Production in Ethiopia

Ethiopia has a favorable climate, comparatively abundant land and labor as well as reasonably good water resources that created ample opportunities for horticultural crops production. The agro-ecological factors of the country give the chances of all-year-round production capability. Research findings and business experiences have attested that Ethiopian soil and climatic condition are very much ideal for growing a variety of vegetables and one of the common vegetables in Ethiopian export business is green bean. Green bean is by far the most promising agro-product of Ethiopia capable of winning the European market. The country's green bean producers can generally be grouped into three major categories and these are, state farms, private commercial farms and small scale farms (Focus Africa, 2012).

Green bean has been among the most important and highly prioritized crops as a means of foreign currency earning in Ethiopia (Gezahegn and Dawit, 2006). The production of green bean for Europe export markets was started by large state farms in the early 1970s (Lemma *et al.*, 2003) and its trade started around 1982, with small quantities being shipped to the Netherlands and Italy during the European winter. The state farms production was changed in the 1990s with the entry of private exporters following liberalization and the government's aggressive export promotion of horticultural crops but the role of smallholders in the green bean industry has been limited to private exporters only. It was estimated that more than 80 per cent of beans produced in Ethiopia are from large-scale state owned farms and as compared to Kenya and Zambia, the share of smallholder out growers in green bean production is quite small in Ethiopia (Okello *et al.,* 2007).

2.3. Soil and Climatic Requirements of Green Bean

Green bean is shallow rooted with most of the root absorbing surface in the top foot of the soil (Henry, 2009). They are grown on many soil types (sandy loam, or coarser, to silt loam soils) in a pH range of 5.5 to 7.5. The optimal pH for snap bean is 6.0 to 6.8 (Hodges, 1990). Bean prefers a loose-textured and well-drained soil with moderately high organic matter content. Excessively wet soils encourage root diseases and nutrition problems. Green bean do not tolerate salinity, and field should be selected that are low in salinity and a 50 per cent yield reduction can be expected with soil salinity of 3.6 EC (dS/m at 25^{o}C) (Henry, 2009).

Green bean is a warm season crop and they require a short growing season (Henry, 2009; Rowell and Strang, 2011). The crop does not tolerate frost or long periods of exposure to near freezing temperatures at any stage of growth. Usually high temperatures do not affect it if adequate soil water is present, although high nocturnal temperatures will inhibit pollination. The optimal temperature for seed emergence is 25^{o}C and for plant growth is 18.3 to 29.4^{o}C. Green bean require 1,050 to 1,150 degree-days of heat with a base of 10^{o}C while the temperatures above 32.2^{o}C cause blossoms to drop and ovules to abort. Heavy rains during flowering can also cause flower drop (Katung *et al*., 2009).

2.4. Nutrient Requirement of Green Bean

Green bean are species with low nitrogen fixing abilities (Graham, 1981; Lawn and Ahn, 1985; Henry, 2009) and unlike other leguminous crops it does not nodulate with the native rhizobia (Ali and kushwaha, 1987) and an effective nodulation caused either by commercial inoculants or by indigenous soil-bacteria (Vessey, 2002). In the conditions when the soils have low organic matter (0.3-1.0%) levels, it resulted either nil or very low viable count of effective rhizobia and low N supplying capacity (Ladha *et al.,* 1996). Hence, it is generally recommended that producers should always inoculate their seeds with commercially available fresh inoculants of superior quality.

The benefit of biological nitrogen fixation is realized only if symbiosis of plant with the bacteria operates efficiently. The factors determining the symbiotic process are the genetic constitution of the host plant and bacteria, environment, and technological inputs such as inoculums, fertilizers and pesticides (Munns, 1977). Tropical soils have a diverse range of physical, chemical and biological properties. These affect biological nitrogen fixation by their impacts on rhizobia populations. Thus, the ineffectiveness of nitrogen fixation in tropical soils can in most instances, be attributed to the lack of suitable bacteria (Date, 1988), and can be overcome by the use of inoculants to increase the rhizobia populations (Graham, 1981). But unlike to this, inoculations are not widely used in the developing world and, therefore, the process of biological nitrogen fixation is largely ineffective in tropical soils.

Generally, the biomass production, yield and nutritional quality of green bean pod are limited by the fertility of the soil where it is planted; thus, it is necessary to carry out agronomic practices such as application of fertilizer and biofertilizer to increase its biomass production, yield and nutritional quality (El-Awadi *et al.*, 2011; Salinas-Ramrez *et al.*, 2011). So, fertilizers (especially nitrogenous) are the most critical input for increasing crop production and had been recognized as the main element for its production (Mukhopadhyay *et al*., 1986; Slaton *et al.*, 2007; Henry, 2009; El-Awadi *et al.*, 2011)**.**

The other major essential plant nutrient is phosphorus and as observed that 50 kg P ha^{-1} was the maximum requirement for French bean while in the case of bush beans the highest pod yield was obtained with the application of 75 kg P ha^{-1} (Nasrin and Jahan, 2010). As Eira et al. (1974) found in an experiment that the economic rate of P application for French beans was 55 kg ha-1. The most obvious effect of phosphorus is on the root development, particularly the lateral and fibrous rootlets (Arya and Kalra, 1988) and also it has role on crop nutrition (Fox, 1986).

Generally, a mineral fertilizers application is essential for plant growth, development and yield productivity of snap bean plants. Many investigators reported that increasing NPK levels of application improved the plant growth, yield and green pod quality of snap bean (Mahmoud *et al.*, 2010). And before the application of nutrients a soil test is recommended to determine the need for fertilizer. The nitrogen applications should be split in to one pre-plant and the second is by side dressings (Hodges, 1990).

2.5. Nitrogen in the Soil

According to Marschner (1995) nitrogen is referred to as one of the primary macronutrients because of the general probability of plants being deficient in these nutrients and also they are required in large quantities from the soil relative to other essential nutrients. Hofman and Cleemput (2004) reported that total N content of surface mineral soils normally ranges between 0.05 and 0.2 per cent, corresponding to approximately 1750 to 7000 kg N ha^{-1} in the plough layer. Lower as well as higher amounts can be found, depending on the various soil-forming processes. Of this total N content only a small proportion, in most cases less than five per cent, is directly available to plants, mainly as nitrate N (NO_3^-–N) and ammonium N (NH_4^+-N). Organic N, being the rest, gradually becomes available through mineralization. Theoretically, plants prefer NH_4^+ over NO_3^-, since NH_4^+ does not need to be reduced before incorporation into plant compounds. In most well drained soils, oxidation of NH_4^+ is rapid and, as a consequence, NO_3^- is generally present in higher concentrations in soil than is NH_4^+. In addition, the relative ease of movement of NO_3^- through the soil facilitates its absorption by plants. Therefore, most plants have evolved to grow better with NO_3^- and, a number of studies have shown that plant growth may be enhanced with a mixed supply of NH_4^+ and NO_3^-.

The three main forms of inorganic N fertilizers are in the form of ammonium (NH_4^+), nitrate (NO_3^-) and urea ($CO(NH_2)_2$). The effectiveness of inorganic fertilizers is influenced by the principles of ion exchange. Because of its positive charge, NH_4^+-N is adsorbed by the negatively charged soil colloids (clay and organic matter) and thus retained from leaching. The negatively charged NO_3^--N is subject to leaching, which is most important in sandy-textured soils (Hofman and Cleemput, 2004).

Urea ($CO(NH_2)_2$) is 46 per cent N, all in amide form ($-NH_2$) and it has high N content and the most commonly used N fertilizer in the world. It has hygroscopic nature and when applied to the soil, the $–NH_2$ is first converted to NH_4^+ and subsequently to NO_3^-. When urea is applied, it rapidly hydrolyses in 10-14 days, under well-drained conditions by the urease enzyme and the soil pH increases. Depending on the buffer capacity of the soil, this may lead to volatilization of NH_3 in high pH soils, especially with surface application. Volatilization losses of 20 per cent are common, and sometimes it is up to 60 per cent (Hofman and Cleemput, 2004). Similarly, in most condition only 30 to 50% of the inorganic nitrogen fertilizer applied is used by the crop. The rest is lost by volatilization, denitrification, or leaching of nitrate into the groundwater (Salinas-Ramirez *et al*., 2011).

2.6. Role of Nitrogen in the Plant Growth

The efficient use of N, P and K fertilizers play an important role in enhancing the production and productivity of the crop by increasing cell division and multiplication and the N is required for plant growth in much greater quantities than most other nutrients. Plant life could not exist on earth in the absence of N (Olsen and Kurtz, 1982; Tucker, 1999; Hofman and Cleemput, 2004). It is essential component of many compounds of plant, such as chlorophyll, nucleotides, proteins, alkaloids, enzymes, hormones and vitamins and generally it is a constituent of the building blocks of almost all plant structures. It also improves development and activity of roots as well as support uptake of other nutrients (Olsen and Kurtz, 1982; FAO, 1986; Hofman and Cleemput, 2004). It promotes rapid growth, increases leaf size and quality, hastens crop maturity, and promotes fruit and seed development and it plays a role in almost all plant metabolic processes, increased rate of photosynthesis and vigorous vegetative growth (Hazra and Som, 1999; Tucker, 1999).

A certain level of N must be present in plant cells for optimum utilization of carbohydrates produced during photosynthesis. A growing crop must have a continuous free energy input to synthesize molecules for active transport of ions and other materials throughout the plant. A carrier of this energy is adenosine tri-phosphate (ATP), which is N containing compound (Olsen and Kurtz, 1982).

High N supply favors the conversion of carbohydrate in to protein which in turn promotes the formation of protoplasm. However, the presence of N in excess promotes development of the above ground organs with relatively poor root growth. Synthesis of proteins and formation of new tissues are stimulated, resulting in abundant dark green (high chlorophyll) tissues of soft consistency. This increases the risk of lodging and reduces the plants resistance to harsh climatic conditions and to foliar diseases (Olsen and Kurtz, 1982; Lincoln and Edvardo, 2006).

When plants are deficient in N, it becomes yellow in appearance and stunted growth (Olsen and Kurtz, 1982; Lincoln and Edvardo, 2006). The loss of protein from chloroplasts produces yellowing or chlorosis which affects the lower leaves first as N is a mobile nutrient (Hofman and Cleemput; 2004; Lincoln and Edvardo, 2006). This leads to poor assimilate formation and results in premature flowering, shortening of the growth cycle and reduced yield (Hofman and Cleemput, 2004; Lincoln and Edvardo, 2006). Similarly, Hazra and Som (1999) reported that N deficiencies in plants induce change in carbohydrate synthesis and degradation pathway and also the inadequate available N reduces crop growth and production (Mengel and Kirby, 1982).

2.7. Varieties

There are diverse botanical varieties of the species of *Phaseolus* that vary in terms of growth habit, seed and pod characteristics, agronomic features, and response to biotic and abiotic stresses (Kay, 1979). Varieties commonly grown in developing countries are introduced from temperate countries where breeding programs are more advanced and these varieties may not be well adapted to tropical environments (CIAT, 1992). The higher snap bean yields have been achieved through use of adapted varieties and proper management practices (Henry, 1989). According to Lemma (2003), introduced snap bean varieties showed variability in growth and pod yield performance indicating the possibility of utilizing the potential of green beans in Ethiopia.

The vegetative growth, total pod yield as well as pod quality of snap bean are generally affected by genotype of the variety (Abdel-Mawgoud *et al*., 2005). In Ethiopia two types of bean varieties are under production for export and local use; these are bobby and fine beans

(Lemma, 2003). And the common green beans varieties which are in the hands of investors are fine beans (Curumbe, Pretoria, Serengeti, Sapporo, Lomami and Adante) and bobby beans (Volta, Polister, and Contender blue, Contender yellow) (EHDA, 2003). As indicated by Lemma *et al.* (2006) Melka 1, Melka 3 and Melka 5 are some of the selected snap beans cultivars for local and export market.

2.8. Green Bean Quality

The pods of green bean are picked when they are reached nearly full size and the seeds are still small. Pods at this stage are firm, crispy flesh and having low fiber content (Kovatch, 2003). Marketable pods are fleshy, tender, and green for only a short period; they will quickly become tough, fibrous, and over mature if not harvested on time. Shape, color, curvature, pod length and diameter are also some of the quality attributes in green beans (Cajiao, 1992; Lemma, 2003).

Pods should be straight and without excessive seed development, and free of taints and odors, fungal infections, insect contamination, mechanical damage, excessive scarring, surface moisture, as well as decayed, bruised, or broken pods, typical color to variety and uniform sized ones. Dead flowers should be removed from the ends and the stem attachment should be removed from the stem of the pod (IDEA, 2001; Lemma, 2003). Similarly, as Cajiao (1992) reported that low fiber content in pod walls and absence of string are also important quality determining factors and are taken into account by consumers.

2.9. Nitrogen Fertilizer Levels and Effects on Growth, Yield and Quality of Green Bean

2.9.1. Effects on plant growth

Nitrogen is the major limiting nutrient for most crop species and N fertilizer has effect on vegetative growth of bean plants (Peck and MacDonald, 1984; Bengston, 1991). Ghosal *et al.* (2000) indicated that effect of N fertilizer applications at different rates (0, 40, 80 and 160 kg ha^{-1}) on French bean varieties was shown significant increase on growth attributes with increase in the rate of N as against control (0 N).

Studies on snap bean by El-Awadi *et al.* (2011) shown that plant height, number of leaves and branches per plant was shown a significantly increased with successive increment on the application of N. The largest values were recorded from the highest (240 kg ha^{-1}) N application while the minimum values were obtained from the lowest (80 kg ha^{-1}) N application for all parameters. In another study made by El-Tohamy *et al.* (2009) indicated that taller and shorter plant of snap bean was recorded from the highest (145 kg ha^{-1}) and lowest (29 kg ha^{-1}) N application, respectively. Likewise, Tewari and Singh (2000) reported that plant height and number of branches per plant of French bean increase with successive increased in the rates of N.

As Rahman *et al.* (2007) found that plant height of French bean responded significantly to different levels (0, 100, 150 and 200 kg ha^{-1}) of N and the taller and shorter plant was obtained from 150 kg N ha^{-1} and control treatment (0 N), respectively. In another conducted research by Mahmoud *et al.* (2010) who reported that taller plant was obtained from higher (333 kg ha^{-1}) N application while the shorter plant was from lower (239 kg ha^{-1}) rate of N application.

Study conducted on the effect of N rates on plant height and number of branches per plant of cluster bean was shown an increment with successive increased in the rates of N while the lowest value was obtained from the control (zero N) treatment (Anurag *et al.*, 2003; Khalid, 2004; Ayub *et al*., 2010; Ayub *et al*., 2011). Similarly, Bozorgi *et al.* (2011) reported that on faba bean the maximum and minimum values for plant height and number of branches per plant were recorded from the highest (60 kg ha^{-1}) N application and from the control (0 N) treatment, respectively.

The root depth is enhanced by optimal N availability (Olsen and Kurtz, 1982) and the application of N also improves development and activity of roots (Olsen and Kurtz, 1982; FAO, 1986; Hofman and Cleemput, 2004). Nitrogen promotes rapid growth, increases leaf size and quality, hastens crop maturity, and promotes pod and seed development and it plays a role in almost all plant metabolic processes and increased rate of photosynthesis (Hazra and Som, 1999; Tucker, 1999).

Results of the studies by Mahmoud *et al.* (2010) reported that application of different N rates (239, 286 and 333 kg ha^{-1}) were shown significant variations on leaf and shoot dry matter of snap bean and the maximum and minimum values were recorded from the application of highest and lowest rate of N fertilizers, respectively. El-Awadi *et al.* (2011) found that highest dry weight of leaves per plant of snap bean was recorded from the highest (240 kg ha^{-1}) N application while the minimum values were obtained from the application of lowest (80 kg ha^{-1}) rate of N. Likewise, the highest shoot dry weight of faba bean cultivars were obtained from the highest (200 kg ha^{-1}) N application while the lowest value was recorded from the control (0 N) treatment (Daur *et al*., 2008).

A study on cluster bean was shown that plant dry matter increased at each increased level of N and the lowest value was recorded from the control (0 N) treatment (Ayub *et al.*, 2010; Ayub *et al.*, 2011).

2.9.2. Effects on yield and yield components

The application of N fertilizer affect pod yield on bean plants (Peck and MacDonald, 1984; Bengston, 1991) and as reported by Franco *et al.* (2008[a]) the appropriate management of N fertilization is fundamental to increase dry bean yield. Franco *et al.* (2008[b]) indicated that yield of dry bean cultivars in relation to the N fertilization was dependent on N fertilization level and on the environment conditions.

Results of studies on French bean by Ghosal *et al.* (2000) suggested that effect of N fertilizer applied at different rates (0, 40, 80 and 160 kg ha^{-1}) on the yield of French beans varieties was shown significant increment with increase in the rate of N as against control. Similarly, Dhanraj *et al.* (2001) reported that increase in yield of French bean with increasing N levels up to 120 kg ha^{-1} as compared to 0 and 60 kg ha^{-1} N.

Rahman *et al.* (2007) indicated that yield and yield components of French bean responded significantly to different levels (0, 100, 150 and 200 kg ha^{-1}) of N and the highest number of pods per plant and yield was shown from 150 kg N ha^{-1} while the lowest value was obtained from the control (0 N) treatment. Similarly, Salinas-Ramirez *et al*. (2011) reported that maximum number of pods m^{-2} was observed from the highest (200 kg ha^{-1}) N application while the lowest value was from the control (0 N) treatment on snap bean and also the pod yield of French bean increased with increasing rate of N application (Srinivas and Nailk, 1988).

In French bean significant variation was observed on yield and yield attributes due to the effect of different levels of N (0, 50, 100 and 150 kg ha^{-1}) and the N level had significant effect on number of pods per plant and pod yields. The highest pod yield was obtained from 100 kg N ha^{-1} while the lowest was in the control (0 N) treatment (Saha *et al.*, undated). In another studies on snap bean was shown, maximum and minimum number of pods per plant was recorded from the highest (145 kg ha^{-1}) and lowest (29 kg ha^{-1}) rate of N application, respectively (El-Tohamy *et al.*, 2009).

Results of the studies by Mahmoud *et al.* (2010) reported that application of different N rates (239, 286 and 333 kg ha^{-1}) were shown significant variations on average pod weight and pod yield of snap bean and the maximum and minimum values were recorded from the application of highest and lowest rate of N fertilizers, respectively. El-Awadi *et al.* (2011) found that highest average pod weight and pod yield of snap bean was recorded from the highest (240 kg ha^{-1}) N application while the minimum values were obtained from the application of lowest (80 kg ha^{-1}) rate of N. In another studies conducted on bush bean was also shown, the number of pods per plant and pod yield was increased when the N rates are increase and the maximum value was recorded from the highest (40 kg ha^{-1}) N application while the lowest value was recorded from the control (0 N) treatment (Nasrin and Jahan, 2010).

The application of N was significantly increased the yield of cluster bean at each increment of N rate (Khalid, 2004; Ayub *et al.,* 2010; Ayub *et al.,* 2011). Similarly, the increased in the rates of N application improved the yield by increasing their yield components on dry bean (Liebman *et al.*, 1995) and navy bean (Blaylock, 1995).

According to Sehirali *et al.* (1981) and Liebman *et al.* (1995) the effects of N fertilizer applications on bean yield have been statistically significant and the increased in the rates of N, increases the grain yield compared with the control plots. In another conducted research by Boroomadan *et al.* (2009) reported that maximum soybean yield was obtained from the highest (40 kg ha^{-1}) N application while the lowest was from the control (0 N) treatment. Likewise, the highest grain yield of faba beans cultivars were obtained from the highest (200 kg ha^{-1}) N application while the lowest value was recorded from the control (0 N) treatment (Daur *et al.*, 2008).

A study on field bean by Bildirici and Yilmaz (2005) indicated that highest number of pod per plant was found from higher (60 kg ha^{-1}) N application while the lowest was from control (0 N) treatment. Sehirali *et al.* (1981) found that pod number per plant and yield was shown a significantly increased as increase in N compared with the control (0 N) treatment on of dry bean.

In garden bean the application of different rate of N (0.36, 0.66, 0.96, 1.27 g N pot^{-1}) fertilizer was shown significantly increased the total fresh and dry weight of bean pods and the maximum and minimum value was recorded on the highest and lowest rate of N applications, respectively (Kovács *et al.*, 2008).

According to Bozorgi *et al.* (2011) indicated that maximum and minimum seed yield and number of pods per plant of faba bean were obtained from the highest (60 kg ha^{-1}) N application and control (0 N) treatment, respectively. Similarly, Osman *et al.* (1996) reported that largest value for number of pods per plant and yield of faba beans was observed from the highest (120 kg ha^{-1}) N application while the smallest value was recorded from the control (0 N) treatment.

A study on cluster bean was shown that plant dry matter increased at each increased level of N and the lowest value was recorded from the control (0 N) treatment (Ayub *et al.*, 2010; Ayub *et al.*, 2011).

2.9.3. Effect on quality parameters

Nitrogen fertilization affect quality of pods on bean plants (Peck and MacDonald, 1984; Bengston, 1991). The smallest pod length of French bean was observed from control treatment as compared to the other rates of N fertilizer (Tewari and Singh, 2000). As Nasrin and Jahan (2010) indicated that longest pod was recorded from the highest (40 kg ha^{-1}) N application while the shortest pod was observed from the control (0 N) treatment on bush bean.

Studies conducted by Rahman *et al.*, (2007) on French bean were shown that the largest and smallest values for pod length and circumference were observed from 150 kg N ha^{-1} and control (0 N) treatment, respectively. El-Tohamy *et al.*, (2009) found that maximum value for pod length; diameter and protein content were recorded from the highest (145 kg ha^{-1}) N application while the minimum value was obtained from the lowest (29 kg ha^{-1}) rate of N on bean plants.

Results of the study on snap bean by Mahmoud *et al.* (2010) indicated that maximum value for pod length and protein content were recorded from application of higher (333 kg ha^{-1}) N rate while the minimum values were observed from lower (239 kg ha^{-1}) N application. Similarly, El-Awadi *et al.* (2011) observed that maximum and minimum values for pod length and protein percentage of snap beans was recorded from the highest (240 kg ha^{-1}) and lowest (80 kg ha^{-1}) N application, respectively.

Bildirici and Yilmaz (2005) reported that maximum protein content was recorded from highest (60 kg ha^{-1}) N application where as the minimum value was obtained from the control (0 N) treatment on field bean. Likewise, the protein contents were increased with increase of N application on guar Modaihsh *et al.* (2007); soybean (Morshed *et al*., 2008; Boroomadan *et al*., 2009) and cluster bean (Sheikh, 2004; Khalid, 2004; Ayub *et al*., 2010; Ayub *et al*., 2011).

2.10. Green Bean Varieties and Effects on Growth, Yield and Quality of Green Bean

2.10.1. Effects on plant growth

According to Elballa *et al.* (2004) and Lemma *et al.* (2006) reported that plant height was shown a significantly difference among snap bean varieties and the same result was reported on cluster bean (Sortino and Gresta, 2007; Ayub *et al.,* 2010); guar (Vahidy and Yousufzai, 1999) and faba bean (Daur *et al.*, 2008). In another studies, varieties were shown significantly difference on number of branches per plant on faba bean (Daur *et al.,* 2008) and cluster bean (Sortino and Gresta, 2007 and Ayub *et al.*, 2010).

Studies conducted by Balkaya and Demir (2003) and Lemma *et al.* (2006) reported that days to 50% flowering were shown significant variations among green bean varieties. Similarly, days to flowering and maturity were shown significantly difference among the varieties on cluster bean (Singh *et al.*, 2003) and faba bean (Daur *et al.*, 2008).

In another study by Abdel-Mawgoud *et al.* (2005) reported that dry weight of shoot of snap bean were shown significance difference among varieties and also the shoot dry weight differed significantly among varieties on Faba bean (Berger *et al.*, 2002; Daur *et al.*, 2008) and cluster bean (Garg *et al.*, 2003).

2.10.2. Effect on yield and yield components

The yielding potent of different varieties were shown significant variations and one way of increase its yield is to introduce high yielding varieties (Bilal *et al*., 2000), compatible with climate of the area. Dehghani *et al.* (2008) reported that environmental and genotypes interactions significantly influence genotypes yield. As the report shown that, significant variations on pod yield were shown among the varieties on snap bean (Balkaya and Demir, 2003; Abdel-Mawgoud *et al.,* 2005; Lemma *et al.,* 2006); cluster bean (Garg *et al.*, 2003; Ayub *et al*., 2010) and faba bean (Berger *et al*., 2002; Pekşen *et al.*, 2006; Daur *et al.*, 2008).

As stated by Balkaya and Demir (2003) and Elballa *et al.* (2004) the number of pods per plant on snap bean was shown significant variations among varieties. Similarly, Daur *et al.*, (2008) indicated that faba bean varieties were shown significantly difference on number of pods and weight of pods per plant. In another study by Abdel-Mawgoud *et al.* (2005) reported that average pod weights of snap bean were shown significance difference among varieties.

2.10.3. Effect on quality

Studies reported that the significantly difference on pod length and diameter were shown among green bean varieties (Balkaya and Demir, 2003; Abdel-Mawgoud *et al.,* 2005; Lemma *et al.*, 2006) and Faba bean (Daur *et al.,* 2008). According to Ayanoglu and Engin (1995) the protein content were shown significant differences among the varieties of dry bean; guar (Kays *et al.*, 2006) and cluster bean (Sortino and Gresta, 2007). In another conducted study by Balkaya and Demir (2003) reported that pod color of snap bean was shown significant variations through varieties.

3. MATERIALS AND METHODS

3.1. Description of the Study Site

The experiment was conducted at Yassin Legesse Flower Farm located in Bishoftu during the cropping seasons of 2011/12 under irrigation. Bishoftu is located 47 km east of Addis Ababa. The study area is located at geographic coordinates of latitude 08°44' N and longitude of 38°58' E and at an altitude of 1860 meters above sea level (m.a.s.l.). The major soil type of the experimental area was vertisol. It receives an annual average rainfall of 851 mm and the mean minimum and maximum temperatures are 8.9°C and 24.3°C, respectively.

Composite soil sample was collected from the experiment field to analyze the physico-chemical properties of the soil before the experiment was conducted. The analyses were carried out at Debre Zeit Agricultural Research Center (DZARC) Soil Laboratory. The physical and chemical properties of soils of the experimental site before planting are presented in Table 1.

Table 1. Physical and chemical properties of soils of the experimental site before planting

Soil properties	Values
Clay (%)	53
Silt (%)	38
Sand (%)	9
Textural group	Clay
pH (1:2.5)	7.45
EC (1:2.5) (dS/m)	0.10
Organic C (%)	1.08
CEC Cmol (+)/Kg	46.73
Ex. K Cmol (+)/Kg	1.22
Avail. P (mg/Kg)	17.58
Total N (%)	0.10
C:N ratio	10.8

3.2. Description of Treatments and Experimental Design

3.2.1. Varieties

Four green bean varieties namely Melka 1, Melka 3, Melka 5 and Contender blue were used in the present study and their description is shown in Appendix Table 2. The first three varieties were selected because of their good agronomic and yield performance as evaluated by Melkassa Agricultural Research Center (MARC) in different locations. The varieties Melka 1 and Melka 5 are in the pipeline to be released as varieties for wider production while Melka 3 is already released in 2012. The fourth variety (Contender blue) is popular one and widely grown in most commercial growers such as Ethio Vegfru P.L.C. and UAAIE. All the varieties are bobby beans and bush types. The seeds of Contender blue were kindly provided by Ethio Vegfru P.L.C while the rest varieties seeds were provided by MARC.

3.2.2. Fertilizer treatments

The fertilizer treatments consisted of five levels of N (0, 40, 80, 120 and 160 kg ha^{-1}) in the form of Urea (46% N). A uniform recommended rate of phosphorus (92 kg ha^{-1}) in the form of Triple Super Phosphate (46% P_2O_5) was applied during sowing. The nitrogen fertilizer was divided in two equal splits and the first half was applied during sowing and the remaining half was side dressed 4 (four) weeks after sowing.

3.2.3. Experimental design

A 4X5 factorial experiment involving four varieties (Melka 1, Melka 3, Melka 5 and Contender blue) and fiver N rates (0, 40, 80, 120 and 160 kg ha^{-1}) were laid out in randomized complete block design (RCBD) with three replicates. The treatment combinations and their details are shown in Appendix Table 3. The treatments were randomly assigned to each plot (experimental units). Plot size was 2 x 2 meters and the seeds were sown at the spacing of 40 cm between rows and 10 cm between plants. There were five rows per plot and 20 seeds were sown per row. The total number of plants per plot was therefore 100. A distance of 75cm was maintained between each plot and 1.5 meters between each block.

3.3. Cultural Practices

The land was prepared according to standard practices locally adopted by commercial green bean growers. Cultural practices (cultivation, weeding and application of water) were done as per the standard or recommendation (Lemma, 2003) and preventive spraying of appropriate chemicals (Mancozeb, Dynamec and Stroby) was done to control the occurrence of any disease and pests infestation as the symptoms of diseases and pests are appears during whole growing season and there was no major disease and insect pest incidence encountered. Harvesting of the pods was done for four times in four days interval (Tantawy *et al*., 2009).

3.4. Data Collected

Growth, yield and yield components and quality parameters were collected throughout the experiment period accordingly. The details of data collection techniques are described below:

3.4.1. Growth parameters

1. **Plant height (cm):** Plant height of ten randomly selected plants per plot was measured from the ground level to the tip point of the stem at the harvest stage.
2. **Tap root length (cm):** Tap root length of ten randomly selected plants per plot was measured from the crown of the plant to the tip of root at the harvest stage.
3. **Root volume (ml/plant):** Root volume of ten randomly selected plants per plot was measured at the harvestable stage by using water displacement method. The measuring cylinder was filled with water and the initial reading value was taken and the root was immersed completely in to the water and the final reading value was recorded and finally root volume was calculated by subtracting the reading values of final from initial.
4. **Total leaf area per plant (cm^2/plant):** Leaf area of ten randomly selected plants per plot was measured by using leaf area meter (Area Meter AM 200-002 ADC Bio-scientific Ltd) in cm^2 at the harvest stage.

5. **Numbers of days to 50% flowering**: Number of days from the date of sowing to the date on which 50% of the plants in a plot produced flowers.
6. **Number of primary branches per plant**: The number of primary branches per plant was recorded from ten randomly selected plants per plot by counting the number of branches arising from the base of the stem at harvest stage.
7. **Shoot and root dry weight (g/plant):** Ten sample plants were taken for determination of fresh weight and dry weight of shoot and root at harvest stage. After taking the fresh weight of shoot and roots, the samples was dried in an oven at $70^{o}C$ to a constant weight.

3.4.2. Yield and yield components

1. **Total pod yield (t/ha):** The pods were harvested from 40 plants in the three middle rows and converted to tons per hectare.
2. **Marketable 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.
3. **Unmarketable yield (t/ha):** The pods were sorted based on visual observations and measurement; and pods which are bleached, insect and disease damaged, curved, pod length (<12cm) and pod diameter (<8mm) was considered as unmarketable and finally the unmarketable yield per plot was converted to tons per hectare.
4. **Total number of pods per plant:** Total number of pods per plant was recorded from the mean of number of pods per plants from the 40 plants in the three middle rows.
5. **Average marketable pod weight (g):** Average marketable pod weight was measured from the mean of 25 randomly selected marketable pods. Pods were measured using a sensitive balance (BP 1600-S).
6. **Dry weight of pods (g/plant):** Dry weight of pods were recorded by taking 25 pods per plot from total production randomly and put in the oven at $70^{o}C$ to dry to a constant weight and finally it was converted to average dry weight of pods per plant.

3.4.3. Pod quality parameters

1. **Fibreless nature:** Fiber content determined as snap- ability was assessed by breaking the pod and observed visually and rating 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 (Essubalew, 2011).
2. **Color:** Twenty five randomly selected pods per plot were taken and separated based on their color. The results was recorded on the basis of 1 to 5 scale (1= bleached, 2= light green, 3=moderate green, 4= green and 5= dark green) (Balkaya and Demir, 2003).
3. **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) (Esubalew, 2011).
4. **Pod length (cm):** The average pod length was measured from the mean of 25 randomly selected pods per plot using ruler.
5. **Pod diameter (mm):** 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).
6. **Pod protein percentage (%):** Percent of protein content in pods harvested from each plot determined using modified Kjeldahl method of protein analysis to include the reduction of the organic-N, NH_3-N, NO_3-N and $N0_2$-N (Nelson and Sommer, 1973). This analysis was carried out at Debre Zeit Agricultural Research Center Soil Laboratory.

3.5. Data Analysis

The data collected on different growth, yield and pod quality were checked for normality and meeting all ANOVA assumptions. Then, the data was subjected to Analysis of Variance (ANOVA) and correlations using SAS statistical software version 9.2 (SAS Institute Inc., 2008). When ANOVA showed significant differences, mean separation was carried out using LSD (Least Significant difference) test at 5% level of significance.

The ANOVA model for the analysis was:

$y_{ijK} = \mu + R_i + A_j + B_k + (AxB)_{jk} + \varepsilon_{ijk}$

μ = over all mean effect

Ri = the effect of blocks at the i^{th} level

A_j= the effect of treatment at the j^{th} level

B_k = the effect of treatment at the k^{th} level

$(AxB)_{jk}$ = effect of treatment combination at the j^{th} and k^{th} level

ε_{ijk} = a random error

3.6. Economic Analysis

To consolidate the statistical analysis of the agronomic data, economic analysis was done for each treatment. For economic evaluation, cost and return, benefit to cost ratio (B:C) and marginal rate of return (MRR) was calculated according to the procedure given by CIMMYT (1998). B:C ratio was calculated as the ratio of net return to total cost while the MRR also calculated as the ratio of marginal benefit to marginal cost. To estimate economic parameters, green beans pod was valued at an average open market price of 5.00 birr per kg and wage rate of 20 birr/ workdays was used for fertilizer application and the cost of harvesting, grading and transportation was 0.45 birr per kg. The value of urea (927 birr/100kg) was considered in the budget.

4. RESULTS AND DISCUSSION

4.1. Effect of Varieties, Nitrogen rates and their Interaction on Growth Attributes of Green Bean

In the present study growth parameters of green bean (plant height, total leaf area, days to 50% flowering, shoot and root dry weight, number of primary branches, root volume and tap root length) were recorded to study the response of varieties to the different N levels. Results indicated that green bean varieties and rates of N application have shown significant ($P<0.01$) variations for all growth parameters, but the N rates did not show significant ($P<0.05$) difference on tap root length (Appendix Table 4).

The interaction effects of varieties with rates of N application have shown significant ($P<0.05$) variation on root volume, tap root length and number of primary branches but not significant for plant height, total leaf area, days to 50% flowering and shoot and root dry weight.

4.1.1. Plant height

The result of this experiment indicated that tallest plant was observed from Melka 3 (37.41 cm) while the shortest plant was from Contender blue (25.18 cm) and the variety Melka 3 has shown 48.57 per cent increment on plant height as compared to the Contender blue (Figure 1). This is in agreement with the findings of Elballa *et al.* (2004) and Lemma *et al.* (2006) who reported that plant height was significantly different among snap bean varieties and the same result was also reported on cluster bean (Sortino and Gresta, 2007; Ayub *et al.,* 2010) and faba bean (Daur *et al.*, 2008). The possible reason for the variation on plant height among varieties could be due to the genetic factor.

In the rates of N applications, the shortest plant was recorded from the control treatment while the tallest plant was obtained from the application of 160 kg N ha^{-1} which is statistically similar with 120 kg N ha^{-1} (Figure 1). The application of 120 and 160 kg N ha^{-1} increased the plant height by 35.95 and 38.41 per cent as compared to the control treatment, respectively. This finding is in agreement with the results obtained by El-Tohamy *et al.* (2009) who reported that increased the level of N fertilizer resulted an increase in vegetative growth of snap bean and the tallest and shortest plant was recorded from the highest (145 kg ha^{-1}) and lowest (29 kg ha^{-1}) N application, respectively. Similarly, Rahman *et al.* (2007) indicated that plant height of French bean responded significantly to different levels (0, 100, 150 and 200 kg ha^{-1}) of N and the plant height increases with the increase of N up to 150 kg ha^{-1} and decrease thereafter and the shortest plant was obtained from the control treatment (0 N).

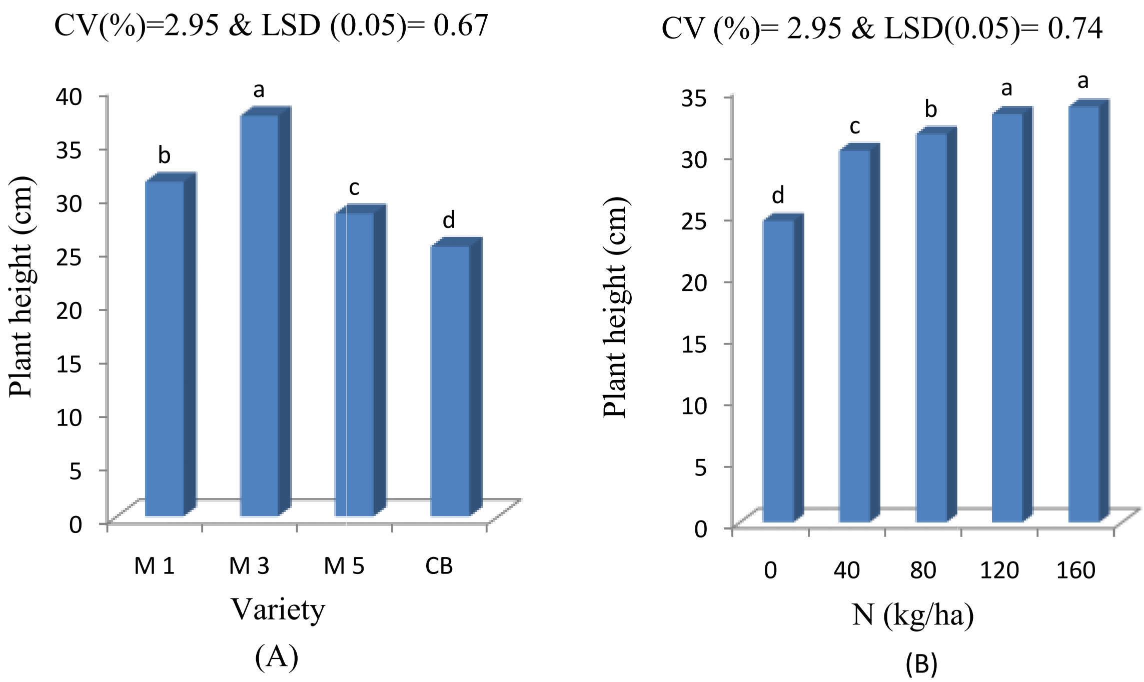

Figure 1. Effects of varieties and nitrogen rate on plant height of green bean (A = varieties and B = nitrogen treatments)

Means followed by the same letter within a treatment are not significantly different at 5% P level.
M 1 = Melka 1, M 3 = Melka 3, M 5 = Melka 5 and CB = Contender blue.

The probable reasons for the increment of plant height as the rates of N increased could be due to the fact that N is considered as one of the major limiting nutrients in plant growth and the adequate supply of N promotes higher photosynthetic activity, vigorous vegetative growth and taller plants. In line with this, when plants are deficient in N, it becomes yellow in appearance and stunted growth (Olsen and Kurtz, 1982; Lincoln and Edvardo, 2006).

4.1.2. Total leaf area

In the present study the total leaf area ranged between 2083.51 and 2839.28 cm^2/plant among the varieties and the maximum and minimum total leaf area was recorded from Melka 3 and Contender blue, respectively (Figure 2).

CV(%)= 9.69 and LSD (0.05)= 178.94 CV(%)= 9.69 and LSD (0.05)= 200.07

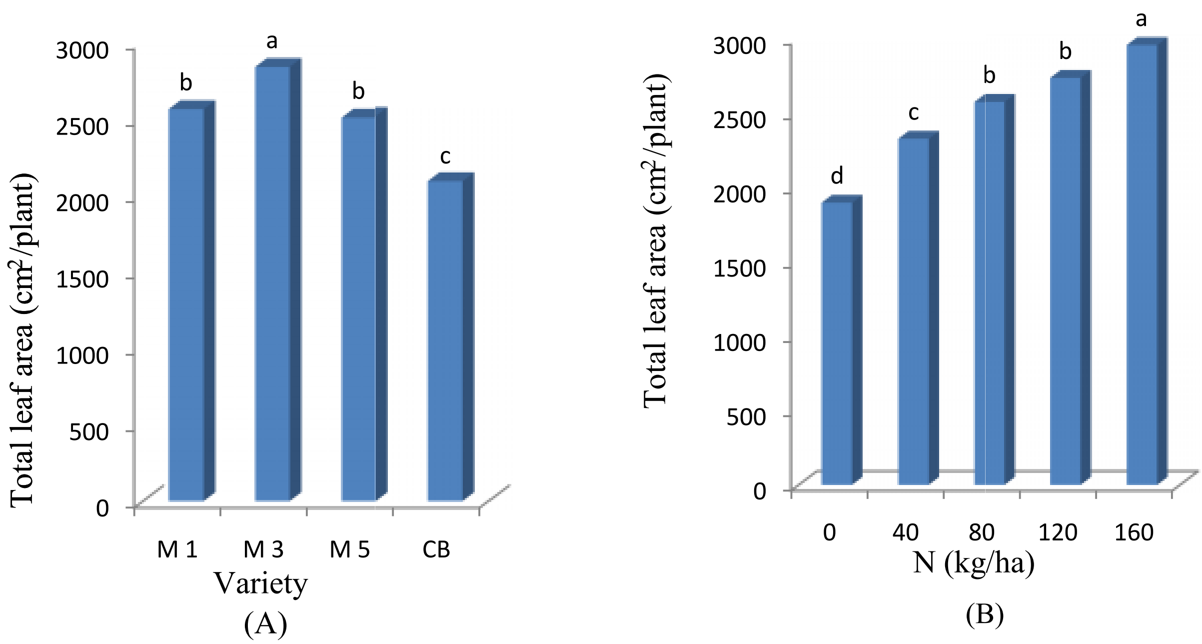

Figure 2. Effects of varieties and nitrogen rate on total leaf area of green bean (A = variety and B = nitrogen treatment)

Means followed by the same letter within a treatment are not significantly different at 5% P level.
M 1 = Melka 1, M 3 = Melka 3, M 5 = Melka 5 and CB = Contender blue.

This result was in agreement with the work of Lima *et al.* (2005) who reported that leaf area index varies among common bean varieties and Abdel-Mawgoud *et al.* (2005) also observed that number of leaves have shown variations among snap bean varieties. The possible reasons for the variation observed in the total leaf area among varieties could be due to inherent characteristics

Application of 160 kg ha^{-1} N resulted in the highest (2957.42 cm^2/plant) total leaf area and the lowest (1896.26 cm^2/plant) was obtained from the control (a 50.6 per cent increment over the control) (Figure 2).

In support of the present finding, El-Awadi *et al.* (2011) reported that number of leaves per plant of snap bean has shown a significant increment with successive application of N. The largest value was recorded from the highest (240 kg ha^{-1}) N application while the minimum values were obtained from the application of lowest (80 kg ha^{-1}) N. Bohloo *et al*. (1992) indicated that the highest total leaf area as a result of higher rate of N application may be due to N is essential for chlorophyll and protoplasm formation. Likewise, adequate supply of N promotes higher photosynthetic activity and vigorous vegetative growth and as result increases leaf size and total leaf area (Lincoln and Edvardo, 2006).

4.1.3. Days to 50% flowering

In this study the maximum (51.13) days to 50 % flowering was recorded for Melka 1 while the minimum (46.40) days was for Contender blue (Table 2). In agreement with this finding, Balkaya and Demir (2003) and Lemma *et al.* (2006) reported that a day to 50% flowering was significantly different among green bean varieties. The possible reasons for the variation in the days to 50% flowering among varieties could be due to genetic factors of the varieties.

The days for 50% flowering ranged from 46 to 51 days for the rates of N application and the maximum days for 50% flowering were recorded from the application of 160 kg N ha^{-1} while the minimum days was recorded from the control treatment (Table 2). Application of 160 kg N ha^{-1} delayed days to 50% flowering by five days compared to the control. The probable reasons could be the application of N fertilizer increased the leaf area which increases the amount of solar radiation intercepted and consequently increases days to flowering. High N levels promoted excessive vegetative growth and delayed flowering. In the contrary, the lower application of N leads the plant to poor assimilate formation and results in premature flowering, shortening of the growth cycle and reduced yield (Hofman and Cleemput, 2004; Lincoln and Edvardo, 2006).

Table 2. Effects of varieties and nitrogen rate on days to 50 per cent flowering and shoot and root dry weight of green bean

Factors	Days to 50% flowering	Shoot and root dry weight (g/plant)
Varieties		
Melka 1	51.13^{a}	28.22^{b}
Melka 3	48.27^{c}	31.83^{a}
Melka 5	49.13^{b}	25.86^{b}
Contender blue	46.40^{d}	20.86^{c}
LSD (5%)	0.508	2.434
Nitrogen kg ha^{-1}		
0	46.00^{e}	21.09^{c}
40	47.75^{d}	24.78^{b}
80	48.92^{c}	27.00^{b}
120	50.00^{b}	29.79^{a}
160	51.00^{a}	30.79^{a}
LSD (5%)	0.57	2.72
CV (%)	1.41	12.34

Means followed by the same letter within a column in a treatment are not significantly different at 5% P level.

4.1.4. Shoot and root dry weight

Shoot and root dry weight per plant ranged from 20.86 to 31.83 g/plant for varieties and the highest and lowest value was obtained from Melka 3 and Contender blue, respectively (Table 2). Melka 3 has shown 52.59% higher shoot and root dry weight as compared to the Contender blue. In agreement with the present study Abdel-Mawgoud *et al.* (2005) have reported that varieties have shown significant variability in shoot dry weight of snap bean and on faba bean (Peksen *et al*., 2006; Daur *et al*., 2008). Variation in shoot and root dry weight among genotypes could be associated with differences in genetic make-up.

Dry weight of shoot and root per plant was also significantly different for the N application rates. It ranged from 21.09 to 30.79 g/plant (Table 2). The largest value was recorded from 160 kg N ha^{-1} which is statistically similar with 120 kg N ha^{-1} while the smallest value was recorded from the control treatment. The application of 120 and 160 kg N ha^{-1} resulted in 41.25 and 45.99% increment on dry weight of shoot and root as compared to the control treatment, respectively. This study was in line with the work of Salinas-Ramirez *et al.* (2011) who reported that higher dry weight of leaves and stems was recorded from the highest N (200 kg ha^{-1}) application while the lowest was from the control (0 N) on snap bean. In agreement with this finding, McAndrew (2002) reported that the smallest plant dry weight was recorded on the control treatment while the largest value was recorded from the highest rate of N application in dry bean. Similarly, Daur *et al.* (2008) reported that application of highest (200 kg ha^{-1}) rate of N on faba bean resulted in maximum shoot dry weight while the minimum value was recorded from control (0 N) treatment. In support of the present study, N application significantly affected the plant dry matter of cluster beans and it was increased at each increased level of N. The lowest dry matter content was recorded from the control (0 N) treatment (Ayub *et al.*, 2010; Ayub *et al.*, 2011). This could be due to the fact that increase in the rate of N fertilizer might have contributed to better growth and development of the crop that led to the production of more shoot and root and also their dry matter contents increased.

4.1.5. Root volume

In the present study, the highest root volume was observed from Melka 1 with the application of 120 kg N ha^{-1} while the lowest root volume was observed from Contender blue with control treatment which is statistically similar with Melka 1with the control; Melka 3 with 0, 40, 80 and 120 kg N ha^{-1}; Melka 5 with 0, 40, 80 and 120 kg N ha^{-1} and Contender blue with 0, 40, 80, 120 and 160 kg N ha^{-1} application (Table 3).

The difference in root volume among the varieties could be attributed to their genetic makeup. The probable reason for the increment of root volumes as the application of N was increased is due to the root volumes are enhanced by optimal N availability (Olsen and Kurtz, 1982). While the application of N is lower, the growth of plants will be stunted and as a result the root volume will be minimal. In line with this, application of excess N promotes development of the above ground organs with relatively poor root growth and root volume (Olsen and Kurtz, 1982; Lincoln and Edvardo, 2006).

Table 3. Interaction effects of varieties and nitrogen level on root volume, tap root length and number of primary branches of green bean

Factors		Root volume (ml/plant)	Tap root length (cm)	Number of primary branches per plant
Varieties	Nitrogen kg ha^{-1}			
Melka 1	0	4.91^{d-g}	25.94^{abc}	4.00^{ef}
	40	5.34^{def}	26.00^{abc}	4.30^{cde}
	80	6.78^{bc}	26.67^{a}	4.30^{cde}
	120	8.56^{a}	26.11^{abc}	5.00^{b}
	160	7.12^{b}	21.50^{def}	5.80^{a}
Melka 3	0	4.00^{fg}	25.61^{abc}	4.20^{de}
	40	4.33^{efg}	26.28^{ab}	4.30^{cde}
	80	4.45^{d-g}	25.33^{abc}	4.50^{cd}
	120	5.22^{d-g}	24.39^{a-e}	4.50^{cd}
	160	5.56^{cde}	24.16^{a-e}	4.70^{bc}
Melka 5	0	4.12^{fg}	22.89^{b-e}	3.40^{g}
	40	4.32^{efg}	23.28^{a-e}	3.70^{fg}
	80	4.65^{d-g}	23.72^{a-e}	4.00^{ef}
	120	5.07^{d-g}	24.39^{a-e}	4.20^{de}
	160	5.78^{b-d}	25.00^{a-d}	4.30^{cde}
Contender blue	0	3.90^{g}	18.39^{f}	4.30^{cde}
	40	4.66^{d-g}	18.50^{f}	4.40^{cde}
	80	4.90^{d-g}	22.67^{cde}	4.60^{bcd}
	120	4.04^{fg}	24.15^{a-e}	5.00^{b}
	160	4.04^{fg}	21.00^{ef}	5.50^{a}
LSD (5%)		1.41	3.60	0.49
CV (%)		16.74	9.15	6.71

Means followed by the same letter within a column in a treatment are not significantly different at 5% P level.

4.1.6. Tap root length

The result shown in Table 3 indicated that the longest tap root length was observed from Melka 1 with the application of 80 kg N ha^{-1} which was not statistically different from Melka 1 with 0, 40 and 120 kg N ha^{-1}; Melka 3 with 0, 40, 80, 120 and 160 kg N ha^{-1}; Melka 5 with 40, 80, 120 and 160 kg N ha^{-1} and Contender blue with 120 kg N ha^{-1} while the shortest tap root length was observed from Contender blue with control treatment and which was statistically similar with Melka 1 at 160 kg N ha^{-1} and Contender blue with 40 and 160 kg N ha^{-1}. The application of 80 kg N ha^{-1} on Melka 1 gave 45.02 per cent increment on root length over Contender blue with control treatment.

The difference in tap root length among the varieties could be attributed to their genetic makeup. The tap root length increase until the maximum tap root achieved might have created high competition between plants for minerals especially N and the growth and developments of plants at this situation makes the plants to produce longer tap roots running in search of nutrients. In support of this finding, Olsen and Kurtz (1982) reported that root depths are enhanced by optimal N availability. Extension of roots in turn to facilitate absorption of water and other nutrients required for growth. However, the presence of N in excess promotes development of the above ground organs with relatively poor root growth and shorter tap root length.

4.1.7. Number of primary branches

The result of this experiment revealed that the number of primary branches per plant ranged between 3.4 and 5.8 and the highest number of primary branches was recorded from Melka 1 with the application of 160 kg N ha^{-1} which was statistically similar with Contender blue with 160 kg N ha^{-1} while the lowest number of primary branches was obtained from Melka 5 with control, which was not statistically different from Melka 5 with the application of 40 kg N ha^{-1} (Table 3). In agreement with this finding, varieties were significantly different for the number of branches per plant on snap beans (Abdel-Mawgoud *et al*., 2005), faba bean (Daur *et al.,* 2008) and cluster bean (Sortino and Gresta, 2007; Ayub *et al.*, 2010). The difference in number of primary branches among the varieties could be attributed to their genetic makeup. In agreement with this finding, El-Awadi *et al.* (2011) reported that number of branches per plant has shown a significant increment with successive application of N. The maximum and minimum number of primary branches was recorded from the highest (240 kg ha^{-1}) and lowest (80 kg ha^{-1}) N application, respectively. Likewise, Tewari and Singh (2000) also reported that number of branches per plant in French beans increased with successive increments in the rates of N. The possible reason for the increased number of branches per plant with an increase in N application might be due to the occurrence of less nutrients competition between plants, when the application of N was lower it resulted in increase in competition which as a consequence reduced the number of branches per plant.

4.2. Effect of Varieties, Nitrogen Rate and their Interaction on the Yield and Yield Components of Green Bean

In the present study the yield and yield components (total pod yield, marketable pod yield, unmarketable pod yield, total number of pods per plant, average marketable pod weight and dry weight of pods) were recorded to study the response of varieties to the different N levels. The findings of this experiment indicated that the main effects of variety and N application rate were significant ($P<0.01$) for all yield and yield components however the interaction effects of varieties and N treatment was not significant ($P<0.05$) for all yield and yield component parameters (Appendix Table 5).

4.2.1. Total pod yield

Total pod yield ranged from 12.51 to 14.04 t/ha for varieties and the maximum yield was recorded from Melka 3 while the minimum was from Contender blue which is statistically similar with Melka 1 (12.55 t/ha) (Table 4). Melka 3 produced 12.23% higher production as compared to Contender blue. In agreement with the finding of this result Balkaya and Demir (2003), Abdel-Mawgoud *et al.* (2005) and Lemma *et al.* (2006) reported that significant variations on pod yield was shown among snap bean varieties. Variation in yield among varieties could be associated with differences in genetic make-up that may exist for radiation and nutrients use efficiency or plant adaptation to target environments.

In the case of N treatment, the highest and lowest total pod yields were 15.09 and 10.07 t/ha, respectively (Table 4). The highest production was recorded from the application of 120 kg N ha^{-1} which was not significantly different from the application of 80 kg N ha^{-1} (14.48 t/ha) while the lowest yield was recorded from the control treatment. The application of 80 and 120 kg N ha^{-1} increased total pod yield by 43.79 and 49.85% as compared to the control treatment, respectively. These findings are in agreement with the results of Dhanraj *et al.* (2001) who reported significant increase in yield of French bean with an increase in the rate of N and the yield increases with increasing N levels up to 120 kg ha^{-1} as compared to 0 and 60 kg ha^{-1} N.

The minimum yield obtained from the control treatment was probably because of the limited vegetative growth of plants due to no N application and as a result there are limited photosynthates available; but increased supply of N fertilizer could result in more foliage and leaf area and higher supply of photosynthates and the result was supported by the works of Hazra and Som (1999) and Tucker (1999). The higher supply of photosynthates due to the increased N application might have induced formation of higher pod length and diameter, average pod weight and number of pods per plant (Rahman *et al.*, 2007; El-Tohamy *et al.*, 2009; Mahmoud *et al.*, 2010; El-Awadi *et al.*, 2011) and it might have contributed to the higher yield of green bean.

4.2.2. Marketable pod yield

The result presented in Table 4 indicated that marketable pod yield for the varieties ranged from 9.49 to 11.40 t/ha. The higher marketable pod yield was recorded from Melka 3 while the lower was from Melka 1, which was at par with Contender blue (10 t/ha). Melka 3 produced 20.13% higher marketable pod production compared to Melka 1. The present study was supported by Snodgrass *et al.* (2011) who reported that marketable pod yield has shown significant variations among snap bean varieties. The possible reason for the observed difference on marketable pod yield among the varieties of green bean could be due to the differences in genetic makeup and as a result of this productivity and adaptability of the varieties were shown variations.

Table 4. Effects of varieties and nitrogen rate on total, marketable and unmarketable pod yield of green bean

	Pod yield (t/ha)		
Factors	Total	Marketable	Unmarketable
Varieties			
Melka 1	12.55^{c}	9.49^{c}	3.06^{a}
Melka 3	14.04^{a}	11.40^{a}	2.64^{bc}
Melka 5	13.31^{b}	10.44^{b}	2.87^{ab}
Contender blue	12.51^{c}	10.00^{bc}	2.51^{c}
LSD (5%)	0.71	0.87	0.32
Nitrogen kg ha^{-1}			
0	10.07^{d}	7.95^{c}	2.12^{c}
40	12.39^{c}	9.86^{b}	2.53^{b}
80	14.48^{a}	11.54^{a}	2.96^{a}
120	15.09^{a}	12.11^{a}	2.98^{a}
160	13.49^{b}	10.22^{b}	3.27^{a}
LSD (5%)	0.79	0.97	0.36
CV (%)	7.33	11.33	15.82

Means followed by the same letter within a column in a treatment are not significantly different at 5% P level.

Similarly, N application has shown variation on marketable yield and the highest (12.11 t/ha) marketable yield was recorded from 120 kg N ha^{-1} application which was statistically similar with the application of 80 kg N ha^{-1} (11.54 t/ha) while the lowest (7.95 t/ha) marketable yield was recorded from the control treatment (Table 4). The application of 80 and 120 kg N ha^{-1} increased marketable pod yield by 44.16 and 52.33 % compared to the control treatment, 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. As a consequence of this higher number of pods per plant, heavier pod weight and the increment in pod length and diameter was recorded (Rahman *et al.*, 2007; El-Tohamy *et al.*, 2009; Mahmoud *et al.*, 2010; El-Awadi *et al.*, 2011); finally due to this fact marketable pod yield was increased.

4.2.3. Unmarketable pod yield

Results presented in Table 4, has shown that minimum unmarketable pod yield was obtained from Contender blue (2.51 t/ha), which was at par with Melka 3 (2.64 t/ha) while the maximum was recorded from Melka 1 (3.06 t/ha) which was not significantly different from Melka 5 (2.87 t/ha). The finding of this study was in line with Essubalew (2011) who reported that unmarketable pod yield was shown significant variations among green bean varieties. The possible reason for the observed difference among the varieties of green bean with regard to unmarketable pod yield could be genetic makeup.

In the case of N treatments, the unmarketable pod yield ranged between 2.12 and 3.27 t/ha (Table 4). The highest unmarketable pod yield was obtained from the application of 160 kg N ha^{-1} and which is statistically similar with 120 kg N ha^{-1} and 80 kg N ha^{-1} while the lowest value was recorded from the control treatment. The application of 80, 120 and 160 kg N ha^{-1} increased unmarketable pod yield by 39.62, 40.57 and 54.25% compared to the control treatment, respectively. The possible reason for the increment of unmarketable pod yield as N application increases is probably due to proportional increments with the increment of total pod yields and the major reasons for the un-marketability was under size (pod length and diameter) and curved pods.

4.2.4. Total number of pods per plant

In the present study, the number of pods per plant has shown variations due to varieties and nitrogen application treatments. The largest number of pods per plant was recorded from Contender blue (16.60) and the smallest was from Melka 5 (13.32) which was at par with Melka 3 (14.3) (Table 5). The finding of this study is supported by Balkaya and Demir (2003) and Dursun (2007) who reported that snap bean varieties were shown variations on number of pods per plant and Salehi *et al.* (2008) reported the same result on common beans. The possible reason for the observed difference on number of pods per plant among the varieties of green bean could be due to the variations in genetic makeup of the varieties for the productivity and adaptability under Debre Zeit conditions.

In the rates of N application, number of pods per plant ranged from 12.24 to 17.44 and the maximum value was recorded from the 120 kg N ha^{-1} application while the minimum number of pods per plant was recorded from the control treatment (Table 5). The number of pods per plant increased by 42.48% at 120 kg ha^{-1} N application as compared to the control. These results are in agreement with the works of Rahman *et al.* (2007) who reported that highest number of pods per plant was recorded in the treatment that received 150 kg N $ha^{-1}$and decrease thereafter while the lowest pod number was recorded on the control (0 N) treatment. In line with this finding, El-Tohamy *et al.* (2009) reported that maximum and minimum number of pods per plant on snap bean was obtained from the highest (143 kg ha^{-1}) and lowest (29 kg ha^{-1}) N application, respectively. The possible reasons for the maximum number of pods per plant observed from the higher N application was related to the increase in the rate N fertilizer resulted in better vegetative growth which in turn enables the crop to produce greater photo assimilate for the production of more number pods.

4.2.5. Average marketable pod weight

Results presented in Table 5, show that average weight of marketable pods for varieties ranged from 4.44 to 5.70 g and the highest pod weight was recorded from Melka 3 which is statistically similar with Melka 5 (5.49 g), while the lowest was recorded from Contender blue. This finding is supported by Abdel-Mawgoud *et al.* (2005) and Dursun (2007) who reported that snap bean varieties have shown significant variations on average pod weight. Variation in average individual weight of pods among genotypes could be associated with differences in genetic make-up.

In the rate of N application, the highest (5.50 g) average marketable pod weight was obtained from 120 kg N ha^{-1} which was statistically similar with the application of 80 kg N ha^{-1} (5.43 g) and 160 kg N ha^{-1} (5.29 g) and the lowest value was recorded from the control (4.61 g) treatment (Table 5). These results are in agreement with the works of Mahmoud *et al.* (2010) and El-Awadi *et al.* (2011) who have reported that average pod weight of snap beans has shown a significant increment with successive application of N and minimum value was recorded from the lowest rate of N. The possible reasons for the highest average pod weight obtained from the higher N application could be due to the increased supply of N fertilizer was resulted for more foliage, leaf area and higher supply of photosynthates which may have induced formation for bigger pods there by resulting in higher pod yields.

Table 5. Effect of varieties and nitrogen levels on the yield and yield components of green beans

Factors	Total number of pods per plant	Average marketable pod weight (g/pod)	Dry weight of pod (g/plant)
Varieties			
Melka 1	14.54[b]	5.06[b]	5.76[a]
Melka 3	14.30[bc]	5.70[a]	5.86[a]
Melka 5	13.32[c]	5.49[a]	5.21[b]
Contender blue	16.60[a]	4.44[c]	5.13[b]
LSD (5%)	1.21	0.36	0.41
Nitrogen kg ha^{-1}			
0	12.24[c]	4.61[c]	3.69[e]
40	13.93[b]	5.02[b]	4.89[d]
80	15.25[b]	5.43[a]	6.29[b]
120	17.44[a]	5.50[a]	7.04[a]
160	14.61[b]	5.29[ab]	5.53[c]
LSD (5%)	1.35	0.40	0.46
CV (%)	11.12	9.30	10.03

Means followed by the same letter within a column in a treatment are not significantly different at 5% P level.

4.2.6. Dry weight of pods

In the present study, varieties and rates of nitrogen application have shown variation on dry weight of pods per plant and the maximum and minimum value was 5.86 and 5.13 g/ plant among the varieties, respectively (Table 5). The maximum value was recorded from Melka 3 which was at par with Melka 1 (5.76 g/plant) while the minimum value was recorded from Contender blue which was not significantly different from Melka 5 (5.21 g/plant). The varieties Melka 3 and Melka 1 have shown 14.23 and 12.28% higher average dry weight of pods per plant as compared to the Contender blue, respectively. The finding of this study was in line with Essubalew (2011) who reported that average dry weight of pods per plant was significantly different among green bean varieties. The difference among the varieties could be probably due to their genetic makeup.

The average dry weight of pods per plant ranged from 3.69 to 7.04 g/plant for the rate of N application and the highest and lowest values was recorded from the application of 120 kg N ha^{-1} and control treatments, respectively (Table 5). This study was in line with the work of Salinas-Ramirez *et al.* (2011) who reported that pod dry weight of snap beans has shown a significant increment with successive application of N and minimum value was recorded from the lowest rate of N (0 N). The increase in pod dry weight per plant from the higher rate of N is probably due to the availability of enough nutrients with little competition among plants which finally resulted in better accumulation of photosynthates in their sink (pods) as compared to the control.

4.3. Effect of Varieties, Nitrogen Rate and their Interaction on Pod Quality Parameters of Green Bean

In the present study pod quality parameters (pod length, diameter, color, straightness, fibreless natures and pod protein content) were recorded. Results indicated that varieties and the rates of nitrogen application have shown significant ($P<0.01$) variations for all quality parameters except for the pod straightness which was not significant due to rate of nitrogen application (Appendix Table 6). No interaction effect between varieties and nitrogen levels were observed for all pod quality parameters.

4.3.1. Pod length

In the present study, pod length among varieties ranged from 12.00 to 13.56 cm and the highest value for pod length was recorded for Melka 3; which was statistically similar with Melka 5 (13.03 cm) while the lowest value was for Contender blue (Table 6). Melka 3 and Melka 5 have shown 12.91 and 8.49% increment on pod length as compared to Contender blue, respectively. Balkaya and Demir (2003) and Abdel-Mawgoud *et al.*, (2005) reported that snap bean varieties have shown highly significant variations on the pod length as in the present study. Similarly, Lemma *et al.,* (2006) reported variations in pod length of snap bean varieties (Melka 1, Melka 3 and Melka 5). The variation in pod length among varieties could be associated with differences in genetic make-up.

In the case of N application, the minimum and maximum pod length value was 11.8 and 13.57 cm, respectively (Table 6). The highest value for pod length was recorded from the application of 120 kg N ha^{-1} and not significantly different with the application of 80 kg N ha^{-1} (13.29 cm) while the lowest value was recorded from the control treatment. The 15.00 and 12.63% pod length increment was observed from 120 and 80 kg ha^{-1} N application as compared to the control treatment, respectively. In agreement with the present study Rahman *et al.*, (2007) reported that longest pod was observed from the application of 150 kg N ha^{-1} while the shortest pod was obtained from control (0 N) treatment on French bean. Similarly, El-Tohamy *et al.* (2009) reported that an increase in the rates of N fertilizer resulted in an increment of pod length on snap beans and the maximum pod length was recorded from the highest (145 kg ha^{-1}) N application while the minimum was obtained from the lowest (29 kg ha^{-1}) application of N. The possible reasons for the longest pod length obtained from the higher N application was due to the increased supply of nitrogen fertilizer which resulted in more foliage, leaf area and higher supply of photosynthates which may have induced formation for longer pods.

4.3.2. Pod diameter

The data in Table 6 shows that pod diameters ranged from 8.43 to 9.93 mm for varieties and the highest pod diameter was recorded for Melka 5 which was not significantly different from

Melka 1 (9.46 mm) while the lowest was for Contender blue. This finding was in agreement with the results obtained by Balkaya and Demir (2003) and Abdel-Mawgoud *et al.* (2005) who reported that snap bean varieties have shown highly significant variations on pod diameter. Likewise, Lemma *et al.* (2006) reported that pod diameter was significantly different among snap bean varieties (Melka 1, Melka 3 and Melka 5). The variation in pod diameter among varieties may be associated with differences in genetic make-up.

Table 6. Effect of varieties and nitrogen rates on quantitative pod quality parameters of green bean

Factors	Pod length (cm)	Pod diameter (mm)	Pod protein (%)
Varieties			
Melka 1	12.71[b]	9.46[ab]	18.53[b]
Melka 3	13.56[a]	9.34[b]	17.77[c]
Melka 5	13.03[ab]	9.93[a]	19.71[a]
Contender blue	12.00[c]	8.43[c]	18.27[bc]
LSD (5%)	0.55	0.48	0.65
Nitrogen kg ha^{-1}			
0	11.80[d]	7.58[d]	17.76[d]
40	12.51[c]	8.80[c]	18.08[cd]
80	13.29[ab]	9.61[b]	18.52[bc]
120	13.57[a]	10.46[a]	18.94[ab]
160	12.94[bc]	10.01[ab]	19.54[a]
LSD (5%)	0.62	0.53	0.73
CV (%)	5.84	6.94	4.74

Means followed by the same letter within a column in a treatment are not significantly different at 5% P level.

In the rate of N application, widest (10.46 mm) and narrowest (7.58 mm) pod diameter was obtained for the application of 120 kg ha^{-1} N and control treatment, respectively (Table 6). The application of 120 kg N ha^{-1} has shown statistically similar with 160 kg N ha^{-1}. Rahman *et al.* (2007) reported that narrowest and widest pod diameter of French bean was recorded from the control and 150 kg N ha^{-1} application, respectively which was in agreement to the present study. This result was also in line with the study of El-Tohamy *et al.* (2009) who reported that increment in pod diameter was due increased rates of N fertilizer on snap bean. The widest and narrowest pod diameter was recorded from the highest (145 kg ha^{-1}) and lowest (29 kg ha^{-1}) rate of N application, respectively. The possible reasons for the maximum pod diameter obtained from the highest N application could be due to the increased supply of N fertilizer that may result in more foliage, leaf area and higher supply of photosynthates which may have induced formation for higher pod diameter.

4.3.3. Pod protein content

The results presented in Table 6 showed that protein contents among the varieties ranged from 17.77 to 19.71 % and the superior performance in protein content was observed from Melka 5 while the lowest was from Melka 3 which was at par with Contender blue (18.27 %). Ayanoglu and Engin (1995) and Bildirici and Yilmaz (2005) reported that protein content was significantly different among bean varieties and similar result was also recorded on cluster bean varieties (Sortino and Gresta, 2007; Ayub *et al.*, 2010). The reasons for protein content variations among varieties could be due to the genotype factors.

In the application of N, the protein content ranged between 17.76 and 19.54 % and the highest protein content was obtained from the application of 160 kg ha^{-1} N which was not significantly different from the application of 120 kg ha^{-1} N (18.94%) while the lowest was recorded from the control treatment and statically similar with 40 kg N ha^{-1} (18.08%) application (Table 6). The application of 160 and 120 kg ha^{-1} N brings about 10.02 and 6.64% protein increment over the control treatment, respectively. This result is supported by the work of El-Tohamy *et al.* (2009) who reported that increase in rates of N applications significantly increased protein contents on snap bean and the maximum value was recorded from the highest (145 kg ha^{-1}) N application while the minimum value was obtained from the lowest (29 kg ha^{-1}) rate of N application. Similarly, studies conducted by El-Awadi *et al.* (2011) observed that maximum and minimum protein content of snap bean was recorded from the highest (240 kg ha^{-1}) and lowest (80 kg ha-1) N application, respectively. The possible reason for the increment of protein content as the application of nitrogen increased could be due to the N is utilized to synthesize amino acids, which in turn form proteins (Olsen and Kurtz, 1982; Hofman and

Cleemput, 2004; Ayub *et al.*, 2010; Ayub *et al.*, 2011). In line with this finding high N supply favors the conversion of carbohydrate into protein and as a result protein content increased (Olsen and Kurtz, 1982; Lincoln and Edvardo, 2006).

4.3.4. Pod colour

The presence of green pod color is one of the quality parameters for green bean. Data in Table 7 shows that pod color was significantly different for varieties and N application treatments. Contender blue and Melka 1 have shown the highest and lowest value for green pod colors, respectively. This result was in agreement with results obtained by Balkaya and Demir (2003) and Snodgrass *et al.* (2011) who reported that snap bean varieties were different in pod colors. The reasons for pod color variations among varieties could be due to the difference in genetic makeup.

In the application of N, the highest value for green pod colors was recorded from the application of 160 kg N ha^{-1} and which is statically similar with the application of 120 kg N ha^{-1} while the lowest value was obtained from the control treatment and not significantly different from the 40 kg N ha^{-1} application (Table 7). The probable reason for the improvement of green pod color at the higher N dose could be due to the fact that N is an essential component of chlorophyll (green pigments) and also adequate supply of N promotes the formation of dark green color (Olsen and Kurtz, 1982; Hofman and Cleemput, 2004).

4.3.5. Pod straightness

In the present study, effects of varieties were shown significant variations for pod straightness value (Table 7). The straightest pod was recorded for Melka 3 while the least value for pod straightness was for Melka 5. N application did not bring any significant effect on pod straightness. Literatures that are related to this result were not found and it was not possible to provide likely explanation to justify the result.

Table 7. Effect of varieties and nitrogen rates on qualitative pod quality parameters of green bean

Factors	Pod color (1 to 5 scale)*	Pod Straightness (1 to 3 scale)**	Pod fibreless nature (1 to 3 scale)***
Varieties			
Melka 1	2.30^{c}	2.51^{b}	2.79^{c}
Melka 3	3.18^{b}	2.81^{a}	2.90^{b}
Melka 5	3.31^{b}	2.14^{c}	2.86^{b}
Contender blue	3.77^{a}	2.58^{b}	2.96^{a}
LSD (5%)	0.18	0.14	0.05
Nitrogen kg ha^{-1}			
0	2.88^{c}	2.44	2.83^{c}
40	2.93^{c}	2.49	2.85^{bc}
80	3.19^{b}	2.53	2.88^{abc}
120	3.31^{ab}	2.56	2.90^{ab}
160	3.39^{a}	2.54	2.93^{a}
LSD (5%)	0.20	ns	0.06
CV (%)	7.58	7.44	2.52

Means followed by the same letter within a column in a treatment are not significantly different at 5% P level.
*= pod color (1=bleached, 2=light green, 3=moderately green, 4=green and 5=dark green), **= pod straightness (1=curved, 2=slightly straight and 3=straight) and ***= pod fibreless nature (1=fibrous, 2=moderately fibrous and 3=fibreless).

4.3.6. Pod fibreless nature

The results presented in Table 7 showed variations in pod fibrous content among the varieties. The best quality green beans are those having less fibrous content and the lowest and highest of fibrous content on pods were recorded for Contender blue and Melka 1, respectively. This finding was in agreement with the results obtained by Abdel-Mawgoud *et al.*, (2005) who reported that snap bean varieties were significantly variable in pod fiber content. The possible reasons for pod fibrous content variations among varieties could be due to the genotype factors.

The effect of N treatment has shown variations on pod fiber content and the highest fiber content was recorded from the control and which was at par with 40 and 80 kg N ha^{-1} application while the lowest value was recorded from the 160 kg N ha^{-1} and it was statically similar with the application of 80 and 120 kg N ha^{-1} (Table 7). This result is supported by the finding of Salinas-Ramirez *et al.* (2011) who reported that fiber content reduced when the application of N increased on snap beans. 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.

4.4. Correlation Analysis between Parameters

As indicated in Table 8 the correlation among different parameters and total leaf area had a significant correlation with plant height ($r=0.80^{**}$), number of primary branch ($r=0.35^{**}$), days to 50% flowering ($r=0.67^{**}$), shoot and root dry weight ($r=0.77^{**}$), root volume ($r=0.35^{**}$) and tap root length ($r=0.32^{*}$). The possible reason for the existence relation between total leaf area and those parameters are as plant height and number of primary branches increased; the plant has vigorous vegetative growth and as a result the total leaf area increased. Similarly, when days to 50% flowering delayed, the plant has higher vegetative growth and as a consequence the total leaf area increased. The plant height had shown a positive correlation with, number of primary branch ($r=0.29^{**}$), shoot and root dry weight($r=0.83^{**}$), root volume ($r=0.36^{**}$), tap root length ($r=0.41^{**}$) and days to 50% flowering ($r=0.57^{**}$).

Shoot and root dry weight had a strong and positive significant correlation with days to 50% flowering ($r=0.65^{**}$), root volume (r=0.55**) and tap root length (r=0.41**). The possible reason for the existing relation could be the increased in plant height, total leaf area, root volume and tap root length resulted for the increment of shoot and root dry weight.

In the present study it was observed that total pod yield had significantly positive correlation with plant height ($r=0.63^{**}$), total leaf area ($r=0.62^{**}$), days to 50% flowering ($r=0.48^{**}$), number of primary branches ($r=0.27^{*}$), shoot and root dry weight ($r=0.53^{**}$), marketable pod yield ($r=0.96^{**}$), unmarketable pod yield ($r=0.40^{**}$), total number of pods per plant ($r=0.64^{**}$), average marketable pod weight ($r=0.57^{**}$), pod dry weight ($r=0.79^{**}$), pod length ($r=0.61^{**}$) and pod diameter ($r=0.68^{**}$). In supporting with the present study Shaban (2005) reported that total pod yield was strongly positively correlated with number of pods per plant ($r=0.51^{**}$), pod length ($r=0.84^{**}$) and pod diameter ($r = 0.84^{**}$), respectively. The possible reasons for the existence of this relation among the parameters are as the total leaf area increased the plants produce higher photosynthates and as a result the total pod yield was higher. In line with this when the increased in yield components (number of pods per plant, average marketable pod weight, pod dry weight, pod length and pod diameter) it resulted for higher total pod yield.

Marketable pod yield had significantly positive correlation with plant height ($r=0.56^{**}$), total leaf area ($r=0.49^{**}$), days to 50% flowering ($r=0.29^{*}$), shoot and root dry weight ($r=0.43^{**}$), total number of pods per plant ($r=0.64^{**}$), average marketable pod weight ($r=0.48^{**}$), pod dry weight ($r=0.69^{**}$), pod length ($r=0.54^{**}$) and pod diameter ($r=0.55^{**}$). The probable reason for the existence relations among the parameters are as the increased in total leaf area, the production of photosynthates increased and marketable pod yield was higher. In line with this when the increased in yield components (number of pods per plant, average marketable pod weight, pod dry weight, pod length and pod diameter) it resulted for the increment of marketable pod yield.

A positive significant correlation was observed in total number of pods per plant with number of primary branch ($r=0.48^{**}$) and pod dry weight ($r=55^{**}$). Similarly, average marketable pod weight had a strong significant correlation with plant height ($r=0.67^{**}$), total leaf area ($r=0.66^{**}$), days to 50% flowering ($r=0.43^{**}$), shoot and root dry weight ($r=0.58^{**}$), pod dry weight ($r=0.49^{**}$), pod length ($r=0.59^{**}$) and pod diameter ($r=0.55^{**}$).

Pod dry weight had significantly positive correlation with plant height ($r=0.62^{**}$), total leaf area ($r=0.57^{**}$), days to 50% flowering ($r=0.54^{**}$), number of primary branches per plant ($r=0.32^{**}$), shoot and root dry weight ($r=0.58^{**}$), pod length ($r=0.64^{**}$) and pod diameter ($r=0.66^{**}$), respectively.

Positive and highly significant correlation was obtained between pod length and plant height ($r=0.68^{**}$), total leaf area ($r=0.59^{**}$), days to 50% flowering ($r=0.50^{**}$), root volume ($r=0.55^{**}$), tap root length ($r=0.37^{**}$) and pod diameter ($r=0.62^{**}$). Similarly, pod diameter was positive correlation with plant height ($r=0.57^{**}$), total leaf area ($r=0.63^{**}$), days to 50% flowering ($r=0.70^{**}$) and root volume ($r=0.44^{**}$), respectively.

Generally the strong positive correlation was observed among most growth, yield and yield components and quality parameters of green bean.

Table 8. Simple correlation coefficients among different parameters

Parameters	PH	LA	F	RV	TRL	PB	TY	MY	UNMY	TNPP	AMPW	PDW	SRDW	PL	PD	P
PH	1.00	0.80**	0.57**	0.36**	0.41**	0.29*	0.63**	0.56**	0.40**	0.14	0.67**	0.62**	0.83**	0.68**	0.57**	0.04
LA		1.00	0.67**	0.35**	0.32*	0.35**	0.62**	0.49**	0.58**	0.16	0.66**	0.57**	0.77**	0.59**	0.63**	0.32*
F			1.00	0.69**	0.39**	0.37**	0.48**	0.29*	0.74**	0.15	0.43**	0.59**	0.65**	0.50**	0.70**	0.47**
RV				1.00	0.23	0.31*	0.18	0.06	0.46**	0.08	0.20	0.48**	0.55**	0.31*	0.44**	0.25
TRL					1.00	-0.15	0.25	0.21	0.19	0.01	0.38**	0.27*	0.41**	0.37**	0.25	-0.01
PB						1.00	0.27*	0.17	0.42**	0.48**	-0.01	0.32**	0.25	0.12	0.23	0.09
TY							1.00	0.96**	0.40**	0.64**	0.57**	0.79**	0.53**	0.61**	0.68**	0.23
MY								1.00	0.13	0.64**	0.48**	0.69**	0.43**	0.54**	0.55**	0.12
UNMY									1.00	0.16	0.45**	0.53**	0.48**	0.41**	0.61**	0.45**
TNPP										1.00	-0.02	0.55**	0.07	0.12	0.24	0.01
AMPW											1.00	0.49**	0.58**	0.59**	0.55**	0.25**
PDW												1.00	0.58**	0.64**	0.66**	0.20**
SRDW													1.00	0.65**	0.63**	0.06
PL														1.00	0.62**	0.24*
PD															1.00	0.44**
P																1.00

* and ** indicate significant differences at 5 and 1% levels of probability, respectively. PH= plant height, LA= total leaf area, F= days to 50% flowering, RV= root volume, TRL= tap root length, PB= number of primary branch, TY= total pod yield, MY= marketable pod yield, UNMY= unmarketable pod yield, TNPP= total number of pods per plant, AMPW= average marketable pod weight, PDW= pod dry weight, SRDW= shoot and root dry weight, PL= pod length, PD= pod diameter and P= pod protein content.

4.5. Partial Budget Analysis

The economic analysis revealed that highest marginal rate of return (MRR) was 1306.67% from Melka 3 at 40 kg N ha^{-1} and followed by 1130.48% from Melka 5 at 40 kg N ha^{-1} (Table 9). In the case of Melka 1 and Contender blue the highest MRR (487.80 and 809.75%) was obtained from 40 and 80 kg N ha^{-1}, respectively. Other treatments gave more yields but due to higher cost of fertilizer levels involved, MRR were lower or negative i.e. dominance. The increase in level of N fertilizer had positive effect on yields but involved higher initial costs. Keeping in view the socio-economic conditions of the farmers in the area, it is imperative to consider cost of production as an important factor in the introduction of technological inputs. With the highest MRR and acceptable increase in yields, the N fertilizer level 40 kg ha^{-1} got the first priority with Melka 3 and Melka 5 and also 40 and 80 kg N ha^{-1} resulted for the higher economical return for variety Melka 1 and Contender blue, respectively. Generally, this study clearly indicated that the application of N fertilizer at a rate of 80 and 40 kg ha^{-1} is the most economic option for a green bean grower in Bishoftu especially in experimental area for Contender blue and the rest varieties, respectively.

Table 9. Partial budget analysis of green bean varieties as influenced by nitrogen

Varieties	Nitrogen	Average Yield (kg/ha)	Adjusted Yield 10% (kg/ha)	Gross field benefits (Birr/ha)	Total cost that vary	Net benefit (birr/ha)	B:C	MRR
M 1	N0	10706.67	9636	43843.80	0.00	43843.81		
M 1	N1	12063.33	10857	49399.35	945.15	48454.20	51.27	487.80
M 1	N2	13390	12051	54832.05	1890.40	52941.19	28.01	474.74
M 1	N3	13670	12303	55978.65	2835.55	553143.10	18.74	21.31
M 1	N4	12933.33	11640	52961.99	3780.80	49181.18	13.01	D
M 3	N0	10193.33	9174	41741.70	0.00	41741.69		
M 3	N1	13440	12096	55036.80	945.15	54091.65	57.23	1306.67
M3	N2	15940	14346	65274.30	1890.40	63383.90	33.53	983.04
M 3	N3	16220	14598	66420.90	2835.55	63585.35	22.42	21.31
M 3	N4	14413.33	12972	59022.59	3780.80	55241.78	14.61	D
M 5	N0	9546.67	8592	39093.60	0.00	39093.61		
M 5	N1	12386.67	11148	50723.40	945.15	49778.25	52.67	1130.48
M 5	N2	14840	13356	60769.80	1890.40	58879.78	31.15	962.82
M 5	N3	15990	14391	65479.05	2835.55	62643.50	22.09	398.26
M 5	N4	13816.67	12435	56579.26	3780.80	52798.46	13.96	D
CB	N0	9856.67	8871	40363.05	0.00	40363.06		
CB	N1	11673.33	10506	47802.30	945.15	46857.15	49.58	687.10
CB	N2	12396	12396	56401.79	1890.40	54511.39	28.84	809.75
CB	N3	14470	13023	59254.65	2835.55	56419.10	19.90	201.84
CB	N4	12786.67	11508	52361.41	3780.80	48580.61	12.85	D

M 1= Melka 1, M 3= Melka 3, M 5= Melka 5 and CB= Contender blue

5. SUMMARY AND CONCLUSION

Green bean is one of the most cultivated leguminous vegetables in the world. It has been among the most important and highly prioritized crops as a means of foreign currency earning and an important protein supplement in cereals and root crops based food habit in Ethiopia. Selection of the most suitable variety and determining the appropriate rate of N are very important to increase yield and quality in green bean.

In line with this, a study was conducted to assess the effects of N application on growth, yield and quality of green bean varieties at Bishoftu during the offseason of 2011/2012 with the objective of determining the optimum level of N and identify appropriate green bean varieties for higher yield and quality under Bishoftu conditions. The experiment consisted of four bush type bobby bean varieties namely, Melka 1, Melka 3, Melka 5 and Contender blue and five levels of N (0, 40, 80, 120 and 160 kg N ha^{-1}).The soil type of the experimental site was vertisol. The study was conducted in 4x5 factorial arrangements in a RCBD design with 3 replications.

The findings of the study revealed that varieties and rates of N showed highly significant influences on plant growth attributes, yield and yield components and pod quality parameters. Variety Melka 3 produced the highest value for plant height, total leaf area, shoot and root dry weight, total pod yield, marketable pod yield, average marketable pod weight, pod dry weight, pod length and pod straightness, while in the pod quality parameters the highest value for pod color and fiber less nature was observed from Contender blue.

In the case of N application 120 kg N ha^{-1} resulted maximum value for total pod yield, marketable pod yield, number of pods per plant, average marketable pod weight, pod dry weight, pod length and pod diameter. The highest value for plant height, shoot and root dry weight, unmarketable pod yield, pod protein content, pod color and pod fibreless nature was recorded from the application of 160 kg N ha^{-1} and which was at par with 120 kg N ha^{-1}.

The application 80 kg N ha^{-1} statistically similar with 120 kg N ha^{-1} on most parameters like total leaf area, total pod yield, marketable pod yield, unmarketable pod yield, average marketable pod weight, pod length, pod protein, pod color and pod fibreless nature.

The correlation indicated that the total pod yield had significantly and positive correlation with plant height (r=0.63**), total leaf area (r=0.62**), days to 50% flowering (r=0.48**), number of primary branches (r=0.27*), marketable pod yield (r=0.96**), unmarketable pod yield (r=0.40**), total number of pods per plant (r=0.64**), average marketable pod weight (r=0.57**), pod length (r=0.61**) and pod diameter (r=0.68**). The correlation was indicated that total pod yields have shown the existence of close association with those parameters.

With regard to partial budget analysis variety Melka 3 and Melka 5 with 40 kg N ha^{-1} gave the highest MRR (1306.67, 1130.48) and B:C (57.23, 52.67), respectively.

In conclusion, considerations have to be taken in respect of total pod yield as wells as the quality of pods produced. Therefore, on the basis of the results of the present study, it is indicative that green bean can grow well in the study area and farmers can benefit more by practicing the application of 80 kg N ha^{-1} with variety Melka 3 resulted in high yield and quality of green bean. The higher pod quality parameters like pod color and pod fiber less nature was recorded form Contender blue. While considering the economic analysis, Melka 3 with 40 kg N ha^{-1} gave the highest economical return and followed by Melka 5 with 40 kg N ha^{-1} to the farmers.

Future line of work

1. Similar experiment is suggested to be carried out especially during the main rainy season at different soil type since this experiment was conducted during the off season and repetition of the experiment for more seasons would help us draw sound conclusions and recommendations.
2. Integrated use of organic and inorganic fertilizers could bring sustainability of green bean production, thus studies in this regard may be suggested to be done under Bishoftu condition.
3. Further studies on the reduction of unmarketable yield are suggested to be conducted.

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7. APPENDICES

Appendix Table 1. Nutrients contents in green beans per 100 g

Nutrient	Amount
vitamin C	12.20 mg
vitamin K	14.40 mcg
vitamin A	690.00 IU
manganese	0.22 mg
fiber	2.70 g
folate	33.00 mcg
vitamin B6	0.14 mg
molybdenum	5.00 mcg
magnesium	25.00 mg
tryptophan	0.02 g
potassium	211.00 mg
vitamin B2	0.10 mg
iron	1.03 mg
vitamin B1	0.08 mg
phosphorus	38.00 mg
calcium	37.00 mg
protein	1.83 g
vitamin B3	0.73 mg
choline	15.30 mg
copper	0.07 mg
omega-3 fats	0.07 g

Sources: (WHFoods, 2012)

Appendix Table 2. Detail description of the varieties

Characteristics	Varieties			
	Melka 1	Melka 3	Melka 5	Contender blue*
Plant height (cm)	26	36	28	-
Flower color	White	White	Purple	White
Ground coverage	High	Large	Medium	Medium
Days to 50% flowering	56	48	52	-
Pod length (cm)	10.8	12.4	11.8	-
Pod diameter (cm)	1.2	1.2	1.1	-
Fiber ness	Nil	Nil	Nil	Nil
Pod curvature	Straight	Straight	Straight	Straight
Pod shape	Round	Round	Round	Round
Yield q/ha	124-137	110-140	129-146	-

Source: Lemma *et al.* (2006) and * = Personal observation

Appendix Table 3. Details of treatment combination

Treatment	Treatment Combination	Notation
T_1	Melka 1 at 0 kg N ha^{-1}	M_1N_0
T_2	Melka 1 at 40 kg N ha^{-1}	M_1N_1
T_3	Melka 1 at 80 kg N ha^{-1}	M_1N_2
T_4	Melka 1 at 120 kg N ha^{-1}	M_1N_3
T_5	Melka 1 at 160 kg N ha^{-1}	M_1N_4
T_6	Melka 3 at 0 kg N ha^{-1}	M_3N_0
T_7	Melka 3 at 40 kg N ha^{-1}	M_3N_1
T_8	Melka 3 at 80 kg N ha^{-1}	M_3N_2
T_9	Melka 3 at 120 kg N ha^{-1}	M_3N_3
T_{10}	Melka 3 at 160 kg N ha^{-1}	M_3N_4
T_{11}	Melka 5 at 0 kg N ha^{-1}	M_5N_0
T_{12}	Melka 5 at 40 kg N ha^{-1}	M_5N_1
T_{13}	Melka 5 at 80 kg N ha^{-1}	M_5N_2
T_{14}	Melka 5 at 120 kg N ha^{-1}	M_5N_3
T_{15}	Melka 5 at 160 kg N ha^{-1}	M_5N_4
T_{16}	Contender blue at 0 kg N ha^{-1}	CBN_0
T_{17}	Contender blue at 40 kg N ha^{-1}	CBN_1
T_{18}	Contender blue at 80 kg N ha^{-1}	CBN_2
T_{19}	Contender blue at 120 kg N ha^{-1}	CBN_3
T_{20}	Contender blue at 160 kg N ha^{-1}	CBN_4

Appendix Table 4. Mean squares for growth attributes of green bean

Source of Variation	PH	TLA	DF	DWSR	RV	TRL	PB
Varieties (V)	502.99**	1462805.67**	57.91**	317.20**	14.73**	60.46**	2.15**
Nitrogen (N)	206.96**	1994595.05**	45.64**	184.54**	4.87**	8.33ns	2.26**
V X N	1.65ns	89069.62ns	0.12ns	8.00ns	1.58*	9.62*	0.19*

Ns, * and ** implies non significant, significant and highly significance differences at 5% level of probability, respectively. PH = plant height, TLA = total leaf area, DF = days to 50% flowering, SRDW= shoot and root dry weight, RV = root volume, TRL = tap root length and PB = Number of primary branches

Appendix Table 5. Mean square for yield and yield components of green bean

Source of Variation	TPY	UMPY	MPY	TNPP	AMPW	DWP
Variety (V)	7.89**	0.90**	9.85**	28.64**	4.63**	2.09**
Nitrogen (N)	47.02**	2.41**	28.51**	43.70**	1.58**	19.91**
V X N	1.19ns	0.07ns	1.41ns	3.02ns	0.08ns	0.34ns

Ns, * and ** implies non significant, significant and highly significance differences at 5% level of probability, respectively. TPY = total pod yield, UMPY = unmarketable pod yield, MPY = Marketable pod yield, TNPP = total number of pods per plant, AMPW = average marketable pod weight and DWP = dry weight of pod.

Appendix Table 6. The mean square for pod quality parameters of green beans

	Pod quality parameters					
Source of Variation	Pod length	Pod diameter	Pod protein (%)	Pod color	Pod straightness	Pod fibreless nature
Varieties (V)	6.278**	5.899**	10.221**	5.612**	1.155**	0.077**
Nitrogen (N)	5.947**	22.113**	5.918**	0.613**	0.025ns	0.019**
V X N	0.082ns	0.303ns	0.099ns	0.073ns	0.040ns	0.002ns

Ns and ** implies non significant and highly significance differences at 5% level of probability, respectively.

Appendix Table 7. Meteorological data of the study area in the year 2011

Month	Rainfall (mm)	Temperature (^oC)			Mean RH (%)
		Max	Min	Mean	
January	0.2	23.1	8.3	15.7	45
February	0	28.8	8.7	18.75	60
March	106.3	26.5	13.3	19.9	36
April	17	29.7	12.2	20.95	50
May	112.5	30	8.3	19.15	65
June	29.2	27.9	11	19.45	50
July	134.6	26.9	13.5	20.2	60.5
August	241.7	25	14.9	19.95	70.8
September	82.6	25	14.9	19.95	65.2
October	0	25.8	8.2	17	46.2
November	0	25.9	9.5	17.7	70
December	0	24.7	8.2	16.45	68

The Meteorological data of the study area were obtained from Debre Zeit Agricultural Research Center (DZARC)