DETERMINATION OF SOWING DATE AND PLANT SPACING FOR PRODUCTION OF GREEN BEAN (*Phaseolus Vulgaris* L.) VARIETIES UNDER JIMMA CONDITION, SOUTHWESTERN ETHIOPIA

M.Sc. THESIS

ESSUBALEW GETACHEW SEYOUM

OCTOBER 2011
JIMMA UNIVERSITY

DETERMINATION OF SOWING DATE AND PLANT SPACING FOR PRODUCTION OF GREEN BEAN (*Phaseolus Vulgaris* L.) VARIETIES UNDER JIMMA CONDITION, SOUTHWESTERN ETHIOPIA

A Thesis Submitted to the Department of Horticulture and Plant Science, School of Graduate Studies

JIMMA UNIVERSITY
Collage of Agriculture and Veterinary Medicine

In Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN HORTICULTURE
(VEGETABLE SCIENCE)

By
ESSUBALEW GETACHEW

October 2011
Jimma University

APPROVAL SHEET OF THESIS
SCHOOL OF GRADUATE STUDIES
JIMMA UNIVERSITY

As Thesis research advisor, I herby certify that I have read and evaluated this Thesis prepared, under my guidance, by **Essubalew Getachew**, entitled: **"Determination of sowing date and plant spacing for production of green bean (*Phaseolus vulgaris* l.*)* Varieties under Jimma condition, Southwestern Ethiopia"** I recommend it be submitted as fulfilling the Thesis requirement.

Ali Mohammed (Ph.D)	________________	____________
Name of Major-Advisor	Signature	Date
Abush Tesfaye (M.Sc)	________________	____________
Name of Co-Advisor	Signature	Date

As members of the Examining Board of the Final M.Sc Thesis Open Defense Examination, we certify that we have read, evaluated the thesis prepared by Essubalew Getachew Seyoum and examined the candidate. We recommended that it be accepted as fulfilling the Thesis requirement for the degree of Master of Science in Agriculture (Horticulture) with specialization of Vegetable Science.

____________________	________________	__________
Name of Chairperson,	Signature	Date
____________________	________________	__________
Name of Internal Examiner	Signature	Date
____________________	________________	__________
Name of External Examiner	Signature	Date

DEDICATION

This thesis work is dedicated to my beloved family, especially to my father Ato Getachew Seyoum, to my mother W/ro Hargewein Abrham, to my brother Mentesinot Getachew, to my sister Yetmwork Getachew, and Kese Getaye Legesse, for giving me love and their committed partnership in the success of all my life.

STATEMENT OF AUTHOR

First, I declare that this thesis is my bona fide work and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at the Jimma University College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made available to borrowers under 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.

Brief quotations from this thesis are allowable without special permission provided that an accurate acknowledgement of the source is made. Requests for permission for extended quotation form or reproduction of this manuscript in whole or in part may be granted by the Head of the Department of Horticulture or the Dean of the School of Graduate Studies when the proposed use of material is for scholarly interest. In all other instances, however, permission must be obtained from the author.

Name: Essubalew Getachew

Signature: _________________

Place: Jimma, Ethiopia

Date of Submission: _________________

ACKNOWLEDGEMENT

First and foremost, I would like to thank the Almighty **GOD** for blessing me invaluable gifts of health, strength, believes, love, hope, patience and protection to me, my families and for people who helping me throughout my study. Had not been the will of God, nothing would have been possible for me.

I express my heartfelt gratitude to my major advisor Dr. Ali Mohammed and co-adviser Ato Abush Tesfaye for their diligent guidance, supervision and encouragement from proposal preparation to final write-up of this thesis. Without the encouragement, insight and professional expertise of my advisors, the completion of this work would not have been possible.

I am deeply thankful to Jimma University College of Agriculture and Veterinary Medicine for granting me the research expenses. I also gratefully acknowledge the immense contribution made by Melkassa Agricultural Research Center; especially the Horticulture research division staff, namely Dr. Lemma Dessalegne, Ato Shimeles Aklilu, W/ro Selamawit Ketema, Ato Asmare Dagnew and Ato Yosef Alemu. They were extremely kind and cooperative in providing me with the necessary experimental materials, such as planting materials (seeds) and the basic information with regards to green bean that have made my work very smooth.

Special thanks goes to the Academic staff of Jimma University College of Agriculture and Veterinary Medicine namely Mr. Amsalu Nebyu, Mr. Abebe Negusie, and Mr Yehenew Getachew for their encouragement and constructive idea from the very beginning of proposal preparation to the final thesis write-up.

The author is also thankful to the following colleagues: Ato Berhanu Tsegaye, Ato Solomon Girma, Ato Sentayehu Muse, Ato Tesfaye Fantu, Ato Abiy Tarequne, and Ato Zerihun Belachew for their sincere support, advice and exchange of idea during the entire study period.

The author extends his heartfelt gratitude and appreciation to Ato Almeseged Amanuel for his kind-hearted treatment and dedicated help in mobilizing and organizing the necessary facilities that enabled me to accomplish the field research work successfully and timely in the field.

I would like to thank all the administrative staff members of JUCAVM especially W/rt Arafate Kassahune, W/rt Tigist Damene, W/rt Jimmawork Gebre, W/rt Toyiba Semhene, W/rt Fantu G/Mariyam, W/ro Yergalme Mekonnene, W/rt Juliyana G/Silassie, W/ro Wubite Germa, Ato Nasier A/Mecha, Ato Abiyot Hunde, and Techale Birhan.

Last but not least, I would like also to express my sincere gratitude to my parents; Getachew Seyoum, W/ro Hargewein Abraham, Mentesinot Getachew, Yetmwork Getachew, Kese Getaye Legesse and grand mother, father, and uncles for their dedication in brought me up and providing me strong support throughout my life and academic career.

BIOGRAPHICAL SKETCH

The author was born on February 14, 1985 in Jimma, Jimma town of Oromiya Administrative Region. He attended his elementary school at Jimma Dil Fire Elementary School from 1991 to 1996 and his Junior Secondary school at Jimma Setto Semero Junior Secondary School from 1997-1999. He started his high school study in 2000 at Jimma Compressive and Secondary School and completed it in 2003. He attended his secondary school in Jimma from 2000-2001 in Jimma Compressive and secondary school and when he passed the Ethiopian General Secondary Education Certificate he joined the preparatory class at Jimma from 2002-2003 in Jimma Academic and Vocational Training Institute.

Passing the Ethiopian Higher Education Entrance Qualification Certificate, then he joined to Jimma College of Agriculture (Now Jimma University College of Agriculture and Veterinary Medicine, JUCAVM) in 2004 and graduated in 2007 with B.Sc. degree in Horticulture. Soon after graduation the author was employed in the then Ethiopian Agricultural Rural Development office in the South Nations and Nationalities and Peoples Region under Konta Special District Agriculture and Rural Development office for six months and then he joined Private Company at Lamme Kaffa Coffee and Spice Agro- Industry P.L.C for one year and three months, served as an agronomist. He has joined the School of Graduate Studies at Jimma University in September 2009 for an M.Sc degree in Horticulture; specializing in Vegetable Science.

TABLE OF CONTENTS

Contents **Page**

LIST OF TABLES

Table **Page**

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF TABLES IN THE APPENDICES

Appendix Table **Page**

ABREVIATIONS

ANOVA	Analysis of Variance
BPEDORS	Bureau of Planning and Economic Development of Oromia Regional State
CSA	Central Statistics Agency
FAO	Food and Agriculture Organization of the United Nation
HDC	Horticultural Development Corporation
HDE	Horticultural Development Enterprise
IDEA	Investment in Developing Export Agriculture
JARC	Jimma Agricultural Research Center
JAVTI	Jimma Academic and Vocational Training Institute
JUCAVM	Jimma University Collage of Agriculture and Veterinary Medicine
MARC	Melkasa Agricultural Research Center
SNNPR	South Nations, Nationalities and Peoples Region
RIBD	Randomized Incomplete Block Design
UAAIE	Upper Awash Agro Industry Enterprise
PAR	Photosynthetically Active Radiation

DETERMINATION OF SOWING DATE AND PLANT SPACING FOR PRODUCTION OF GREEN BEAN (*Phaseolus Vulgaris* L.*)* VARIETIES UNDER JIMMA CONDITION, SOUTHWESTERN ETHIOPIA

ABSTRACT

Green bean (Phaseolus vulgaris L.*) takes the highest share among the leading vegetables exported to European and Middle East markets. Recently, it is becoming one of the most important vegetables in local markets as well.* A*s green bean is a new introduction to Jimma area, identification of adaptable varieties with appropriate sowing date and plant spacing can provide the basis for effective green bean production. However, there is hardly any recommendation for cultivation of green beans for Jimma and similar areas. Therefore, a 5 x 4 x 2 factorial experiment arranged in Randomized Incomplete Block Design (RIBD) with three replications was conducted at Jimma, Southwestern Ethiopia from June 2010 to December 2011 with the objectives of determining appropriate sowing date, plant spacing and identifying the best candidate variety for better yield and quality of green beans (Phaseolus vulgaris L.) under Jimma condition. The treatments consisted of five different levels of plant spacing (50 cm x 7 cm, 40 cm x 15 cm, 40 cm x 10 cm, 40 cm x 7 cm, 30 cm x 15 cm), four levels of sowing date (July 3rd, July 18th, August 2nd and August 17th) and two verities (Melka-1 and Melka-5). In view of that, data were collected pertaining to growth, yield and quality of green beans and analyzed using Genstat version 11 (VSN International, 2008).The results revealed that the difference between the two varieties was highly significant ($P \leq 0.05$) for all parameters studied. The variety Melka-5 gave high total and unmarketable pod yield; while Melka-1 variety gave high tenderness quality of green bean (1.780). Sowing of green beans on the 3rd and 18th of July resulted in high total pod yield (7182 kg/ha) and (7000 kg/ha) respectively; while sowing on the 3rd of July resulted in high marketable pod yield (4326 kg/ha). Total unmarketable pod yield was observed when sowing was done on the 3rd and 18th of July; while more number of seeds per pod was observed as a result of sowing on the 18th of July and* 2nd August (*2.253) and (2.243), respectively. The incidence of Angular leaf spot was significantly ($P \leq 0.05$) higher for July 3rd sowing; whereas high incidence of floury leaf spot was recorded from sowing on the 18th of July and high rust infestation was observed when Melak-1 sown at the 2nd of August. More snapping and tenderness quality was observed when sowing was done on the 3rd of July. Green beans spaced at 40 cm x 7 cm gave significantly high leaf area, total marketable (2531 kg/ha) and unmarketable (2609 kg/ha) pod yield; while tenderness quality was higher at 50 cm x 7 cm spacing (1.708). The interaction effects between Melka-5 and July 3rd sowing gave high total number pod per plot; while Melka-5 sown on the 18th of July produced high value for straightness quality, and Melka-1 with July 3rd sowing gave high fibreless quality. Green bean sown on July 3rd with a spacing of 40 cm x 15 cm gave high total number of pods per plot, while the interaction effects between 50 cm x 7 cm with sowing on July 3rd resulted in high straightness quality. On the basis of the results of the present study, it is indicative that green beans can grow well in the study area and farmers can benefit more by practicing narrow plant spacing (40 cm x 7 cm) and earlier sowing (July 3) with variety Melka-5 to achieve high productivity and quality of green beans. However, repeating of the experiment for more seasons would help us draw sound conclusions and recommendations. Moreover, further studies are needed with regard to the improvement, nutritional quality and packages of agronomic practices for green bean cultivation.*

Key words*: Green beans, variety, spacing, sowing date, yield and quality*

1. INTRODUCTION

Green beans (*Phaseolus vulgaris* L.) belong to the family Leguminaceae (Smarrt, 1976; Bose *et al*., 2002) and sub-family *papilionadiae* and the genus *Phaseolus* (Yoldas and Esiyok, 2009). It is a diploid species with a chromosome number of 2n=2x=22. There are diverse botanical varieties of the species *Phaseolus* that vary interms of growth habit, seed and pod characteristics, agronomic features, and response to biotic and abiotic stresses (Westphal, 1974; Kay, 1979).

According to Rai and Yadov (2005), green beans have originated in Southern Mexico and Central America. Southern Mexico and warm regions of Guatemala were also considered as primary centers of origin; while Peru, Ecuador and Bolivia as secondary centers. According to Rubatzkey and Yamagucbi (1999) the green bean and its many biotypes evolved from wild *P. aborigineus* in the Andean regions. However, Singh (2001) indicated two distinct gene pools of common bean, Andean origin and Mesopotamia. The first cultivar of green bean was believed to be selected from Peru and spreads to Europe and then to Asia. It is speculated to have been introduced to Ethiopia by the Portuguese in the 16th century (Frew, 2002).

Green bean is one of the most cultivated leguminous vegetables in the world and it is the most important food legume. Commonly farmers grow beans in two forms, as dry beans and green beans (where the green pods are consumed as a vegetable). Asia and Europe with more than 50% and 30% of world production, respectively, are the dominant green bean producers. China and Turkey are the leading countries with more than 17 and 13% of the world production, respectively (Rubatzkey and Yamagucbi, 1999). Even though, Africa is considered to be the secondary center of diversity for green beans, women are the primary growers of beans at small scale level, on small plots (Bose *et al.*, 2002).

The annual production of green beans in the world covers an area of greater than 960,272 ha with a total production of 6,814,403 tons (FAO, 2009). Currently in Ethiopia, green bean production occupies total area coverage of above 15,379 ha, with an average total production of 6,803 tons (FAO, 2009). The major production areas of snap bean in Ethiopia are the highland areas, such as (Holeta, Sendafa, Sebeta, Debrezit areas etc.); sub-humid highlands and semi-arid zone in the Rift Valley and eastern regions of the country, especially the Upper Awash Agro-industry Enterprise (UAAIE) and the lake region of the country are the most important areas of green beans production in the country. The main production system is growing beans sole and/or intercropping with maize, banana, sorghum, cassava and sweet potato, due to its short duration and tolerance to shading (Westphal, 1974).

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; Kay, 1979). Nowadays in Ethiopia green bean is one of the most important export vegetable among the other vegetables and it is extensively produced by state enterprises and private investors and small scale farmers (on contract basis) in the rift valley region, mainly for export to European markets (Lemma *et al.*, 2006). Green bean is also one of the leading vegetables exported to European and Middle East markets, with the highest share among all vegetables. Recently, it is becoming one of the most important vegetables in local markets, in a big hotels and festivals and in the preparation of various dishes. It has been considered as an important protein supplement in cereals and root crops based food habit in the country (Lemma, 2003).

In Ethiopia, the production of green beans for Europe export markets was started by large commercial farmers in the early 1970s. More recently, the European market for this crop has expanded considerably and thus export becomes viable for over a much longer season that created a surplus of non-exportable grades to enter into the local market, and that resulted in the expansion of local consumption (Lemma *et al.*, 2003).

However, the local market for green bean was limited, despite the availability of high export market (Sam and Yosef, 1985). According to Godfery *et al.* (1985) the demand for green beans in the local market of Ethiopia is very low due to the unfamiliarity of

Ethiopians with green beans and it is not commonly incorporated in their diet. According to Sam and Yosef (1985) the major production problems under Ethiopian condition are: 1) Limited genotype screening and inconsistency in the number entries in the period 2) Higher diseases and pests were with rain-fed varietal screening than with those under irrigated conditions, 3) During dry season production, and the frequency and amount of irrigation for optimum crop yield has not been worked out yet and high post-harvest losses (Lemma, 2003).

The genetic potential and the environment, to which a crop is exposed, determine its yielding ability (Godfery *et al*., 1985). Improving the yield limiting factors may lead to increase in productivity in green bean and other crops. However, little work, such as varietal tests for specific environment has been done on green beans in the country. The National Vegetable Crops Improvement Program at Melkassa Agricultural Research Center have introduced green bean accessions from different parts of the world, evaluated some of the introduced accessions, and recommended three improved varieties for low land areas of the country (Lemma, 2003).

It is imperative to identify factors that play crucial role in improving production and productivity of green bean in specific niches. Site-specific factors, cultural practices and sowing date influence yield and yield characteristics of green bean. Selection of the most suitable variety, determining suitable sowing date and applying appropriate cultural practices and others are very important for increasing quality and yield of green bean. Among various factors, optimum sowing date and best variety are of primary importance to obtain potential yield (Amanullah *et al*., 2002).

In the earlier trials that were undertaken by different research stations in Ethiopia, planting density of 50cm x 25cm and 40cm x 20cm were adopted for rain-fed and irrigated planting, respectively. Later, a standard 40cm x 10cm planting distance has been adopted irrespective of planting under rain-fed or irrigated conditions, which was not clear how this standard planting was identified without having optimum planting density, including number of plants per hill (Godfery *et al*., 1985).

The diverse agro-ecological conditions in Jimma area make it a suitable place for the production of green bean in the area. The conducive agro-ecology for green bean and there are long hours of suitable irrigation water is available in ample quantity and the well-drained soil in the area is suitable for growing nearly all types of horticultural crops. Due to the country's export oriented production policy, international airport has been built in the area and this encourages efforts to export fresh horticultural products to the international market. Thus, currently large numbers of farmers and private investors are being encouraged to work in the production of green bean through ample man power and intensive government extension effort (Tamru Abeshu Personal Communication, 2010).

Some preliminary varietals studies have been under taken at Jimma with the objective of introducing the crop as a source of protein and vitamins to small scale farmer in the farming system of Jimma area (Lemma, 2003). In 1970/71 at Jimma total pod yield (81q/ha) under irrigation and 51q/ha under rain fed condition were conducted.

In Ethiopia, particularly in Jimma zone, there are different production problems of green beans. To mention some, there is no systematic and continuous research in relation to adaptability and seed production potential of the cultivars, lack of awareness, serious diseases and pest and lack of appropriate agronomical and cultural practices for the crop. However, the most important agronomic problems in Jimma zone are absence of information on the appropriate planting date and optimum plant spacing (Lemma, 2003).

Therefore, this research was conducted with the following objective:-

- ❖ To determine appropriate sowing date, optimum plant spacing, variety and their combinations for better yield and quality attributes of green beans under Jimma condition.

2. LITERATURE REVIEW

2.1. Importance of Green Bean

Green bean (*Phaseolus vulgaris* L.) is the most important leguminous vegetables. It is produced in many countries of the world for local use and export market (Lemma, 2003). Green bean serves as a green vegetable and it provides protein, calories, vitamins and minerals, such as calcium, phosphorus and iron. It is consumed when the pods are immature preferably in the fibreless state. The crop is also an important source of income for small scale farmers and it is also a good source of employment (Lemma, 2003). Green bean is important contributor to the socio-economic improvement of farming community in East and Central Africa (ECA). It is a crop with great potential for addressing food insecurity, income generation and poverty alleviation in the region (Ugen *et al.*, 2005).

Green bean pods, shoots, leaves and immature seeds are consumed after cooking. Processing by canning of frozen pods and seed of shelled-type cultivars represents a significant volume of the total production. Interestingly consumers have strong preferences for green bean pod shape, pod size and color. The protein quality of processed whole pods is good, although it has low level of sulfur containing amino acid (Rubatzkey and Yamagucbi, 1999).

Green bean (tender pod) is a valuable source of mainly protein, calcium, iron and vitamins. It is also used as green vegetables, when pods are immature, tender, delicate, and green shelled seeds or as dry pulses (Rai and Yadov, 2005).

The nutritive value of green bean (tender pod) is quantified by Rai and Yadov (2005) and reported 97.4g moisture, 1.7g protein, 0.1g fat, 4.5g carbohydrates, 1.8g fiber, 0.5g minerals, 221g vitamin A, 0.08g thiamine, 0.06mg riboflavin, 11mg vitamin C, 0.03mg nicotinic acid, 50mg calcium, 28mg phosphorus, 1.70mg iron, 129gm potassium, 37mg sulpher, 4.30gm sodium and 0.21mg copper. Presence of glycosylated flavonoides has been reported and Cis-hex-3-en-ol, oct-2-en-ol, linalool, alpha, terpeniol, pyridine and furfural are primary importance in canned French bean.

2.2. Soil and Climatic Requirements

Green bean is a warm weather crop that requires a short growing season. It is well adapted to areas that receive an annual average rainfall of 500 to 1500mm with optimum 16 to 24^{o}C temperature and a frost free period of 105 to 120 days. Moreover, it performs best on deep, friable and well aerated soil types with optimum pH range of 6.0 to 6.8 (Kay, 1979). Seed germination is optimum between 25 and 30^{o}C; temperature less than 10^{o}C and above 35^{o}C do not permit germination, and under good condition, emergence of seedling occurs within 7 to 10 days interval (Rubatzkey and Yamagucbi, 1999). Optimum growth of the bean plant and yield also occur between 18^{0}C and 29^{0}C. There are usually problems with production if the mean temperature is greater than 29^{0}C. High temperature interferes with pollination, resulting in blossom drop, crooked or deformed pods due to the lack of ovule development. Pods become fibrous and poorly formed. When daytime temperatures turn cooler new flowers form which set new pods. This is called split set where two different stages of maturity occur on the plant which is undesirable (Henry, 2009). Green beans require similar agro ecological condition as dry beans with suitable elevation of 1000 to 2000 m.a.s.l. The lake regions and rift valley are major production areas. Sandy loam soils are suitable for green beans production, even though it requires more frequent irrigation (Lemma *et al.,* 2003). Beans perform best on soils which are neutral or slightly acidic so that lime should be applied when pH levels are below 5.8. Heavy and poorly aerated soils result in reduced yield (IDEA, 2001).

2.3. Cultivars Commonly Produced

In Ethiopia two bean varieties are under production for export and local use; these are Bobby and Fine beans. The bobby type, Amoby variety was produced for export lately this variety replaced by Nerina. Cultivar Xeria was also included in production and export market because of its heavy diseases pressure, decline in yield and quality of the pervious cultivars (Lemma, 2003). The fine type varieties Supermonel and Royalnel are not string less but the pods are harvested before strings are developed. They are more firm in texture than Amboy (Jackson *et el.*, 1992). Currently in Ethiopia green beans 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). According to Lemma (2003) in (1995-2001) alone 68 genotypes were identified as varieties with high yield, pod quality for export and homestead production, tolerance to diseases complex mainly rust. They are potentially superior in terms of pod yield and quality but susceptible to diseases when tested at Melkassa, Horticultural Developments Enterprises and private farms. Based on the yield performance and pod quality and early maturing Cultivars Montano, Palati and Nelson are the better, while mid maturing and high yielder cultivars are S-51, HAB, 407, 408, 438, 419, 409, 410, and 448. On the other hand cultivars B1-44, Opera and L-12 were found to be late maturing and good yielder.

2.4. Cultural Practices

2.4.1. Sowing

The green bean seeds were sown in two rows of 15 cm apart per ridge and 10 cm from each edge of ridge. Spacing in the row was 7.5 cm and the seed was sown 2 to 3 cm deep in the soil moistened by pre- irrigation. However, some varieties have a higher or lower seed weight and the seed rate per hectare should then be calculated accordingly, to the optimum plant population about 356,000/ha (Jackson *et el.*, 1992).

According to IDEA, 2001, green beans were best sown on raised beds in rows 30 cm spaced apart with 8 to 10 cm between the plants. A plant density of around 32 / m^2 is a good target. A sowing rate of 50 to 60 kg of seeds per hectare is average. The seed rate for recent trials in Uganda was 55 kg/ha giving a plant population of 300,000 to 350,000. Sowing depth is usually at 3 to 5 cm.

Under cool and wet conditions green beans are very susceptible to root rot infections, such as *Pythium, Rhizoctonia*, and *Fusarium*. The Provider variety is one of the better ones that germinate under low soil temperatures. Sowing of green bean by mechanical system resulted high yield and quality. The quality may be maintained for only one or two days (Henry, 2009). In India green bean is sown twice in a year, first sowing is done in July to September and second in January to February (Rai and Yadov, 2005).

2.4.2. Spacing

Sowing of green bean at the optimum plant spacing has been found to increase yields with closer spacing. Growers in USA use seeding rates of 8 to l2 seeds per foot in rows 38.1 to 76.2 cm apart, as required to fit available cultivating, spraying and harvesting. Although close spacing have been thought to increase probability of infections from gray and white mold, experience with close row spacing and high plant density since the 1970s suggests that this might not be the case, especially when close spacing's are coupled with increasing the distance between plant in the row and the availability of effective fungicides (Henry, 2009).

According to Bose et al., (2002) increased plant density has bean found to increase yield, which can be obtained by more plant per row and close spacing of rows. Row spacing affected yield and color, narrow rows (22.9 cm) had less color intensity and uniformity and resulting in reducing sensory quality. According to Drake and Silberngel (1982), narrow rows (22.9 cm) produced bean pods containing 20% more ascorbic acid than wide row grown plants (55.9 cm). The bush types of snap bean are planted at the spacing of 45 to 60 cm row to row and 10 to15cm plant to plant. Pole types are sown to one meter row to row distance between two sets of rows 60 to 75 cm and between the two rows of 30 cm for proper yield and quality (Rai and Yadov, 2005).

Increasing the plant spacing per hectare tends to reduce the number of beans per plant but increased total number of pod yield per ha. This resulted in pods being born closer to the stem and higher in the plant canopy, resulting more upright plants. When these factors are coupled with increased distance between plants in a row, they tend to compensate for reduced distance and the potential reduced air drainage. At any given plant spacing, reducing spacing between rows allows increased distance between plants in the row provides the same population per given area. Appropriate spacing between rows at higher plant spacing would be 38.48 to 50.8 cm but when spacing is less than 38.48 cm it gets difficult to accomplish cultural practices due to their large leaves and vine habit (Henry, 2009). Plant densities for hand harvesting and of bush beans are between 45 thousand and 60 thousand plants per ha, whereas from 250 thousand and 450 thousand per ha are grown in mechanically harvested, high density plantings although, very close plant spacing tend to reduce pod color, this is often an acceptable sacrifice for high yield. However, high-density plantings increase the potential for disease (Rubatzkey and Yamagucbi, 1999).

2.4.3. Fertilization

Beans are medium feeders. Since beans are legumes, they will fix nitrogen once a good root system is established; inoculation will speed the process. Excess nitrogen will delay flowering, so side dress only after heavy bloom and setting of pods is important (McDaniel, 2009). Fertilization is particularly difficult in sandy soils because of risk of salt injury to green beans. High levels of salt cause shriveled or desiccated areas on foliage which often resemble cold injury. Initially fertilizer applications are sometimes broadcast rather than banded to reduce salt injury but side dressings of N at vine development and/or bloom are recommended in sandy soils or where there have been leaching rains. In soils where zinc is tied up by high pH and phosphate levels, zinc sulfate may be required. Harvesting one ton of green beans removes 13.62 to 33.59 kg N, 0.908 to 2.724 kg P_2O_5, and 2.27 to 2.72 kg K_2O from the soil (Carol *et al.*, 1999).

A soil test is recommended to determine the need for fertilizer. Applying of excessive nitrogen results in yield losses due to increased lodging, difficult harvesting, and increased pod rot. It also can waste fertilizer and money and possibly contaminate groundwater. A general guideline would be a 1:2:2 fertilizers to bring the level of available nitrogen to not more than 27.18 kg per acre. One-half the fertilizer could be broadcast and the remainder applied in a band 3 inches to the side and 2 inches below the seeds. Rates should be based on the soil test and cropping history (Laurie, 1990).

Green beans are a low user of nutrients and do not require high amounts. If beans follow corn, phosphorus (P) and potassium (K) levels are usually ample for top production. A maintenance recommendation might be 22.65 kg of P_20_5 (phosphate) and 22.65 kg of K_20 (potash) per acre broadcast and disked in prior to planting. Be extremely careful to check equipment as beans are highly susceptible to soluble salt injury, a result of placing the fertilizer too close to the germinating seed row. A high soil test for P and K would require no fertilization Green beans are a legume and do fix some needed nitrogen (N) but the N fixing bacteria are not as active as with other legumes. Inoculation is not practical. Therefore, an N addition is usually helpful. Use about 13.59 of N per ace, applied early when first trifoliate leaf is visible. Do not apply too much N. Some varieties become too bushy and few flower buds will set (Henry, 2009). In Ethiopia application of 200 kg/ha DAP (18/46) at planting and 100 kg/ha (46) urea in four weeks used as general recommendation for green bean production (Lemma, 2003).

2.4.4. Irrigation

Irrigation is required for successful commercial production. Although the crop has an extensive root system, the plant is sensitive to moisture stress, especially during pod-set. Flower drop can occur when soil moisture is less than 60 percent field capacity or the temperature is high with low relative humidity (Laurie, 1990). Because green beans are shallow rooted, they will need to have adequate moisture for top production. The most critical time is the blossom and bud development through pod set period. Green beans are particularly susceptible to blossom drop under water stress, causing a split set (Michael and Kerry, 2004). Water availability at pod fill is also critical to ensure high yields. Because of its shallow root system of snap bean their water requirement is high. Green beans are adaptable to a wide variety of soil types but will have difficulty of emerging in crusted soils. Water stress has a marked influence on pod yield, number of seeds, sieve size distribution, color, firmness, and sloughing (Bose *et al.*, 2002). Irrigation treatment significantly influenced the turbidity of the brine from the canned snap beans (Drake and Silbernagal, 1982). According to them the method of irrigation had a strong influence on snap bean color, ascorbic acid content, relative firmness and turbidity and dry weight.

2.4.5. Diseases

2.4.5.1. Bean rust

The disease caused by fungus *Uromyces appendicultaus* is particularly sever at high humidity areas (Bose *et al.*, 2002). Diseases symptoms are mostly confined to leaves but young stem are also attacked. The symptom is rust pustules, reddish brown appear abundantly on the lower surface of leaves. According to Rai and Yadov (2005) the control measure of bean rust are cultural practices: like good filed sanitation, distraction of infected plant material and fungicide application with Dithane M-45 (0.2%) can effectively control the disease. In Ethiopia bean rust is sever mostly at the dry season period (Lemma, 2003).

2.4.5.2. Angular leaf spot

Angular leaf spot caused by a fungus *Isariopsis griseola Sacc.* The spots are dark brown to green with distinct margined angular as determined by leaf veins and sometimes covered with a gray mold on the lower surface. These spots coalesce covering the entire pod. The disease is sever in wet weather condition (Rai and Yadov (2005). According to Bose et al. (2002) for effective disease control, application of fungicide like benlate (0.25%) powder used as seed dressing, bavistin (0.1%) and calixin (0.1%) are recommended.

2.4.5.3. Bean anthracnose

Bean anthracnose is the most common diseases of beans. The fungus *Colletotrichum lindemuthianum* can infect beans and other legumes. The disease is most severe in high rainfall subtropical to temperate areas than in tropical areas (Bose *et al.*, 2002). The most characteristics symptom of the disease is black sunken crater like cankers on the pods. The lesions remain isolated by yellow-orange margins. Similar spot are also found on the cotyledons and stem of young seedlings and when sever, can cause seedling mortality (Drake and Silbernagal, 1982). To control the disease crop rotation and destruction of infected plant derbies are use full in checking the infection. Furthermore, fungicide application is also best to control the diseases (Rai and Yadov, 2005).

2.4.6. Insect pest

According to Lemma (2003), the major insect pests affecting green bean production in Ethiopia are: bean fly, African ball worm, leaf minor, red spider mites, stem maggot are reported pests. African ball worm is the major one affecting pod quality of green bean.

2.4.7. Crop requirements

Green beans sown 1.9 cm to 2.54 cm deep either just before or at the beginning of the frost-free period. Fall crop green beans sown early enough in the summer for harvest to be completed before the first killing frost. Row spacing for bush type beans is 5 cm in the row and 45 cm to 91 cm between rows (Laurie, 1990). The optimum temperature for plant growth is 15 ^{0}C to 21^{0}C with some growth occurring between 10^{0}C and 26^{0}C. Green beans require 1050 to 1150 degree days of heat with a base of 10^{0}C. It is recommended that seeds are sowed at a depth of 2.54 to 3.81 cm. Narrow rows have been shown to increase yields and decrease mid-season weed competition. They should be seeded at 45.3 to 63.42 kg per acre (5-7 plants per running foot). Wide rows (76 to 91 cm) should be seeded at 33.97 to 40.77 kg per acre (6 to 10 plants per running foot) (Michael and Kerry, 2004).

Green beans require moist soil for germination. Bean seeds require good soil aeration to germinate. When the soil in sides the furrow is compacted by irrigation water it does not contain enough oxygen for good germination (IDEA, 2001). Cover crops and other types of mulch are important on heavy soils to break the crust. Uniform emergence is particularly important for bush type beans which will be once over mechanically harvested. For this, all areas of the field must be well drained and prepared with no crusted, cold or wet areas. Green beans prefer a well drained soil with a pH of 5.5 to 6.0 but the pH can be as low as 5.0 if Mn or Al are not present in toxic concentrations. Liming of the soil to a pH of 6.0 makes the soil suitable for fertilizer usage more efficient. Beans are particularly sensitive to Boron and may experience toxicity problems in field (Laurie, 1990).

Green beans will nodulate and form symbiotic associations with N-fixing bacteria in the soil even without artificial inoculation. Modern cultivars require fertilizer nitrogen for best performance; however plants fixing their own N often get off to a slower start in the cool spring weather and are less uniform in bloom time and subsequent number of days to harvest. Inoculating bean seed with N-fixing bacteria has not been shown to increase yield or even provide nitrogen to green beans. If not the proper strain, the N-fixing bacterium will be ineffective and possibly parasitic (Laurie, 1990).

2.5. Effect of sowing date on green bean yield

Determining the most suitable variety and sowing dates is very important to increase quality and yields in a region. In an environment characterized by short- growing season like early spring frost, low night temperatures and dry conditions, it is important to determine the appropriate crop duration; of which sowing date is an important determinant factor for successful cropping (Rubatzkey and Yamagucbi, 1999). With late sowing, yield is found to decrease due to a short vegetation period of the crop (Yoldas and Esiyok, 2007). Some researchers, however, have reported that yield was increased with a more later sowing dates as compared with early sowing (Chaudhary *et al*., 1989; Rahman *et al*., 2001). According to the results of study by Yoldas and Esiyok (2007) maximum growth and yield was obtained by sowing of beans in July. An early sowing date produced higher yield and plant height but lower pod diameter, dry matter and pod length than the late sowing date. Number of seeds per pod of soybean decreased when sowing was delayed and this was attributed to a decrease in day length and moisture at the late sowing (Ismail and Khalifa, 1987). According to Escalante *et al.* (1989) a significant difference between sowing dates where plants produced a higher number of pods in the earlier sowing dates than the late sowing ones.

The results obtained from different researchers enabled us to ascertain that sowing date was affecting significantly the length and period of sowing; “sowing-80% of production" and the final yield. The length of "sowing-80% of production" period ranged between 60 (sowing in September) and 83 days (sowing in November). No matter what the year, yields both in the average of immature pods and in the average of fresh seed cultivars, was decreased, in an almost always significantly way going from the sowing of February to that in November: t ha^{-1} 35.8, 29.6, 22.3, 16.8 and 10.3 in the cultivars for immature pods; t ha^{-1} 30.7, 19.2, 16.0, 14.1 and 14.0 in the cultivars for fresh seed (Mauromicale *et al.,* 1991).

Sowing date and variety impart significant positive influences on growth parameters. Average plant height ranges between 25.70 and 49.00cm depending on the years and treatment combinations (Yoldas, and Esiyok, 2007). The research also revealed that taller genotypes produced taller plants when sown early and when plants were exposed to July sowings they were similar in plant height for both years, but they gave taller plants than August sowing. Plant height highly affected the sowing date such that decreased significantly due to delayed sowing (Uslu, 1998). There was a difference of more than 5 cm in height between late July and late August. These decreases in plant height were attributed to a shorter vegetative period.

According to Uslu (1998), stated that sowing date had a significant impact on the marketable yield of soybean cultivars. However, the magnitude of response vared from among cultivars and the highest marketable yields of 7688, 6572 and 8661 kg/ha were obtained from sowing of soybean on May 22 in North-eastern USA for cultivars Zhongke 57, Zhongmei 52 and Dongdou 26, respectively. According to Radulovich (1990) reduction of yield could be due to exposure of the plants to a high moisture stress from the period of pod setting (development) up to the final pod harvest. In a different experiment, growth and yield of snap beans were reported to be significantly affected by sowing date. When green bean were sown during midseason tended to be more vigorous than green bean were sown at the earlier or later sowing and produced more total and marketable snap beans. However, heat and soil moisture stress resulted in flower abortion and pod abscission (Laurie *et al.*, 2004).

According to the study conducted by Yan-sheng *et al*. (2010) sowing of soybean on July 5 in the North-eastern USA resulted in the highest marketable yield of 6349 kg/ha for cultivar Dongdou 24 and the lowest yield was found for cultivar Zhongke 57 at sowing date of July 5, while for cultivar Zhongmei 52 at sowing date of July 17, and for cultivar Dongdou 26 around June 20 to July 5. However, the lowest yield for cultivar Dongdou 24 was at the sowing date of May 22. For the cultivar Zhongke 57, there was no yield differences obtained among sowing dates of June 5, June 20, and July 17, while their yields were significantly different with sowing dates of July 5. For the cultivars Dongdou 26 and Dongdou 24, the fresh seed weight increased as sowing of bean was delayed from May 22 to July 5, but sowing at June 20 generated a somewhat larger fresh seed weight than expected, and then declined at sowing date of July 17. Generally, the lowest fresh seed weight was observed for all cultivars at sowing date of July 17 (the latest sowing date).

According to Calvino *et al*. (2003a) delayed sowing shortened the season length mostly by reducing the duration of late reproductive phase. Yield of different cultivars was significantly affected by sowing date wherein the general yield decline per day of sowing delay was 40.8 kg/ha for cultivar Zhongke 57, 34.4 kg/ha for cultivar Zhongmei 52, 54.9 kg/ha for cultivar Dongdou 26 (Yan-sheng *et al.*, 2010). The results of a study involving the evaluation of introduced varieties in long rainy season in Kenya showed that all the snap bean varieties flowered in the range of 41to 43 days whereas in the late season (short rains season) the snap bean varieties flowered in 39 to 41 days (Ndegwa *et al.*, 2001). According to Marlene *et al.* (2008) early planting snap beans took longer days to flower and mature than in the other planting dates. Higher number of snap bean flowers was observed at the earlier sowing date as compared with that of late sowing date (Anisa *et al.*, 1995).

Similarly, the works of Abdul-Hamid *et al.* (1990) and Vieira *et al*. (1990) revealed that depression of plant height could be observed as a result of reduction in plant photosynthetic efficiency bean plants. Moreover, plant height of soybean was found to be decreased significantly as a result of delayed sowings (Uslu and Esendel, 1996). However, Singer *et al*. (1996) reported that highest plant height could be observed at under warm conditions.

Sowing of faba bean at an early sowing date results in more root growth than sowing at the late sowing date (Talal and Ghalibe, 2006). According to Yusufali *et al.* (2006) more number of primary branches was observed in the early sowing than at the late sowing of field bean in Karnataka (India).

Similarly, Lucas and Milbourn (1976) reported that although number of branches per plant generally decreased with increasing density due to there is high competition between plants.

Sowing green beans at different sowing dates results in a difference in diseases development incidence on the crop. According to Bose *et al.* (2002) rust infection on green bean is found to be particularly severe under high humid condition. On the other hand, angular leaf spot incidence is severe when there is high humidity and as the temperature ranges between 16 and 28^0C (i.e. cool and wet weather condition) in which the leaves remain wet for periods of 24 hours and longer are essential for the growth and development of the diseases (Hagedorn and Inglis, 1986). Floury leaf spot incidence was similarly severed under cool temperature and high relative humidity (CIAT, 1981).

2.6. Effect of plant spacing on green bean yield

When beans are sowed at lower plant spacing, they needed a more number of days for blooming (flowering). This could be related to the supportive effects of the availability of more nutrients to the plants because under lower densities there are less number of plants per unit area which permit building up of more vigorous growth and extending the number of days for blooming (Samih, 2008).

Results of studies on soybean (Crothers and Westermann, 1976) suggested that significant vegetative growth will occur in the indeterminate types during the flowering and pod setting period and these results could cause more competition for photosynthate between the reproductive and vegetative growth. In this study a decrease in the yield of semi-vining bean cultivars was observed when plants were established at 300,000 to 700,000 plants/ha and plants were up to 15 cm taller than the adjacent populations at early bloom. The authors believe that the taller plants might have been producing vegetative growth at the expense of seed yields.

According to Jadoski *et al.* (2000), leaf area of individual plants of soybean increased as plant population decreased. Similarly, Zhou *et al.* (2011) reported the competition between plants to vary among the different spacing treatments wherein soybean plants planted in narrow rows spacing had high light interception than in wider rows spacing. Gardineri *et al.* (1978) also reported that regardless of the sowing date, the percentage of PAR interception of bush cultivar was higher when planted at row spacing of 45.5cm than 9l cm. The marketable snap bean pod yields increased linearly as the spacing was reduced in different sowing dates (Tyson and Kostewicz, 1986). On the other hand, the number of branches per plant of green bean increased with increasing of intra row spacing (Pawar *et al.*, 2007). These authors also reported that the dry weight of green beans increased with increase in row spacing from 22.5 cm to 30 cm.

Studies on the effect of spacing on growth and yield of beans by Crothers and Westermann (1976) reported that harvest index to vary among cultivars and higher harvest index was found for the cultivars U-1414 than of cultivars Canyon at all plant populations. The harvest index for the cultivars Canyon was slightly increased as the plant population decreased, whereas that for UI-114 decreased slightly at 300,000 to 400,000 plants/ha, and then increased rapidly at lower plant populations. This decrease in harvest index occurred within the same population range as did the depression in UI-114's seed yield. The relative competition for photosynthate between reproductive and vegetative growth in the indeterminate plant appears more dependent upon plant population levels than in the determinate plant types.

The optimum plant population for seed production of bushy type cultivar was found to be approximately 400,000 plants/ha and a population similar to that reported for optimum pod yields for the snap bean processing industry. This suggested that increased pod yields caused the increased seed yields (Crothers and Westermann, 1976). Yield of green bean increases at the narrow spacing than the wider plants (Cutcliffe, 1967). Similarly, Wahab (1986) reported that higher planting densities of green bean gave higher pod yields per unit area than that of lower planting density.

Results of a research under taken in Kenya on different cultivars revealed that the introduced cultivars R-1515, R-1516 and Lexus had a pod length ranging between 10 and 11cm for extra fine grade and 12 to 14 cm for fine grade while pod diameter was between 3 and 6 mm for extra fine and fine grade beans, respectively (Ndegwa *et al.,* 2001).

2.7. Effects of sowing date and plant spacing on yield and quality of green bean

A negative relation was reported between maturity date and on the degustation estimate of canned green beans (Poryazov, 1985). An optimal combination of the yield and quality was obtained when pods reached 45 mg and 89 mg maturity for cultivars Valja and Zarya, respectively. The degustation estimate decreased with delay of the sowing from the middle of April to late May and increased when sowing was done in mid-July. The decrease was higher in cultivars Valija, as a result it can be sown only early and late in the season. The yield of cultivars Valja increased when the sowing is postponed to middle of June and decreases in July. The yield of cultivars Zarya did not change when the sowing is delayed till the middle of June and decreased slightly in July. To organize a rhythmic green beans production and obtain stable yields throughout the season, it is necessary to use varieties of the cultivars Zarya type while varieties of the Valja type can be used only in the beginning of the season.

According to Gomez and Araya, (1986), an experiment conducted under Turkey ecological conditions indicated that earliness pole and dwarf bean was prompted by years, sowing and varieties. The first harvest date of both pole and dwarf bean was increased by earlier sowing date and delayed with late sowing date even though, it varied between years. Earlier sown crops, before the second week of April and August, gave lower yields where as bad influence of late sowing date on yield depression could easily be seen from the date. Researches show there is significant difference in the yield due to sowing date and cultivars variation. The yield of both pole bean and dwarf were significantly increased with earlier sowing dates (March 15 and July 1) which were linear and also earlier sowing date showed predominately linear yield increases.

On the other hand, the yield was decreased by delaying sowing date. According to Gomez and Araya (1986), working with "Selka Zondra, 4F-89 and Demre Guzeli" beans showed that when sowing was delayed (August 1, September 12, and September 27) yield was significantly decreased, depending on varieties (Corokalo *et al.*, 1992). Accordingly, the highest yield was obtained from sowing on August 1.
Gomez and Araya (1986), working with " bush bean cultivar" in that when sowing was delayed (23 May, 6 June and 13 June) yield was significantly decreased and affected by varieties as well. The highest yields were produced from the earliest (May 23) sowing date and the lowest from the last sowing (June). Similar reports were made by Porzayov (1985) working with "Valya and Zarya cultivar", when sowing on 5 different dates from April to July, yield was significantly decreased and affected varieties too.

The variety Valya produced the highest yield when sown in mid June and Zarya when sown up to May. Similarly, Duman *et al.* (1990) cited by Gomez and Araya (1986) working with "Contender Boncuk, Peker, Altinbelik and Yalova 5 beans, they noted that when sowing was delayed (August 21, September 11), yields were significantly decreased among sowing dates and varieties. The highest yield was obtained from Contender variety in the first sowing date. Corokalo *et al*. (1992) cited by Gomez and Araya (1986) working with 5 new lines determined similar conclusions. Sowing in the spring (24-26) gave higher yields than sowing in the summer (20-24 July).

The increase in the yield achieved by harvesting at an earlier date is mainly due to the increase in the number of harvest. Growth of fruits greatly depends on temperature since high temperatures accelerate fruit growth. Therefore, yield decreases of late sown crops in autumn season appear to be influenced by lower temperatures. When sowing is delayed, then length of individual vegetation periods and the whole vegetation is shortened. The morphological conditions were affected by the vegetation length to great extent and this effect is more pronounced on late sowing dates (Corokalo *et al*., 1992).

In an effort to determine the effect of plant density on yield and quality of beans, Samih (2008) obtained superior yields in the case of high plant populations over that of low plant population of beans. The p content of the pods increased as planting density decreased and no significant effects were detected for N, K and protein contents of the bean pods. This was attributed to the lower competition for nutrients by the lower number of plants per unit area.

According to Drake and Silbernagel (1982) green beans that grow in narrow rows of (22.9 cm) produced bean pods containing 20% more ascorbic acid than those obtained from wide row spacing grown plants (55.9cm). The same author also found that the row spacing had a major influence on all the quality attributes of frozen snap beans. Findings from a research conducted in Kenya on different cultivars showed that the introduced cultivars like R-1515, R-1516 and Lexus had a good result in terms of pod Quality; straight and fibreless pods with an acceptable green color (Ndegwa *et al*., 2001).

From the same study, based on the evaluation in two seasons, all the snap bean varieties had a pod length ranged between 10 and 11cm for extra fine grade and 12 to 14 cm for fine grade while pod diameter was between 3 and 6 mm for extra fine and fine grade beans respectively (Ndegwa *et al.*, 2001).

3. MATERIALS AND METHODS

3.1. Description of the Experimental Site

The experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine Experimental Field Station, Eladalle which is 7 km from Jimma town in the year 2010/2011 main cropping season under rain-fed condition. Jimma is geographically located at 346 km Southwest of Addis Ababa in Oromiya National Regional State at an elevation of 1753 meter above sea level and at latitude of 7^0 42’ 9’’N and 36^0 47’ 6’’ E longitude in Ethiopia. The experimental site receives an average annual rainfall of 1559 mm with maximum and minimum temperatures of 26.8^0C and 13.6^0C, respectively and the average maximum and minimum relative humidity of the area are 67.5 % and 37.9 %, respectively (Appendix 10 and 11). The soil of the experimental site is reddish brown clay classified as Nitisol with pH range of 5.0 to 6.0 (BPEDORS, 2000).

3.2. Experimental Materials

Two most candidate green bean varieties namely Melka-1 and Melka-5, which were already on variety verification stage for release, were used for the study. The materials used for this experiment were obtained from Melkasa Agricultural Research Center (MARC). Detail description of the two varieties is indicated in (Appendix 7).

3.3. Treatments and Experimental Design

The experiment consisted of three factors namely, population density with five levels (50 cm x 7 cm, 40 cm x15 cm, 40 cm x 10 cm, 40 cm x7 cm, 30 cm x 15 cm), sowing date with four levels (July 3, July 18, August 2 and August 17, 2010) and two candidate green bean varieties (Melka-1 and Melka-5) detail treatment combination indicated in (Appendix 6). The five levels of spacing were fixed after consulting three private green bean producing farms (Jitu-2 Horticulture Farm at Debre Zeit, Jitu-2 Horticluture Farm at Koka and Hawassa Green at Hawassa) and by taking the national recommendation as a bench mark and the four level of sowing date were taken by considering the farmer practice at Jimma area. Therefore, the treatments were arranged in 5 X 4 X 2 Factorial Randomized Incomplete Block Design (RIBD) (Rangaswamy, 1995) with three replications. All management practices, such as weeding; fertilizer application, insect pest and diseases control was done as per the general recommendations for green bean (Lemma, 2003).

Table 1.Total number of plants per hectare at each plant spacing

Plant Spacing	Number of plants per ha
50 cm X 7 cm	285,714
40 cm X 15 cm	166,666
40 cm X10 cm	250,000
40 cm X 7 cm	357,142
30 cm X15 cm	222,222

3.4. Field Plot Management

The plot size of the treatments varied depending on their different spacing used in the study. The total experimental area for a single replication was 35 m long and 8 m wide, which is $1925m^2$ and there were four planting rows per plot that were spaced differently as per the respective treatments. Spacing between plots, replication and intra- blocks were 0.5 m, 1 m and 0.5 m, respectively.

The field was ploughed three times by oxen and further hoeing was done at sowing time, before seedbed preparation. Then seeds were sown as per the treatment with a seed rate ranging from 16,333,333 to 77,857,143 per ha. DAP at the rate of 200kg/ha was applied during plating and Urea at a rate of 100kg/ha was applied to all the treatments 36 days after planting for all the treatments.

3.5. Data Collected

Data were collected pertaining to growth, yield and quality parameters throughout the experiment period. The details of data collection technique are described below.

3.5.1. Growth parameters

1. **Plant height (PH) (cm):-** Height of ten randomly selected plants was measured from the ground level to the tip part of plant during harvesting.
2. **Number of Days to 50% flowering**: - The actual count number of days from date of planting to date on which 50% of the plants in a plot produced flowers.
3. **Number of primary branches**: - The number of primary branches arising from the base of the stem counted from ten randomly selected plants.
4. **Tap Root Length (TRL) (cm):-** Tap Root length of ten randomly selected plants was measured from the crown of the plant to the final tip of root at the harvestable stage pods from each plot and the values were averaged.

5. **Root Volume (RV) (ml):-** Root volume of ten randomly selected plants was measured at final harvest by water displacement method.
6. **Leaf Area per Plant (LA) (cm^2/plant):-** Leaf area of ten randomly selected plants was measured using leaf area meter (ADC Bio scientific Ltd Area Meter AM 200, England) at final harvesting stage.
7. **Fresh Root Weight (RW) (g):** - The root weight of ten randomly selected plants was measured using a sensitive balance**.**
8. **Dry Weight of Shoot and Root (g): -** Ten sample plants were taken for determination of fresh and dry weight. After taking the fresh weight of roots and shoots, the samples were dried in an oven at 105^{o}C to a constant weight.

3.5.2. Yield parameters

9. **Total Pod Yield (kg/ha): -** Total weight of pods both marketable and unmarketable were determined from pods harvested from two rows of each plots.
10. **Marketable Pod Yield (kg/ha):-** Harvested pods were separated based on visual observations and pods which are free from insect damage, uniform in color and relatively larger size pod was considered as marketable and weighed.
11. **Unmarketable Pod Yield (kg/ha):-** Pods were separated based on visual observations of their physical appearance and those pods which are bleached, insect damaged, non-uniform color and relatively smaller in size was regarded as unmarketable and their weights determined.
12. **Total Number of Pods per Plot (NTPP):-** The average number of total pods per plot from randomly taken two rows of plants from each plot was recorded.

3.5.3. Pod character

13. **Pod Length (cm):-** The average length (cm) of ten randomly selected ripe fresh pods was taken randomly from ten plants per plot at first harvest.
14. **Pod Diameter (cm):-**The average pod diameter (cm) was measured at the maximum point of 10 randomly taken pods using a digital caliper (Fowler Us Patented USA).
15. **Number of Seeds per Pod (NSP):-** The number of seeds was counted from ten pods taken from the second and third nodes of five randomly selected plants in each plot and the values were averaged to arrive at mean seed number per pod.
16. **Average Individual Marketable Pod Weight (g):** This was recorded by taking ten pods randomly from the whole lot of marketable pods and measuring their weight using a sensitive balance
17. **Dry weight of pods (g): -** Pods from ten randomly selected plants were taken and put in the oven at 105^{o}C to dry to a constant weight.

3.5.4. Physical quality parameters

18. **Snapping Nature: -** Snapping nature of the pods was measured from ten randomly selected pods on the scale of 1-3 (1= Less snapping 2=Moderate and 3= Very-snapping)**.**
19. **Tenderness: -** The tenderness nature of ten randomly selected pods was measured on the scale of 1 to 3 (1= Less tender 2=Moderate and 3= Very tender (Firm)**.**
20. **Straightness: -** Straightness nature of ten randomly selected pods was measured based on 1 to 3 scale (1= Curved, 2= Slightly curved and 3 = Very straight)**.**
21. **Fibreless nature: -** Ten randomly selected pods was cut and checked for their fiberlessness. The result was recorded on the basis of 1 to 3 scale (1= Fibreless, 2= slightly fibrous and 3=Fibrous) (Lemma, 2003).

3.5.5. Disease scoring: - Incidence of diseases was recorded on bases of 1-9 scale. Rust, angular leaf spot and floury leaf spot incidence were scored based on (CIAT, 1981).

3.6. Data Analysis

The data were checked for normality and meeting all the assumptions for ANOVA and subjected to Analysis of Variance (ANOVA) and correlation using Genstat version 11 (VSN International, 2008) with the REML variance components analysis. When ANOVA showed significant differences, mean separation was carried out using LSD (Least Significant difference) test at 5% level of significance (Gomez and Gomez, 1984). All the figures and tables were generated by Excel computer program.

The model for the experiment was:-

Yijkl= µ+Ai +Bj +Ck+ ABij +ACik +BCjk +ABCijk +Єijkl

Where,

Yijkl= the response Measures for the ijklth observation

µ= the overall mean effect

Ai= the effect of the ith level of variety i= 1-2

Bj= the effect of the jth level of Spacing j= 1-5

Ck= the effect of the kth level of Sowing date k= 1-4

(AxB)ij= the effect of the interaction between variety and Spacing

(AxC)ik= the effect of the interaction between variety and Sowing date

(BxC)jk= the effect of the interaction between Spacing and Sowing date

(AxBxC)ijk= the effect of interaction among variety, Spacing and Sowing date

Єijkl= the random error computed for the whole factor

Lz= the effect of the zth replication z= 1-3

4. RESULTS AND DISCUSSION

4.1. Plant Growth Attributes of Green Bean

4.1.1. Plant height

Result pertaining to plant height at harvest showed no significant interaction effects among variety, sowing date and spacing, and also variety with spacing (Appendix 5). The result of this experiment indicated that variety interacted significantly with sowing date for plant height (Fig. 1 and Appendix 1). The maximum height was recorded from Melka-5 sown on 17th August followed by Melka-1 sown on same date. In contrast, the least plant height was scored from Melka-1 sown on 2nd August (Fig. 1). The possible reason for the observed increase in plant height of Melka-5 sown on 17th August could be due to the extended prevalence of sunlight during the growth period which might have stimulated more growth Melka-5 compared to other sowing dates. This result also agrees with the work of Singer *et al.* (1996) who reported maximum plant height at the warmest than the coolest environmental condition. However, this result also agrees with the work of Vieira *et al*. (1990) who reported that the depression of plant height could result from reduction of photosynthetic efficiency of a plant. It was also found that when Melka-5 sown on the appropriate sowing date resulted in superior plant height as compared to Melka-1, implying that genotypically Melka-5 is superior than Melka-1. This result is also in agreement with the work of Lemma *et al*. (2006) who reported that Melka-5 is superior in plant height than Melka-1. This result is also in coherence with the work of Uddin *et al.* (2007) who reported that interaction between planting time and genotypes on soybean varieties resulted in increased plant height in December planting as compared to November planting. The author associated this with the increased temperature intercepted by the genotypes sowed in December planting during its life time. Schench and Smith (1982) as cited in Uddin *et al.* (2007) however, found little effect of soil temperature on plant height of soybean.

However, the current result is in contradiction with the work of Uslu (1998) who reported that plant height decrease significantly due to delayed sowing. The author also reported that there was a difference of more than 5 cm in plant height between late July and late August sowings. These decreases in plant height could be attributed to a shorter vegetative period. The present result also disagrees with the works of Yoldas and Esiyok (2007) who reported that early sowing produced greater plant height than late sowing. The current finding is also in contradiction with the work of Uslu and Esendel (1996) who reported that plant height decreased significantly as a result of delayed sowings. They reported a difference of more than 10 cm between early-May and early-June 1993 sowings. This decrease in the plant height was attributed to a shorter vegetative period and low canopy competition among the plants at the late sowings.

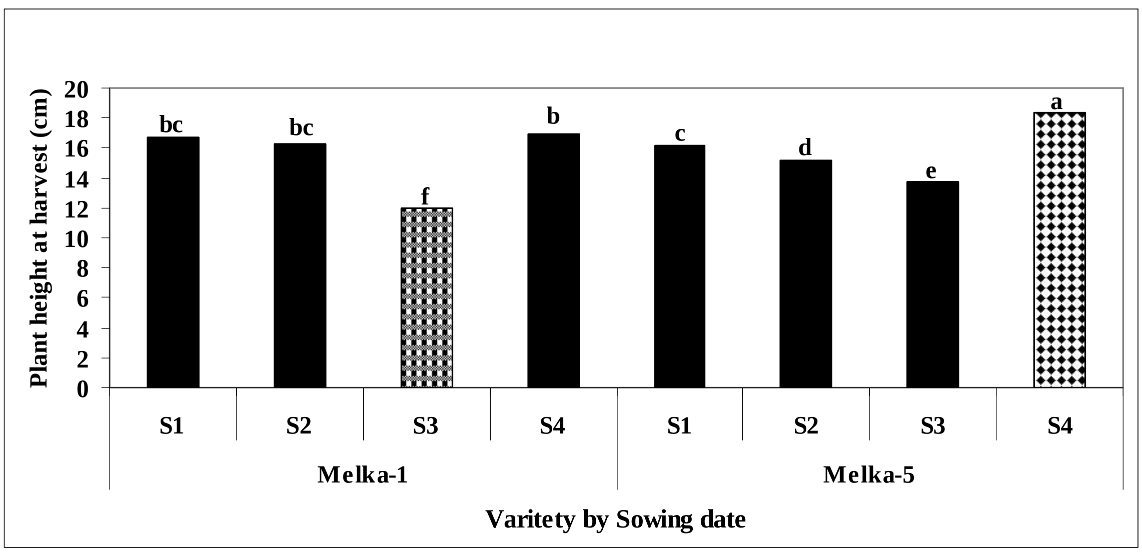

Figure 1. Interaction effect of variety by sowing date on plant height of green bean.

Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (0.673) S1= 3rd July, S_2= 18th July, S_3=2nd August and S_4= 17th August

4.1.2. Days to 50% flowering

The result of this experiment with respect to days to 50% flowering showed non-significant interaction effects among variety, sowing date and spacing (Appendix 5). However, there were a significant ($P \leq 0.05$) interaction effects between variety and sowing date (Fig. 2) and varieties with spacing (Table 2) and (Appendix 5). The late numbers of days to 50% of flowering was recorded for both cultivar Melka-1 and Melka-5 sown on 2nd August whereas the earliest number of days to 50% flowering was recorded for Melka-1 sown on 18th July and for Melka-5 sown on 18th July respectively (Fig. 2 and Appendix 1). The observed difference could be due to high rainfall (water) and less sunlight period that might have lead to production of more vegetative parts rather than reproductive parts as a result of sowing in 18th July. This result agrees with the works of Ndegwa *et al*. (2001) that showed in Kenya all the snap bean varieties flowered in the range of 41 to 43 days in the long rainy season whereas in the late season the snap bean varieties flowered within 39 to 41 days. Similarly, Marlene *et al*. (2008) reported that the snap bean crop with an early planting took more number of days to flower and mature than in the other planting seasons. However, earliest flowering snap bean was observed when it was planted in the late planting season (23rd July) while delayed flowering was observed in snap beans planted in the normal or summer planting season (13th June), hastening its development. This was attributed to the fact that the existence of extreme cold and warm temperature in the early and late planting season respectively. However, this result disagree with the works of Calvino *et al.*(2003a) that reported delayed sowing shortened the length of the growing season mostly by reducing the duration of late reproductive phase. This result is also in-agreement with the work of Anisa *et al.* (1995) who reported higher number of flowers due to earlier sowing date as compared with that of late sowing date.

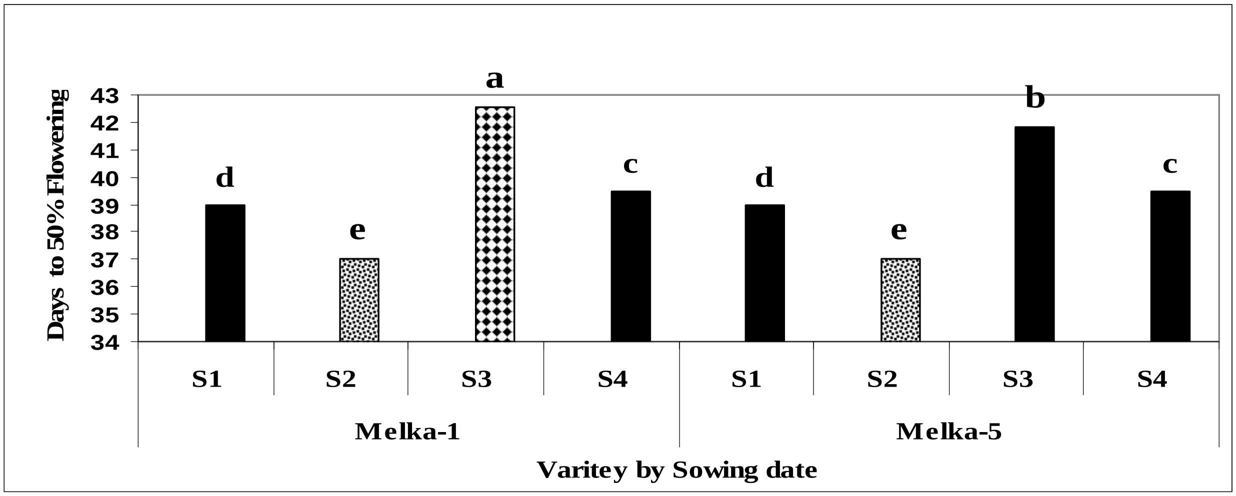

Figure 2. Interaction effect of variety and sowing date on days to 50% flowering of green bean. Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (0.128) S1= 3rd July, S_2= 18th July, S_3=2nd August and S_4= 17th August

Moreover, there was significant (P≤0.05) interaction effect between variety and spacing on days to 50% flowering of green bean (Table 2 and Appendix 2). Accordingly, the longest number of days to 50% flowering was recorded for Melka-1 sown at the spacing of 40 cm x 10 cm. This value was also found to be statically similar with Melka-1 sown at 40 cm x 15 cm and Melka-5 sown at the spacing of 40 cm x 15 cm and the least number of days to 50% flowering was recorded on variety Melka-5 sown at the spacing of 40 cm x 7 cm. This could be probably be due to the fact that at lower density there is a less competition between plants for water, nutrients, and minerals that led to the development of vegetative parts rather than forming reproductive parts. This result is in-agreement with Samih (2008) who reported that beans planted at the lower planting densities required more number of days for blooming (flowering). This could be related to the supportive effects of more availability of nutrients to the planting densities because they have less number of plants per unit area, which permitted the building of more vigorous growth that resulted in more number of days for flowering. The difference in the days to flowering between the two varieties could be probably due to the genetic make-up of the two varieties.

Table 2. Interaction effect of plant spacing and varieties on days to 50% flowering of green bean

Variety	Plant Spacing					Mean	CV (%)	LSD (5%)
	50cmx7cm	40cmx15cm	40cmx10cm	40cmx7cm	30cmx15cm			
Melka-1	39.50[bc]	39.59[ab]	39.67[a]	39.50[bc]	39.25[d]	39.5	0.41	0.160
Melka-5	39.25[d]	39.58[ac]	39.25[d]	39.08[e]	39.43[c]	39.3		
Mean	39.36	39.56	39.46	39.29	39.34	39.4		

Means followed by the same letter(s) are not significantly different at P≤0.05 as established by LSD-test (0.160)

4.1.3. Number of primary branches

There was no a significant interaction effect obtained among variety, sowing date and spacing with respect to the number of primary branches per plant. Nevertheless, the number of primary branches was significantly (P≤0.05) influenced by the interaction between variety and sowing date (Fig. 3 and Appendix 1). Hence, more number of primary branches was observed from Melka-1 sown on the 18th of July followed by Melka-1 sown on the first sowing date (3rd July) whilst, the least number of primary branches was registered from Melka-5 sown on 17th August. The apparent discrepancy in the number of primary branches between early and late sowing dates could be attributed to the difference in moisture content of the soil; early sowing leading to more moisture availability than late sowing and thus affecting vegetative growth including primary branch development. On the other hand, the difference between the two varieties in terms of primary branch production is probably due to their genetic makeup. This outcome is in conformity with the works of Yusufali *et al.* (2006) who reported more number of primary branches with an early sowing than late sowing of field beans in Karnataka in southern India. This finding is also in accordance with the report of Uddin *et al.* (2007) who observed the number of branches per plant in soybean varieties increased in November planting as compared to December planting.

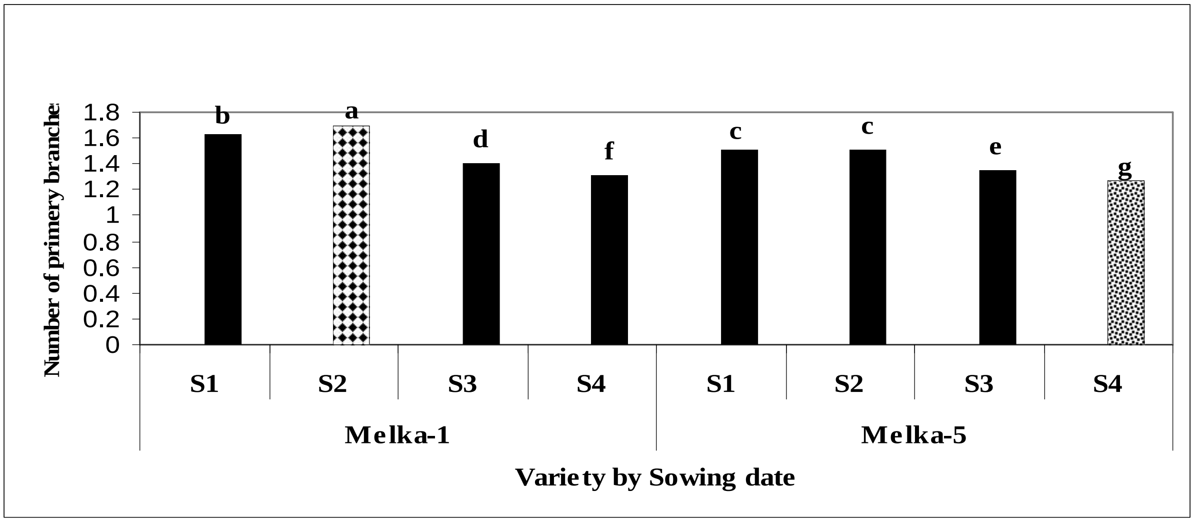

Figure 3. Interaction effect of sowing date and variety on number of primary branches of green bean. Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (0.027) S1= 3rd July, S_2= 18th July, S_3=2nd August and S_4= 17th August

Beans established at different spacing significantly (P≤0.05) differed in terms of their number of primary branches (Table 3). The number of primary branches per plant was significantly affected by plant spacing. Significantly more number of branches was counted from plants spaced at 30 cm by 15 cm followed by plants spaced at 40 cm x 7cm and 40 cm x 10 cm while the least number of branches was recorded from plants established at 50 cm x 7cm. The possible reason could probably be due to the lower competition between plants under the lower density planting for different resources that are essential for the growth and development, where as in the high density wherein competition would be sever between plants which concomitantly might have lead to the production of less number of primary branches. A similar finding was reported by Lucas and Milbourn (1976) who reported that number of branches per plant generally decreased with increasing density due to the occurrence of high competition between plants. This result is also in agreement with the work of Pawar *et al.* (2007) who reported that the number of branches per plant increased with increasing of intra row spacing.

Table 3. Effect of plant spacing on number of primary branches of green bean plants

Spacing	Number of primary branches
50cmx7cm	2.07 (1.43[c])
40cmx15cm	2.10 (1.44[c])
40cmx10cm	2.15 (1.46[b])
40cmx7cm	2.15 (1.46[b)]
30cmx15cm	2.27 (1.49[a])
Mean	2.15 (1.46)
CV (%)	2.39 (1.22)
LSD (5%)	0.05 (0.018)

Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (0.018)**.** *Numbers in the bracket are transformed value in Arcsine*.

4.1.4. Tap root length

With regards to tap root length, the findings of the present study depict that there was no significant interaction effect among variety, spacing and sowing date (Appendix 5). However, there was a significant (P≤0.05) interaction effect between variety and spacing with respect to the tap root length of plants (Appendix 5). Accordingly, the longest tap root was observed from plants of the variety Melka-1 sown at 40 cm x 7 cm, the value of which was statically similar with the result from sowing of Melka-1 sown at a spacing of 40 cm x 10 cm and 30 cm x15 cm. By contrast, the shortest tap root was obtained from plants of the variety Melka-5 established at a spacing of 40 cm x 10 cm (Table 4 and Appendix 2). The observed increase in tap root length in Melka-1 that was planted at different spacing combinations could probably be a response of the variety. Moreover, the maximum tap root length achieved at 40 cm x 7 cm might have created high competition between plants for water, minerals and other resources and the growth and developments of plants at this situation makes the plants to produce longer tap roots running in search of water and other resources.

Table 4. Interaction effect of plant spacing and variety on tap root length of green bean plants

Variety	Plant Spacing					Mean	CV (%)	LSD (5%)
	50cmx7cm	40cmx15cm	40cmx10cm	40cmx7cm	30cmx15cm			
Melka-1	13.62[bc]	12.63[de]	13.88[ab]	14.34[a]	14.01[ab]	13.69	4.75	0.631
Melka-5	12.41[e]	13.39[bc]	11.69[f]	13.59[bc]	13.21[cd]	12.86		
Mean	13.01	13.01	12.79	13.97	13.61	13.28		

Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (0.631)

As depicted in Table 5, sowing green beans on different sowing dates irrespective of variety and spacing imparted significant (P≤ 0.05) differences with regard to the tap root length of plants. As a result, the maximum mean tap root length was found from plants sown on the 18th of July followed by those sown on the 3rd of July whereas, the shortest was registered from sowing on the 17th of August. The highest intensity of rainfall at the study site was observed to be during the month of July and decreased in August. Consequently, the roots of plants from June sowing could get sufficient moisture within their reach and hence didn't develop long tap root to search for moisture. Notably, the shortest tap root length was recorded for late sowing (17th August) which vividly experienced a limited amount of rainfall. This result is in agreement with the work of Talal and Ghalibe (2006) who reported that sowing of faba bean at the early sowing date results in more root growth than sowing at the later sowing date.

Table 5. Effect of sowing date on tap root length of green bean plants

Sowing date	Tap Root Length (cm)
3rd July	13.85[b]
18th July	16.22[a]
2nd August	12.62[c]
17th August	10.42[d]
Mean	13.29
CV (%)	1.91
LSD (5%)	0.254

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ as established by LSD- test (0.254)

4.1.5. Root volume

The analysis of variance for root volume revealed that there was no significant interaction effect among variety, sowing date and spacing, and also between variety and spacing (Appendix 5). However, variety combined with sowing dates significantly ($P \leq 0.05$) affected the root volume of plants (Table 6 and Appendix 1). The maximum root volume was recorded from variety Melka-1 sown on the 3rd of July followed by variety Melka-5 sown on the 18th of July. In contrast, the minimum root volume was scored from Melka-1 sown on the 17th of August, which of course was statically at par with variety Melaka-5 established on the same date. Plants established earlier (3rd July) received more rainfall as compared to late sown ones (17th August) and hence the later might have suffered from shortage of moisture and extended sunlight period which altogether might have induced the production short and few number of fibrous roots by the crops.

Table 6. Interaction effect of sowing date and variety on root volume of green bean plants

Variety	Sowing Date				Mean	CV (%)	LSD (5%)
	3rd July	18th July	2nd August	17th August			
Melka-1	1.3680[a]	0.9814[b]	0.8980[c]	0.4727[d]	0.93	8.61	0.076
Melka-5	0.9585[bc]	0.9847[b]	0.9279[bc]	0.4983[d]	0.84		
Mean	1.16	0.98	0.91	0.48	0.88		

Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (0.076)

4.1.6. Leaf area

The result of this experiment on the total leaf area per plant showed that there was no significant three way interaction effect among variety, sowing date and spacing (Appendix 5). However, there was significant (P≤0.05) interaction effect between variety and sowing date on total leaf area. In addition, there was significant (P≤0.05) main effect of spacing on the total leaf area of green bean (Table 7). The data depicted in Fig. 4 and Appendix 1 shows that the maximum leaf area was observed from Melka-5 sown on 2nd August followed by Melka-1 sown on July 3rd; whereas the lowest leaf area was observed from Melka-1 sown on 17th August and Melka-5 sown on 18th July, respectively. This result is in-agreement with the work of Singer *et al.* (1996) who reported that higher leaf area was recorded for late sowing than early sowing of green bean.

.

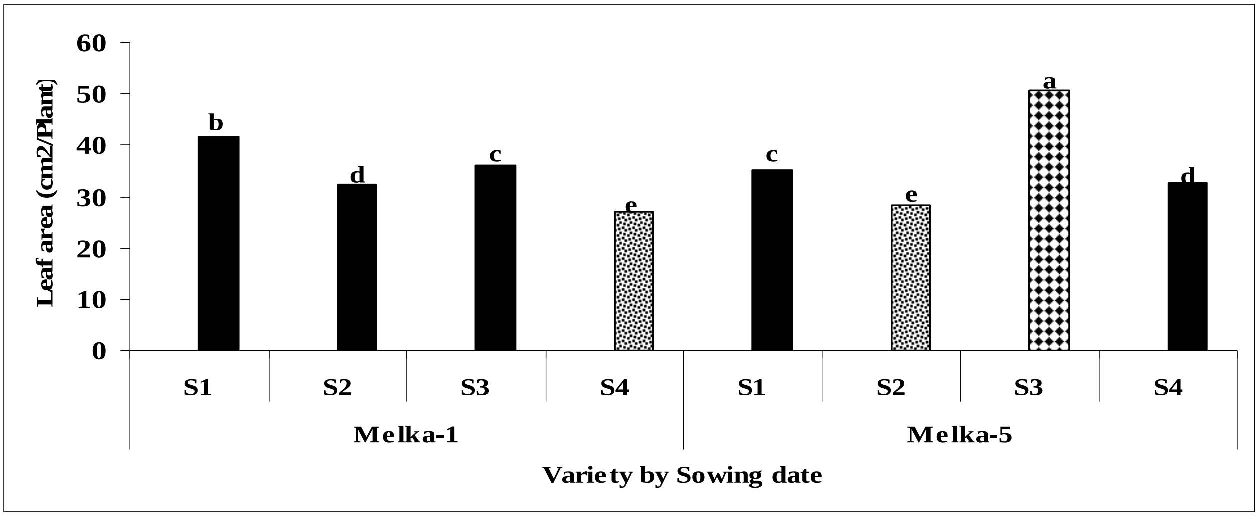

Figure 4. Interaction effect of variety with sowing date on leaf area of green bean.

Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (2.329) S1= 3rd July, S_2= 18th July, S_3=2nd August and S_4= 17th August

As pointed in Table 7, irrespective of the sowing date and variety used different, spacing of plants significantly (P≤ 0.05) affected leaf area per plant. The highest leaf area was observed from plants spaced at 40 cm x 7 cm. In contrast, the lowest leaf area was scored on plants spaced at 40 cm x 15 cm which, however, was statistically at par with the values registered from plants spaced at 40 cm x 10 cm and 30 cm x 15 cm. This result is in agreement with the work of Jadoski *et al.* (2000) who reported increased leaf area of individual plants as plant population decreased. This result also agrees with the works of Zhou *et al.* (2011) who reported that competition between plants varied from spacing to spacing; wherein soybean plants planted in narrow rows spacing attained high light capture than in wider rows spacing. This result is also in conformity with the works of Gardineri *et al.* (1978) who reported that higher percentage of PAR (Pohtosentitically Active Radiation) interception of bush cultivar was higher when bush cultivars were planted at narrow row spacing (45.5cm) than that of wider row spacing (9lcm) irrespective of sowing dates.

Table 7. Effect of plant spacing on leaf area of green bean

Spacing	Leaf Area (cm^2/plant)
50cmx7cm	36.89^{b}
40cmx15cm	34.25^{c}
40cmx10cm	33.18^{c}
40cmx7cm	38.44^{a}
30cmx15cm	34.63^{c}
Mean	35.478
CV (%)	4.13
LSD (5%)	1.465

Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (1.465)

4.1.7. Fresh root weight

The result of this experiment showed that there was no significant interaction effect observed among variety, sowing date and spacing on the root fresh weight (Appendix 5). However, there was significant (P≤ 0.05) interaction effect between variety and sowing date and spacing with sowing date on the root fresh weight of plant (Appendix 5). The highest root fresh weight was observed from Melka-1 sown on the 3rd July, which was 89.59 percent more than the lowest fresh root weight that was observed from Melka-1 sown on 17th August and Melka-5 on 17th August (Fig. 5 and Appendix 1). The observed difference in terms of root fresh weight could be probably due to the fact that at this sowing there is less rainfall received after planting on 17th August and exposure of the plants to more sunlight as compared to the other sowing dates which all together resulted in plants that produced less vegetative part; less fibrous root with less fresh root weight. On the other hand, the difference between the two varieties could be attributed to their genetic makeup. Even though, literatures that support this finding were not found on snap bean and other related phaseolus species, Alem *et al.* (2010) reported similar result in radish that fresh root weight was significantly higher in early sowing than late sowing in Bangladesh.

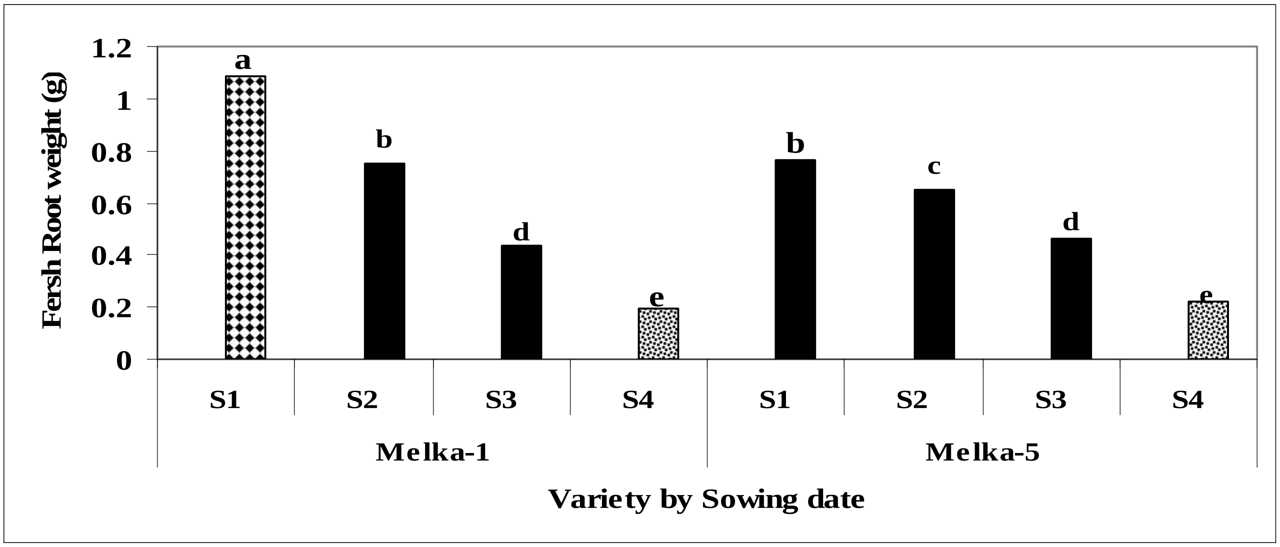

Figure 5. Interaction effects of variety with sowing date on fresh root weight of green bean. Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ as established by LSD- test (0.075) S1= 3rd July, S_2= 18th July, S_3=2nd August and S_4= 17th August

As illustrated in Table 8, sowing of green beans on different dates and at different spacing resulted in significant ($P \leq 0.05$) differences in respect of root fresh weight of plants. As a result, the highest root fresh weight was found on a plot of beans sown on the 3rd of July at a spacing of 40cmx15cm, which was statistically at par with sowing of green beans on same date but at a spacing of 40 cm x 7 cm and 30 cm x 15 cm. On the contrary, the lowest root fresh weight was recorded from plots sown with beans on the 17th of August at spacing of 40 cm x 10 cm. This was again statically similar with the values recorded with sowing at all remaining spacing treatments (50 cm x 7 cm, 40 cm x 15 cm, 40 cm x 7 cm, 30 cm x 15 cm). The availability of sufficient moisture in the soil following the sowing of beans earlier (3rd July) and at the optimum spacing (40 cm x 15 cm, 40 cm x 7 cm and 30 cm x 15 cm) might have favored maximum vegetative growth including root development. The condition gets so sever when planting is too late or too early. Under low density, plants could get the essential resources easily thus resulting in the development of high root fresh weight.

Table 8. Interaction effect of plant spacing and sowing date on root fresh weight of green bean plants

Spacing	Sowing date	Root Fresh Weight (gm)
50cmx7cm	3rd July	0.608 bcd
	18th July	0.690 b
	2nd August	0.496 cde
	17th August	0.200 f
40cmx15cm	3rd July	1.186 a
	18th July	0.732 b
	2nd August	0.345 ef
	17th August	0.211 f
40cmx10cm	3rd July	0.721 b
	18th July	0.708 b
	2nd August	0.433 de
	17th August	0.179 f
40cmx7cm	3rd July	1.004 a
	18th July	0.707 b
	2nd August	0.478 de
	17th August	0.208 f
30cmx15cm	3rd July	1.108 a
	18th July	0.679 bc
	2nd August	0.492 cde
	17th August	0.241 f
Mean		0.57
CV (%)		28.51
LSD (5%)		0.163

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ as established by LSD- test (0.163)

4.1.8. Dry weight of shoot and root

The three-way interaction between variety, sowing date and spacing was non-significant (Appendix 5). The two-way interaction between variety with sowing date and variety with spacing were also non-significant. However, the performance of green bean in terms dry weight of shoot and root was significantly (P<0.05) influenced by the interaction effects of spacing and sowing date (Fig.6 and Appendix 3). The maximum dry weight of shoot and root was obtained as a result of sowing green beans at a spacing of 30 cm x 15 cm on the 3rd of July and this value was statically similar with the dry weight registered due to the combined effect of sowing at 40 cm x 15 cm and the 3rd of July and sowing green beans at a spacing of 40 cm x 7 cm on the 3rd of July. On the other hand, the minimum dry weight of shoot and root was observed owing to the interaction effect between sowing plants at 40 cm x 10 cm and fixing the sowing date on the 17th of August (Fig. 6). This however, was found to be statistically comparable with the effect of sowing on the 17th of August with the rest spacing. This could probably be due to the fact that wider spacing allowed the crop to have less competition for essential soil resources, which might have contributed to better growth and development of the crop that led to the production of more shoot and root. On the other hand, the competition between plants for resources created by narrow spacing might have triggered early establishment, which resulted in more root and shoot growth and development. The importance of early sowing date for higher plant, root and pod dry matter accumulation could be attributed to the availability of adequate amount of moisture during the growing period which resulted in more shoot and root production unlike that of late sowing. These results are in agreement with the findings of Pawar *et al.* (2007) who reported increased dry weight of green beans in response to increased row spacing. This result is also in line with the report of Uddin *et al*. (2007) who reported higher dry weight of shoot and root of soybean plants following December planting as compared to November planting; clearly indicating the effect of different sowing dates on dry matter accumulation.

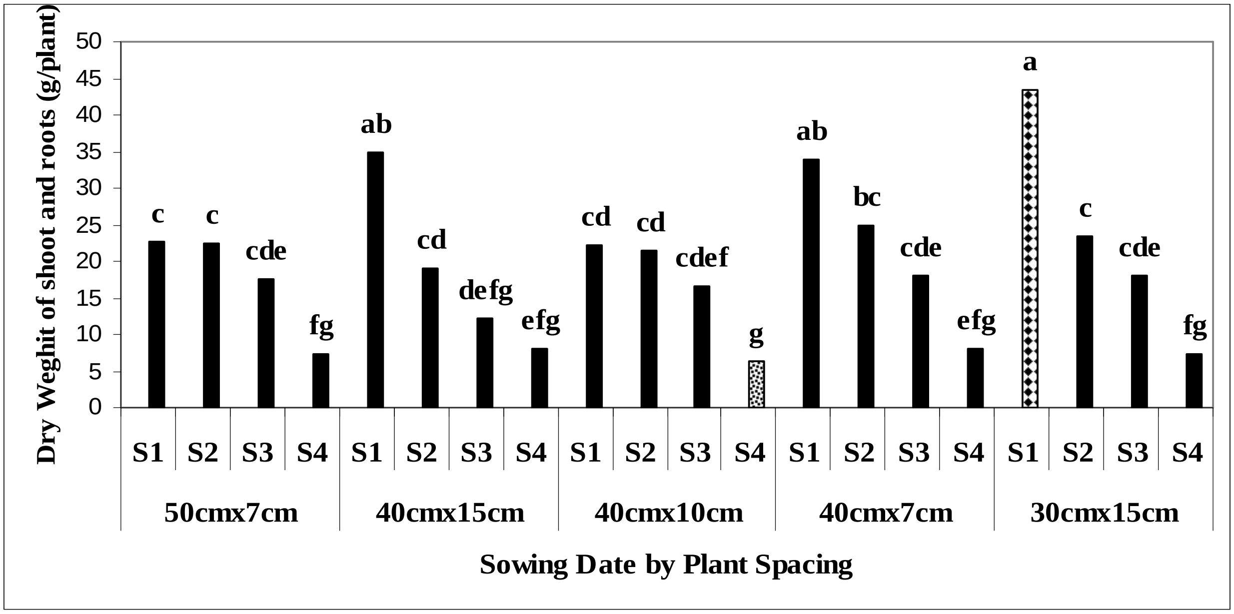

Figure 6. Interaction effects of plant spacing and sowing date on dry weight of shoot and root of green beans. Means followed by the same letter(s) are not significantly different at P$\leq$ 0.05 as established by LSD- test (6.132) S1= 3rd July, S_2= 18th July, S_3=2nd August and S_4= 17th August

4.2. Yield Attributes of Green bean

4.2.1. Total pod yield

Based on the analysis variance, the total pod yield of green beans was not significantly affected due to interaction among variety, sowing date and spacing (Appendix 5). Similarly, the interaction effects between spacing and variety and sowing date with variety did not significantly affect the total pod yield of green beans (Appendix 5). Nonetheless, sowing date, spacing and variety significantly ($P \leq 0.05$) affected the total pod yield of green bean (Appendix 5). The total pod yield (kg/ha) was significantly ($P \leq 0.05$) affected by the different sowing dates (Table 10). Thus the highest total pod yield (kg/ha) was obtained due to sowing on the 3rd of July which, however, was statistically comparable with sowing on the 18th of July. Conversely, the lowest total pod yield was registered from sowing the beans late, the 17th of August. This was probably because of the limited vegetative growth of plants from the late sowing as a result of the limited photosynthates available. This in turn was attributed to the short rains associated with late sowing. This result is in concurrence with the works of Yoldas and Esiyok (2007) that revealed decreased yield due to a short vegetation period of the crop sown late and the maximum growth and yield was obtained by sowing of beans on July. Furthermore, this result is in agreement with the finding of Marlene *et al.* (2008) who reported that the lower pod yield in the late planting season was due to a smaller biomass production from a shorter vegetative growth period and moreover, the decline in pod production may simply result from declining flower production as vegetative growth ceases. Late sowing has negative consequences on yield because the reproductive stage occurs when weather conditions are less favorable. The reproductive period of common bean plants coincide with the highest summer temperatures and this cause abscission of many buds and flowers that results in a significant decrease in productivity.

The result presented in Table 9 depicts that the effect of different spacing treatments on the total pod yield (kg/ha) that was significant at ($P \leq 0.05$). Among the different spacing treatments, plant spacing at 40 cm x 7 cm resulted in the highest total pod yield. Conversely, the lowest total pod yield was obtained from a green bean spaced at 40 cm x

10 cm. There was a difference of 49.43 percent total pod yield between the maximum and the minimum and this is was perhaps due to the large number of plants per unit area under narrower spacing which limited the unnecessary vegetative growth and favored setting of more pods. These findings are in accordance with the findings of Samih (2008) who reported superior yield in the case of high plant populations over that of low densities. This could be attributed to the less sever competition among plants for nutrients and other resources under the context of less number of plants per unit area. Likewise, this result is in harmony with the findings of Cutcliffe (1967) who reported yield of green beans increased at the narrow spacing than the wider. Wahab (1986) also stated that higher planting densities of green bean gave higher pod yields per unit area than that of lower planting density.

Table 9. Effect of plant spacing on total pod yield (kg/ha) and total marketable pod yield (kg/ha), of green beans

Plant Spacing	Parameters	
	TPY (kg/ha)	TMPY (kg/ha)
50cmx7cm	4456^{b}	2531^{c}
40cmx15cm	4362^{b}	2574^{c}
40cmx10cm	3866^{c}	2367^{c}
40cmx7cm	5777^{a}	3473^{a}
30cmx15cm	4817^{b}	2990^{b}
Mean	4655.6	2787
CV (%)	17.46	18.69
LSD (5%)	813.033	520.992

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ as established by LSD- test (813.033 and 520.992)

Table 10. Effect of sowing date on total pod yield (kg/ha), total marketable pod yield (kg/ha), total unmarketable pod yield (kg/ha) and number of seed per pods of green beans

Sowing date	TPY (kg/ha)	TMPY (kg/ha)	TUMPY (kg/ha)
3rd July	7182[a]	4326[a]	2968[a]
18th July	7000[a]	3965[b]	3005[a]
2nd August	2621[b]	1950[c]	897[b]
17th August	1818[c]	906[d]	899[b]
Mean	4655.25	2786.75	1942.25
CV (%)	15.33	16.58	15.92
LSD (5%)	712.215	462.070	309.190

Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (712.215, 462.070 and 309.190)

The effect of varieties on the yield of green beans is presented in Table 11. The total pod yield was found to be significantly (P≤ 0.05) affected by different varieties. The highest total pod yield was obtained from the variety Melka-5 whereas the lowest total pod yield was obtained from Melka-1. The difference between the two varieties used for the study in respect of total pod yield could mainly be due to the genetic makeup of the varieties. The outcome of this study is in agreement with that of Lemma *et al.* (2006) who have already reported a difference in yield between the two varieties of green beans owing to their genetic makeup. The two varieties also manifest differences in respect of earliness and vegetative growth. This result is also in conformity with the findings of Marlene *et al.* (2008) cultivars with long vegetative growth duration had generally higher fresh pod yields than those with short vegetative growth duration in the early and normal planting seasons.

Table 11. Effect of variety on total pod yield (kg/ha), total unmarketable pod yield (kg/ha), dry weight of shoot and root (g/plant) and dry weight of pod (g/plant)

Variety	Total Pod Yield (kg/ha)	Total Unmarketable Pod Yield (kg/ha)	Dry Weight of Shoot and Root (g/plant)
Melaka-1	4323[b]	1712[b]	22.70[a]
Melaka-5	4988[a]	2173[a]	17.10[b]
Mean	4655.5	1942.5	19.9
CV (%)	10.986	11.24	11.04
LSD (5%)	511.560	218.418	2.196

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ as established by LSD- test (511.560, 218.418 and 2.196)

4.2.2. Total marketable pod yield

There was non significant interaction effect either among variety, spacing and sowing treatments or between spacing and variety or sowing date and variety for total marketable pod yield. Furthermore, there was no main effect of varieties on the total marketable pod yield of green bean plants However, results presented in Table 10, pertaining to total marketable pod yield reveal that the effect of different sowing dates was significant ($P \leq 0.05$) (Appendix 5). It is also apparent that among the different sowing dates, sowing on the 3rd of July resulted in the highest total marketable pod yield followed by July 18th whilst, the lowest total marketable pod yield was registered from sowing of green beans on the 17th of August. The highest total marketable pod yield observed during the earliest sowing date (July 3) perhaps emanated from the extend period of rainfall that resulted in better vegetative growth which in turn enables the crop to produce greater photo assimilate in the pod; the sink of the plant. This result is in harmony with the findings of Yoldas and Esiyok (2007) wherein the lowest yield was noted during late sowing owing to a short vegetation period of the crop. Moreover the outcome of this study corroborates with the works of Yan-sheng *et al.* (2010) who, based on their study in Northeastern USA, noticed the highest marketable pod yield of soybean as a result of sowing on July 5 and the lowest on May 22. The decline in marketable yield of vegetable soybean with delayed sowing was substantiated with a shorter season length leading to overall reduction in growth, short days associated with low radiation and low temperature contributing to slower growth rates and lower pod set, and a dramatic reduction on the relative duration of key phonological stages which mostly resulted from reduced photoperiod. In another yet a similar study, Radulovich (1990) mentioned that reduction of yield from late sowing could be due to exposing the plants to a high moisture stress from the period of pod setting (development) up to the final pod harvest. Similarly, in conformity with the result of the present study, Laurie *et al.* (2004) mentioned that the growth and yield of snap bean were significantly affected by sowing dates. However, their findings declared that midseason sowing tended to result in more vigorous plants and more total and marketable snap beans than earlier or later sowing when heat and soil moisture stress resulted in flower abortion and pod abscission.

The influence of spacing on the total marketable pod yield of green beans was significantly different ($P \leq 0.05$) (Table 9). Among the different spacing, 40 cm x 7 cm resulted in the highest total marketable pod yield per hectare. Conversely, the lowest total marketable pod yield was obtained from a green beans spaced at 50 cm x 7 cm which was statically at par with the marketable yield obtained from a spacing of 40 cm x 15 cm and 40 cm x 10 cm. This result is in agreement with the findings of Tyson and Kostewicz (1986) who found that marketable pod yield of snap beans increased linearly as the spacing was reduced in different sowing date.

4.2.3. Total unmarketable pod yield

The result indicted in Fig. 7 reveals that the effect of different spacing treatments on the total unmarketable pod yield was significant ($P \leq 0.05$). Furthermore, the mean separation clearly showed that the plant spacing 40 cm x 7 cm resulted in the highest total unmarketable pod yield. Quite the reverse, the lowest total unmarketable pod yield was obtained from as a result of establishing green beans at 40 cm x 15 cm which produced statistically alike result with sowing of the green beans at 30 cm x 15 cm. The probable reason for the increment of yield under narrow spacing could be associated with the large number of plants per unit area that gave rise to high yield wherein the majority of pods were unmarketable due to poor quality size of pod. The result from the present investigation is in coherence with the findings put forward by Samih (2008) wherein superior yield was obtained from plants of high populations over that of low plant populations. The author explained the observed outcome as the reflection of the lower competition for nutrients among few numbers of plants per unit area.

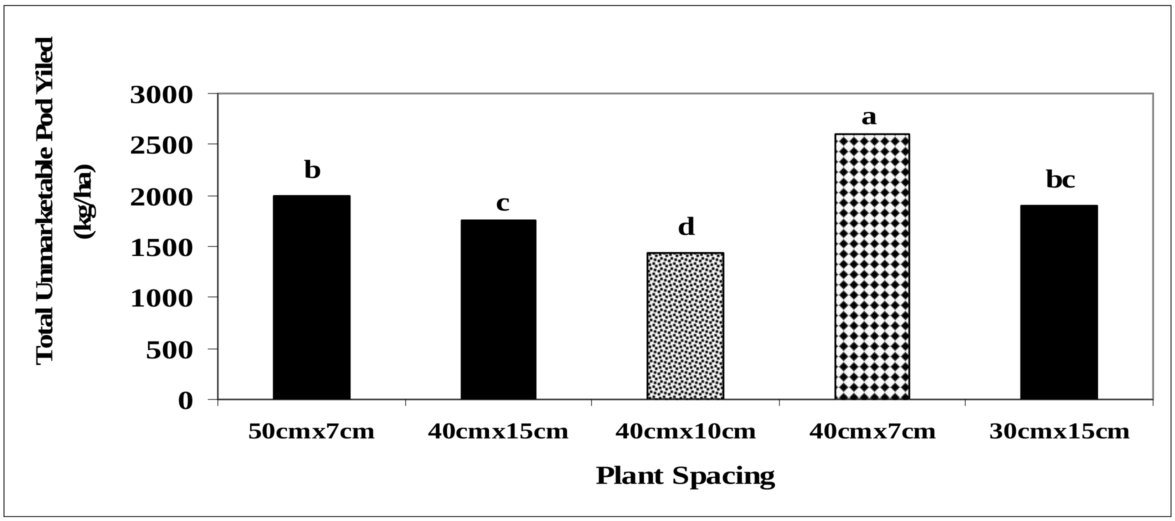

Figure 7. Effects of plant spacing on total unmarketable pod yield (kg/ha) of green bean. Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (345.210)

Sowing date produced a significant (P≤0.05) effect on the total unmarketable pod yield (Table 10). Among the different dates of sowing, 18th of July resulted in the highest total unmarketable pod yield which of course was statistically identical with the effect of sowing on the 3rd of July. On the other hand sowing on the 2nd of August registered the lowest total unmarketable pod yield which again was statistically at par with the result of sowing on the 17th of August. The possible reason for the increment of total unmarketable yield on the first and second sowing dates is probably due to exaggerated high unmarketable yield as a proportion of the total pod yields which obviously is much higher as compared to the other sowing dates.

The main effect of variety on the total unmarketable pod yield was also significant ($P \leq 0.05$), (Table 11). From the two varieties tested, the highest total unmarketable pod yield was obtained from Melka-5. The possible reason for the observed difference between the two varieties green beans with regard to unmarketable pod yield is genetic makeup.

When considering the proportion of the total marketable and unmarketable pod yield to total yield (Table 12), sowing on the 2nd of August produced 1950kg/ha of the total pod of which 76.71% as marketable and the remaining 23.29% as unmarketable pod while sowing on the 17th of August resulted 906kg/ha of pod yield of which 49.51% was marketable whereas the rest 50.31% was unmarketable pod.

Table 12. Total percentage of marketable and unmarketable pod yield of green bean as affected by different sowing dates

Sowing date	Marketable Pod Yield (%)	Unmarketable Pod Yield (%)
3rd July	60.77[b]	39.99[b]
18th July	56.98[bc]	43.02[ab]
2nd August	76.71[a]	23.29[c]
17th August	49.51[c]	50.31[a]
Mean	60.99	39.152
CV (%)	10.62	12.99
LSD (5%)	6.475	5.087

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ as established by LSD- test (6.475 and 5.087)

Table 13. Total percentage of marketable and unmarketable pod yield of green bean as affected by different spacing

Spacing	Parameters	
	Marketable pod Yield (%)	Unmarketable pod Yield (%)
50cmx7cm	56.00[c]	44.00[a]
40cmx15cm	62.07[ab]	37.93[b]
40cmx10cm	58.38[bc]	41.62[a]
40cmx7cm	65.00[a]	35.00[b]
30cmx15cm	63.52[a]	36.48[b]
Mean	60.99	39.01
CV (%)	11.87	14.58
LSD (5%)	7.238	5.688

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$. as established by LSD- test (7.238 and 5.688)

The effect of spacing on the total marketable and unmarketable pod yield as percentage of the total pod yield is given in Table 13. Sowing of green beans at the spacing of 40cmx7cm resulted in the highest total pod yield of 5777kg/ha of which 65% is marketable pod and the rest 35% is unmarketable while sowing of green beans at the spacing of 50cmx7cm resulted in the lowest total pod yield of 4456kg/ha of which 56% is marketable and the rest 44% is unmarketable.

4.2.4. Total number of pods per plot

The result of this experiment revealed that there was no significant ($P>0.05$) interaction effect among variety, spacing and sowing date on the total number of pods per plot. However, there were significant ($P \leq 0.05$) interaction effects between varieties and sowing date and spacing with sowing date (Appendix 5). Accordingly, the highest number of pods per plot was obtained from plants of the variety Melka-5 sown on the 3rd of July whereas the lowest was registered Melka-5 sown on the 17th of August (Table 14). Sowing seeds of adaptable varieties earlier in the season supports proper development of vegetative parts and production more number of pods per plot. The difference between the two varieties used in the present study could imply that, owing to its genetic makeup, Melka-5 is more adaptable and productive under Jimma condition than is Melka-1. This result concurs that of Escalante *et al.* (1989) who likewise noted a significant difference between sowing dates; wherein earlier sowing gave rise to more number of pods than late sowing. Moreover, the finding is consistent with the observations of Ismail and Khalifa (1987) in which case the number of pods of soybean decreased with delayed sowing. They further accounted the difference to the decrease in day length and moisture following late sowing. The difference between the two varieties in terms of the number of pods per plant is perhaps linked with the intrinsic characteristic of them in responding to variations in temperature and availability of moisture and nutrient arising from sowing on different dates in the year.

Table 14. Interaction effect of variety and sowing date on total number of pod per plot of green beans

Variety	Sowing Date				Mean	CV (%)	LSD (5%)
	3rd July	18th July	2nd August	17th August			
Melka-1	422.4[c]	396.4[c]	239.5[e]	193.4[f]	312.93	14.94	50.838
Melka-5	539.7[a]	478.9[b]	304.6[d]	146.9[g]	367.53		
Mean	481.05	437.65	272.05	170.15	340.3		

Means followed by the same letter(s) are not significantly different at P≤0.05 as established by LSD- test (50.838)

As presented in Fig. 8 and Appendix 9, the highest total number of pods of green bean per plot was recorded as a result of sowing at a spacing of 40 cm x 15 cm on the 3rd of July. However, this is value was statically at par the combined effect of spacing at 30 cm x 15 cm and sowing on the 3rd of July and 18th of July, respectively. On the contrary, the lowest total number of pods was harvested green bean plants established at 50 cm x 7 cm on the 17th of August, which, however, was statically comparable with the outcome of sowing green beans on the 17th of August at spacing of 40 cm x 15 cm, 40 cm x 10 cm and 40 cm x 7 cm. This might be due to the fact that early sowing provides the chance for the plant tissue to store more essential plant nutrients which latter will be translocation to the flower and pod development production which, consequently, results in higher pod production.

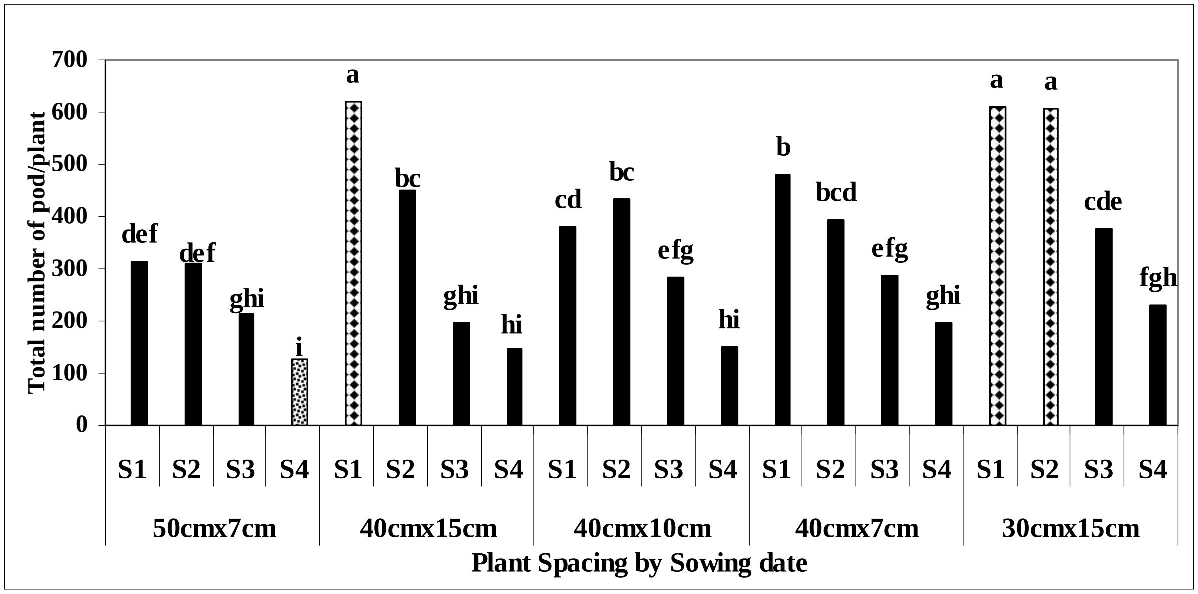

Figure 8. Interaction effects of plant spacing and sowing date on total number of pods per plot of green beans. Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (80.347) S1= 3rd July, S_2= 18th July, S_3=2nd August and S_4= 17th August

4.3. Pod Attributes of Green bean

4.3.1. Pod length

The three -way interaction effects among verities, spacing and sowing date was insignificant for pod length. Similarly, the interaction effect between sowing date and spacing and variety and spacing was not significant. In addition, there was no significant effect observed attributable to the interaction effect among variety, spacing and sowing date on the pod length (Appendix 5). However, the result presented in Table 15 shows the interaction effects between variety and sowing dates on pod length. As indicated, pod length was significantly ($P \leq 0.05$) influenced by the interaction effects between variety and sowing date. The longest pod was observed from Melka-1 sown on the 18th of July which again was found to be statistically similar with Melka-5 sown on the August 2nd; whereas the smallest pod length was obtained from Melka-5 sown on the August 2nd. This result could be due to the fact that with early sowing, plants might have received more rainfall that encouraged the vegetative growth and subsequently produced higher number of pods with short length. These results are in agreement with the works of Yoldas and Esiyok (2007) who reported that the early sowing date produced higher yield, and greater plant height but lower pod diameter, dry matter and pod length than the late sowing date. With an early sowing, there was low temperature observed as compared to late sowing wherein high temperature appeared and aggravated the maximum pod length. This result is also in harmony with the works of Corokalo *et al*. (1992) who discovered that growth of fruits (pods) greatly depending on temperature wherein high temperatures accelerated fruit (pod) growth of green bean.

Table 15. Interaction effect of variety and sowing date on pod length green bean

Variety	Sowing date	Pod Length (cm)
Melka-1	3rd July	11.09e
Melka-1	18th July	13.50a
Melka-1	2nd August	12.34c
Melka-1	17th August	11.79d
Melka-5	3rd July	10.24f
Melka-5	18th July	12.80b
Melka-5	2nd August	13.64a
Melka-5	17th August	12.47c
Mean		12.24
CV (%)		2.06
LSD (5%)		0.253

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ as established by LSD- test (0.253)

4.3.2. Pod diameter

The three-way interaction effects among verities, spacing and sowing date was insignificant for pod diameter. Similarly, the interaction effect between sowing date and spacing and variety and spacing was not significant. In addition, there was no significant effect observed attributable to the interaction effect among variety, spacing and sowing date on the pod diameter at ($P>0.05$), (Appendix 5). However, the present study also revealed significant ($P \leq 0.05$) interaction effects between varieties and sowing date on the pod diameter of green bean (Table 16). Thus, the widest pod diameter was obtained from Melka-1 sown on the 18th of July. This value is, however, statistically at par with pod diameter obtained from Melka-5 sown on July 18th. On the contrary, the narrowest pod diameter was obtained from Melka-5 sown on July 3rd. This finding was perhaps due to the availability of sufficient moisture during early sowing that in turn enhanced the vegetative growth to prepared more assimilates and produced higher yield but with less pod quality (pod diameter) (Yoldas, and Esiyok, 2007). These authors reported that with early sowing date, green beans produced higher yield, plant height but lower pod diameter, dry matter and pod length than the late sowing date. This result is also in conformity with the work of Marlene *et al*. (2008) who reported that mean pod width (diameter) were greater in the late planting season than in the early planting seasons.

Table 16. Interaction effect of variety and sowing date on pod diameter of green beans

Variety	Sowing Date				Mean	CV (%)	LSD (5%)
	3rd July	18th July	2nd August	17th August			
Melka-1	0.5942[g]	0.9465[a]	0.8517[c]	0.7175[e]	0.777	5.07	0.041
Melka-5	0.6559[f]	0.9488[a]	0.9134[b]	0.7693[d]	0.822		
Mean	0.625	0.9477	0.883	0.7434	0.799		

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ as established by LSD- test (0.041)

4.3.3. Average individual marketable pod weight

The three-way interaction between variety, sowing date and spacing was non-significant. Similarly, the two-way interaction between varieties with spacing, sowing date with spacing also non-significant. The main effect of variety, sowing date and spacing also non-significant at ($P>0.05$) for average individual marketable pod weight (Appendix 5). However, the result depicted in Table 17 indicts that the interaction effect of varieties and sowing date on the average individual marketable pod weight of green bean was significant ($P \leq 0.05$). Among the different treatment combinations, Melka-5 sown on the 2nd of August resulted in the highest average individual marketable pod weight. Conversely, the lowest average individual marketable pod weight was obtained from Melka-1 sown on the 17th of August. This result could probably be due to the temperature on the 2nd of August good for pollination and fertilization of flowering bud. This result inline with the finding of Ahmet and Elif (2003) who reported as average pod weight snap bean cultivars sown in 2002 were found heaver than that of 2001 sown. The reason is that temperature decreasing during the growing periods affects the pollination, fertilization and pod set of snap bean cultivars flower negatively, as result in comparison with 2001 years for each growing practice pod production is lower but average pod weight are higher in 2002 years. This result is also similar with the work of Moss and Muirhead (2009) who reported that good pod weights (yield) of snap bean were obtained from midseason sowings of snap bean than that of early and late sowings of snap bean. The difference between the two varieties could probably be due to the genetic make up difference.

Table 17. Interaction effect of variety and sowing date on average individual marketable pod weight of green bean

Variety	Sowing date	Average Individual Pod Weight (g/pod)
Melka-1	3rd July	4.182[e]
Melka-1	18th July	5.434[c]
Melka-1	2nd August	4.568[d]
Melka-1	17th August	3.638[g]
Melka-5	3rd July	3.927[f]
Melka-5	18th July	5.822[b]
Melka-5	2nd August	6.472[a]
Melka-5	17th August	4.541[d]
Mean		4.82
CV (%)		5.11
LSD (5%)		0.247

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ as established by LSD- test (0.247)

4.3.4. Number of seed per pod

The three-way interaction between variety, sowing date and spacing was non-significant. Similarly, the two-way interaction between variety with spacing and sowing date, sowing date with spacing also non-significant. The main effect of variety, and spacing also non-significant for number of seed per pod at ($P>0.05$) (Appendix 5). However, the number of seeds per pod, sowing of green beans on different dates resulted in a significant ($P\leq0.05$) effect (Table 18). The maximum number of seeds per pod was obtained from green beans sown on the 18th of July which of course was statically alike with effect of sowing on the 2nd of August. On the opposite, the minimum number of seeds per pod was recorded from green beans sown on the 17th of August. This result is in coherence with the findings of

Nishoika and Okumura (2008) as cited in Qiu Ying Zhang *et al.* (2010) who reported that total number of nodes per plants, total number of seed per pods and number of pod sets per plants of green soybeans was higher in the early sown plots than in the late sown ones. The findings of the present investigation are also in harmony with the work of Ismail and Khalifa (1987) who observed reduction of number of seeds per pods of soybean with delayed sowing and they attributed this due to the decrease in day length and moisture with the late sowing. Similarly, this result is agreement with the work of Uslu and Esendel (1996) who stated that sowing date significantly affects the number of seeds per pod of soybean.

Table 18. Effect of sowing date on number of seed per pods of green beans

Sowing date	NSPP
3rd July	4.729 (2.141 b)
18th July	5.086 (2.253 a)
2nd August	5.040 (2.243 a)
17th August	4.134 (2.029 c)
Mean	4.75 (2.167)
CV (%)	2.39 (1.67)
LSD (5%)	0.114 (0.036)

Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (0.036). *Number in the bracket are transformed value in Arcsine*.

4.3.5. Dry weight of pod

With respect to dry weight of pods, a significant variation (P≤0.05) was found to be accountable to the interaction effects of spacing and sowing date (Fig. 9 and Appendix 3). However, there appeared to be no three way interaction effect among variety, spacing and sowing date or between varieties by spacing on the dry weight of pods of green beans (Appendix 5). The maximum dry weight of pods per plant was observed as a result of the treatment combination of spacing at 40 cm x 15 cm and sowing date 3rd July and 18th July. This value was statistically similar with what was achieved by planting at same spacing but on 18th of July, spacing of 30 cm x 15 cm and sowing on the 3rd July and 50 cm x 7 cm with sowing on the 18th of July. While, the minimum dry weight of pods per plant was observed from sowing green beans at a spacing of 40 cm x 15 cm on the 17th of August and at 40 cm x 10 cm on at the 17th of August. This value was however statically at par with the result obtained from sowing at all the spacing done on the 17th of August. The apparent increase in pod dry weight of plants from the wider plant spacing is probably due to the availability of enough moisture, water and other resources with little or no sever competition among plants which finally resulted in better accumulation of photosynthates in their sink (pods). A similar finding was reported by Samih (2008) who observed higher values of pod dry weight in bush bean at lower planting densities as compared to higher planting density. The author attributed this to lower number of plants per unit area resulting in more availability of water and soil nutrients which consequently enhanced better photosynthesis and development of maximum stem diameter per plant. The difference among sowing dates could probably be due to the continued abundance and availability of moisture and nutrients that resulted in better pod development and yield as compared to the late sowing dates.

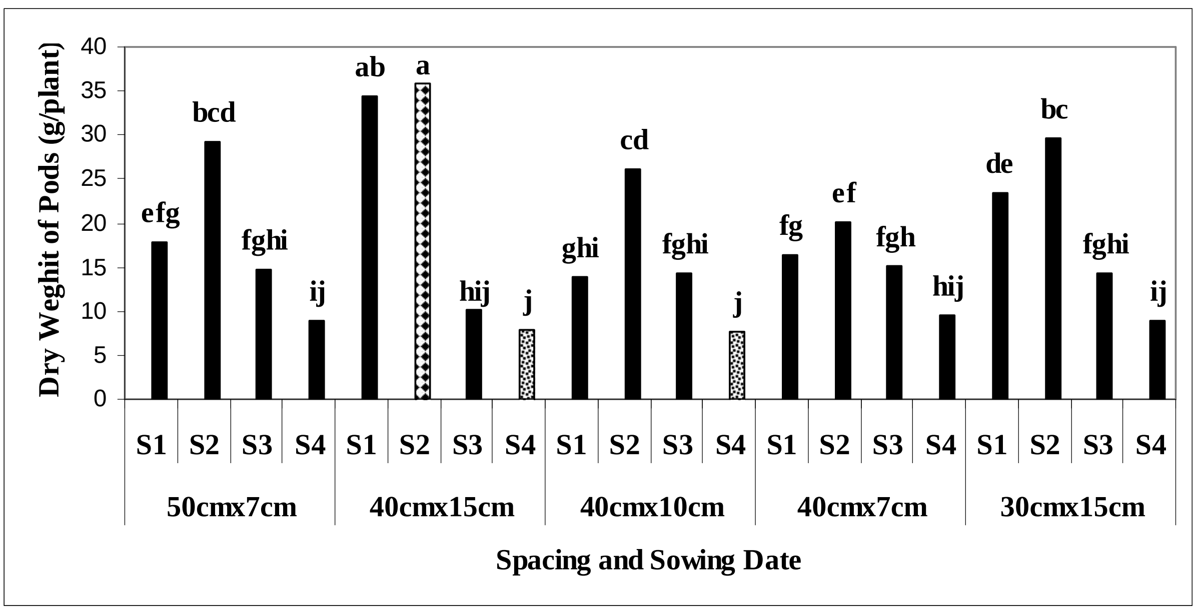

Figure 9. Interaction effect of plant spacing and sowing date on dry weight of pod of green beans. Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (5.024) S1= 3rd July, S_2= 18th July, S_3=2nd August and S_4= 17th August

In addition, the result of this experiment indicted that the interaction between sowing date and varieties significantly ($P \leq 0.05$) affected the dry weight of pods (Table 19). Sowing of the variety Melka-5 on the 18th of July produced the maximum dry weight of pods while sowing of both Melka-1 and Melka-5 varieties on the 17th of August resulted in minimum dry weight of pods. This might probably be due to the fact that early sowing gives chance for the availability of adequate moisture for longer period of time that in-turn gives chance for the translocation of more plant nutrients to the sink i.e., pod and seed; consequently higher dry matter of pod. This result is also in-line with the work of Talal and Ghalib (2006) that reported higher shoot and root growth of faba bean for early sowing, due to the exposure of the crop for lengthy period of moisture and resulted in more pod development. The difference between the two varieties could be probably due to their genetic makeup.

Table 19. Interaction effect of variety and sowing date on dry weight of pod of green beans

Variety	Sowing Date				Mean	CV (%)	LSD (5%)
	3rd July	18th July	2nd August	17th August			
Melka-1	16.87^{c}	25.41^{b}	9.22^{d}	8.49^{d}	14.99	17.75	3.180
Melka-5	25.48^{b}	30.90^{a}	18.23^{c}	8.67^{d}	20.82		
Mean	21.18	28.16	13.73	8.58	17.91		

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ as established by LSD- test (3.180)

4.4. Disease incidence Attributes of Green Beans

4.4.1. Rust (*Uromyces phaseoli)*

The three-way interaction between variety, sowing date and spacing showed non-significant. Similarly, the two-way interaction effects between variety with spacing and sowing date with spacing show non-significant. The main effect of variety, sowing date and spacing also non-significant for rust incidence of green bean at (P>0.05) (Appendix 5). However, the interaction effect between varieties and sowing date on the incidence of rust was found to be significant ($P\leq0.05$) (Fig. 10 and Appendix 4). Of all treatment combinations, Melka-5 sown on the 2nd of August demonstrated the highest incidence of rust whereas the lowest incidence was registered from Melka-1 sown on the 17th of August. The observed high incidence of rust was probably due to the exposure of green beans from early sowing to extended period of rain fall, high humidity and less period of sunlight which all together might have created favorable condition for the disease development. This result is in agreement with the work of Bose *et al.* (2002) who reported that rust infection on green beans to be particularly severe at high humidity condition.

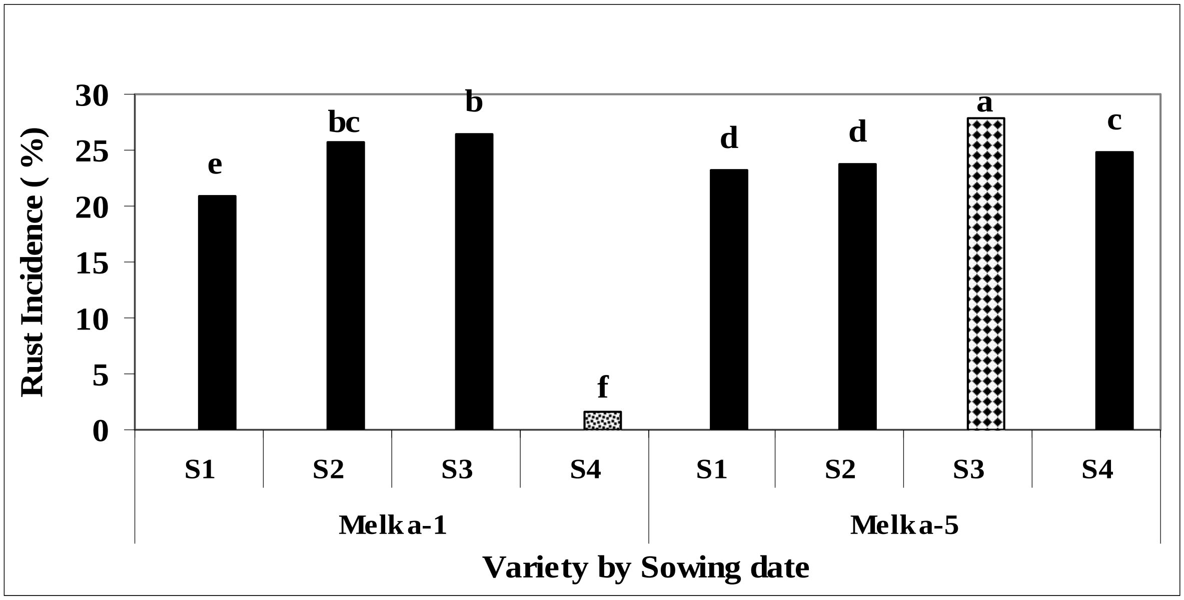

Figure 10. Interaction effect of variety and sowing date on rust incidence (%) green bean Means followed by the same letter(s) are not significantly different at P≤ 0.05 as established by LSD- test (1.014) S1= 3rd July, S_2= 18th July, S_3=2nd August and S_4= 17th August

4.4.2. Angular leaf spot *(Isapriopsis griseola)*

The results depicted in Table 20 demonstrated that the effect of sowing date on the angular leaf spot disease incidence was significant (P≤0.05). Among all the sowing dates, the highest angular leaf spot incidence was observed on the 2nd of August whilst the lowest was observed on the 3rd of July. The discrepancy among the sowing dates in respect of their impact on the development of angular leaf spot is associated with temperature and relative humidity during the growing period of the crop. Plants from the early sowing had a relatively high humidity and conducive temperature as compared to the other sowing dates thus might have been favorable for the growth and development of the pathogen. Likewise Hagedorn and Inglis (1986) reported high angular leaf spot incidence under high humidity condition and temperature ranging between 16 and 28^0C.

Table 20. Effect of sowing date on angular leaf spot and floury leaf spot incidence (%) of green beans

Sowing date	Angular leaf spot incidence (%)	Floury leaf spot incidence (%)
3rd July	12.70 (20.82[d])	12.92 (21.00[b])
18th July	25.89 (30.33[c])	17.58 (24.55[a])
2nd August	31.11 (33.78[a])	12.21 (20.38[c])
17th August	29.82 (32.99[b])	11.00 (19.43[d])
Mean	24.88 (29.48)	13.43 (21.34)
CV (%)	3.86 (2.09)	3.99 (1.89)
LSD (5%)	0.955 (0.615)	0.535 (0.404)

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ established by LSD- test (0.615 and 0.404). *Number in the bracket are transformed value in Arcsine*.

4.4.3. Floury leaf spot (*Mycovellosialla pheseoli*)

Similarly, the incidence of floury leaf spot was significantly ($P \leq 0.05$) affected by different sowing date of green bean (Table 20). The considerably high incidence of floury leaf spot was observed with sowing of green beans on July 18th while the least was observed on the 17th of August. The high pressure of the disease was perhaps the function of the cool and wet environmental condition noticed before flowering and the crop reached to complete maturity. In alignment with the findings of the present study Hagedorn and Inglis (1986) pinpointed the role of cool and wet weather condition on the leaves remain for at least 24 hours for proper initiation, growth and development of the diseases. Similarly, floury leaf spot incidence was reported to be severing under cool temperature and high relative humidity (CIAT, 1981).

4.5. Quality Attributes of Green Beans

4.5.1. Physical quality parameters

4.5.1.1. Snapping nature

The three way interaction effect among varieties, sowing date and spacing on the snapping nature of green bean pods was non-significant (P>0.05). However, the two-way interaction between sowing date and varieties, varieties with spacing, and spacing with sowing date produced no appreciable difference on the snapping nature of the green bean pods. The main effects of varieties and spacing were in non- significant effect (Appendix 5).

The different sowing dates imparted significant ($P \leq 0.05$) effects on the snapping nature of green bean pods (Table 21). Among the tested sowing dates, 3rd July proved to be appropriate for the production of most snapping green bean pods whereas plants from late sowing (17th August) bore the least snapping pods followed by mid season sowing on the 2nd of August. This might be due to the fact that early sowing allows for the availability of high moisture in the soil during the growing period which resulted in more absorption and translocation of nutrients to the sink (pods) that provides more turgidity of the pods, which in turn provides better snapping quality of the pods for green bean.

Table 21. Effect of sowing date on snapping nature, tenderness quality of green bean

Sowing date	Snapping Nature (1 to 3 scale)*	Tenderness (1 to 3 Scale)**
3rd July	1.139a	1.924a
18th July	1.087b	1.846b
2nd August	1.037c	1.511c
17th August	1.007d	1.291d
Mean	1.068	1.643
CV (%)	1.645	4.22
LSD (5%)	0.017	0.069

Means followed by the same letter(s) are not significantly different at P≤0.05 established by LSD- test (0.017 and 0.069)

*= *Snapping Nature* (1= Less snapping 2=Moderate, 3= Very-snapping)

****=** *Tenderness* (1= Less Tender 2=Moderate, 3= Very Tender)

4.5.1.2. Tenderness

Considering the tenderness of the pods there was no significant interaction effect among variety, sowing date and spacing, and also two-way interaction between variety with spacing, variety with sowing date, and spacing with sowing date (Appendix 5). However, the findings of this experiment indicated that variety, sowing date and spacing significantly independently (P≤0.05) affected the tenderness quality the pods. The findings in Table 21 explicitly indicate that the effect of sowing date on the tenderness quality of green bean pods; significantly more tenderness quality pods being the result of early sowing of green beans on the 3rd of July while the least tender pods were the effect of late sowing on the 17th of August. This result is in-line with the report of Edith *et al.* (2006) who reported poor yield of peas with superior tenderness quality for early harvesting. This could be due to yield and harvest attributes were highly season dependent (especially moisture content of the season) and their rates of change over the course of the harvest period also varied with the cultivar and year. Quality declined rapidly once the crop reached optimal maturity, while yield increased in a less predictable manner. However, this result disagrees with the work of Marlene *et al* (2008) who reported non-significant effect of planting season on tenderness quality of snap bean cultivars.

There was significant ($P \leq 0.05$) effect of spacing on the tenderness of green bean pods (Appendix 5). The most tender green bean pods were harvested from plants which were established at a spacing of 50 cm x 7 cm whilst the least tender (most firm) pods were produced as a result of sowing at all spacing other than 50 cm x 7 cm (Table 22). This might be due to the fact that early sowing allows for the availability of high moisture in the soil during the growing period which resulted in more absorption and translocation of nutrients to the sink (pods) that provides more turgidity of the pods, which in turn provides better snapping quality of the pods for green bean.

Table 22. Effect of plant spacing on tenderness quality of green bean pods

Spacing	Tenderness (1 to3 Scale)**
50cmx7cm	1.708[a]
40cmx15cm	1.625[b]
40cmx10cm	1.647[b]
40cmx7cm	1.595[b]
30cmx15cm	1.641[b]
Mean	1.643
CV (%)	5.79
LSD (5%)	0.095

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ established by LSD- test (0.095)

******= *Tenderness* (1= Less Tender 2=Moderate, 3= Very Tender)

Results pertaining to the effect of varieties on the tenderness of green bean pods are given in Table 23. Accordingly, pods of the variety Melka-1 were significantly tender than that of Melka-5. The difference between the two varieties could be probably due to the difference in their genetic make-up.

Table 23. Effect of variety on tenderness quality of green bean pods

Varieties	Tenderness (1 to3 Scale)**
Melka-1	1.780[a]
Melka-5	1.506[b]
Mean	1.643
CV (%)	3.67
LSD (5%)	0.060

Means followed by the same letter(s) are not significantly different at P≤0.05 established by LSD- test (0.060)

4.5.1.3. Straightness

On the basis of the subjective assessment of pods for straightness, the three way interaction among varieties, spacing and sowing date did not show a significant effect and neither did the main effects of variety, sowing date and spacing (Appendix 5). On the other hand, the two-way interaction effect between spacing and sowing date demonstrated a significant (P≤0.05) effect on straightness of pods. In the present study, significantly straight green bean pods were observed from the treatment combination of the spacing 50 cm x 7 cm and sowing date fixed on the 3rd of July. This value was statistically alike with the result registered from the combined sowing of green beans at a spacing of 40 cm x 10 cm or 30 cm x 15 cm later in the season (17th of August).

The least straight pods of green beans were observed from the interaction between spacing at 50 cm x 7 cm and sowing on the 2nd of August. This value was statistically similar with the interaction effect between spacing at 40 cm x 15 cm and sowing date on the 2nd of August and 17th August, spacing at 40 cm x 10 cm or 40 cm x 7 cm and sowing date adjusted to the 18th of July (Table 24).

Table 24. Interaction effect of plant spacing and sowing date on straightness quality of green bean pods

Spacing	Sowing date	Straightness (1 to 3 scale)***
50cmx7cm	3rd July	1.566[a]
	18th July	1.147[efg]
	2nd August	1.110[g]
	17th August	1.247[def]
40cmx15cm	3rd July	1.389[bc]
	18th July	1.278[cde]
	2nd August	1.130[fg]
	17th August	1.184[efg]
40cmx10cm	3rd July	1.389[bc]
	18th July	1.200[efg]
	2nd August	1.262[cdef]
	17th August	1.478[ab]
40cmx7cm	3rd July	1.351[bcd]
	18th July	1.161[efg]
	2nd August	1.397[bc]
	17th August	1.387[bcd]
30cmx15cm	3rd July	1.394[bc]
	18th July	1.280[cde]
	2nd August	1.247[def]
	17th August	1.431[ab]
Mean		1.30
CV (%)		9.01
LSD (5%)		0.117

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ established by LSD- test (0.117)

***= *Straightness* (1= Curved, 2=Slightly curved, 3= Very straight)

The interaction between variety and sowing date resulted in a significant ($P \leq 0.05$) effect in respect of pod straightness in green beans (Table 25). Significantly the highest value for straightness was achieved by pods of Melka-5 sown on the 3rd of July which of course was statistically comparable with values of straightness rated for pods Melka-5 sown on the 18th of July while the least value was from Melka-1 sown on the 2nd of August which again was statically at par with the treatment combination between Melka-5 and sowing on the 17th August.

Table 25. Interaction effect of variety and sowing date on straightness quality of green bean pods

Variety	Sowing Date				Mean	CV (%)	LSD (5%)
	3rd July	18th July	2nd August	17th August			
Melka-1	1.397[b]	1.218[d]	1.162[e]	1.225[d]	1.251		
Melka-5	1.464[a]	1.439[ab]	1.296[c]	1.209[de]	1.352	5.67	0.074
Mean	1.431	1.328	1.229	1.217	1.302		

Means followed by the same letter(s) are not significantly different at $P \leq 0.05$ established by LSD- test (0.074)

***= *Straightness* (1= Curved, 2=Slightly curved, 3= Very straight)

4.5.1.4. Fibreless Nature

The best quality green beans are those that are having less fibrous nature which can be influenced by many factors viz. variety, spacing and sowing dates. In this context, results presented in Appendix 5 demonstrate that the interaction effect among varieties, spacing and sowing date were non-significant and neither were the interaction effects between varieties with spacing and spacing and sowing date on the fibreless nature of green bean pods. Similarly, the effect of varieties and spacing also showed no significant effects (Appendix 5).

On the other hand, the interaction effect between variety and sowing date revealed a significant ($P \leq 0.05$) difference with regard to the fibreless nature of green bean pods (Table 26). The most fibreless pods of green bean were obtained from plants of the variety Melka-1 which were sown early in the season on the 3rd of July. This value, however, was observed to be statistically identical with the result obtained from Melka-5 sown the 17th of August while the least fibreless nature from Melka-1 sown on 18th July which nevertheless was statically comparable with fibreless value given for pods from Melka-1 sown on the 2nd of August and Melka-5 sown on both the 18th and 2nd of August. The justifications provided for tenderness and snapping quality holds true for fibreless too. These findings are in agreement with the results of Marlene *et al.* (2008) who reported highest fiber development in green beans as a result of delayed sowing, owing to the unsuitable weather conditions. They further stated that this nature might compensate for some of the pod yield losses. This result is also in-line with the work of Singer *et al.* (1996) who found that the total fiber content of snap bean pod decreased with increasing water supply. Singer *et al.* (1996) further reported that Giza 3 cultivars treated with excessive water had the lowest pod fiber content and this could be due to high canopy temperatures rather than to water stress period during the pod development stage.

Table 26. Interaction effect of variety and sowing date on fibreless nature quality of green bean pods

Variety	Sowing Date				Mean	CV (%)	LSD (5%)
	3rd July	18th July	2nd August	17th August			
Melka-1	1.404 (1.171[a])	1.072 (1.036[cd])	1.067 (1.032[cd])	1.130 (1.067[b])	1.17 (1.07)	8.79 (3.79)	0.104 (0.04)
Melka-5	1.239 (1.106[b])	1.107 (1.043[cd])	1.049 (1.024[d])	1.424 (1.179[a])	1.20 (1.07)		
Mean	1.32(1.14)	1.09(1.0)	1.06(1.0)	1.3(1.12)	1.2(1.0)		

Means followed by the same letter(s) are not significantly different at P≤0.05 established by LSD- test (0.04) *Number in the bracket are transformed value in Arcsine.*

**= Fibreless nature (1 to 3 Scale)* (1=Fibreless, 2= Slightly fibrous, 3= Fibrous)

5. SUMMARY AND CONCLUSION

Green bean (*Phaseolus vulgaris* L*)* 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, determining suitable sowing date and plant spacing are very important to increase yield and quality in green beans.

In line with this, the present study was conducted at Jimma University College of Agriculture and Veterinary Medicine to assess the growth, yield and quality attributes of two green bean candidate varieties as influenced by different sowing date and plant spacing. Two green bean varieties namely Melka-1 and Melka-5 were sown on four different of sowing dates (3rd July, 18th July, 2nd August and 17th August) and five different plant spacings (50 cm x 7 cm, 40 cm x 15 cm, 40 cm x 10 cm, 40 cm x 7 cm and 30 cm x 15 cm) during the year 2010 under rain-fed condition using RIBD design.

Considering the growth of plants, variety Melka-5 sown on the 17th August resulted in the maximum plant height while the maximum number of primary branches was recorded from Melka-1 plants established on the 18th of July. Melka-5 sown on the 2nd of August produced the maximum leaf area and Melka-1 sown on the 3rd of July resulted in the highest root fresh weight. Similarly, the maximum root volume was observed from the interaction between Melka-1 and sowing on the 3rd of July. The longest tap root was obtained from Melka-1 established at spacing 40 cm x 7 cm and 30 cm x 15 cm and among the sowing dates, the longest tap root was observed sowing at 18th July.

Irrespective of variety, the maximum fresh and dry weight of shoot and root were recorded from plants spaced at 40 cm x 15 cm, 40 cm x 7 cm and 30 cm x 15 cm sown on the 3rd of July.

Though there was no significant difference between varieties and among the sowing dates in respect of days to flowering, in respect of days to flowering; Melka-5 sown at 40 cm x 7 cm showed the earliest flowering.

Pertaining to yield, the highest total and marketable pod yield were obtained from green bean plants sown the 3rd of July while the maximum total unmarketable pod yield was obtained because of sowing on the 3rd and 18th July.

Among the varieties tested in the present study, Melka-5 gave the highest total and unmarketable pod yield while Melka-1 produced pods with the maximum tenderness value and the highest dry weight of shoot and roots.

The incidence of diseases in association with the treatments depicted that the highest incidence of rust was observed on variety Melka-5 when sown on the 3rd of July while maximum incidence of angular leaf spot was recorded from plants established on the 2nd of August. On the other hand, floury leaf spot was more serious in plots sown on the 18th of July.

With reference to the quality of pods, the longest pods were observed from Melka-1 sown on the 18th of July and Melka-5 sown on the 2nd of August while the maximum average individual pod weight was recorded as a result of sowing Melka-5 on the 2nd of August and the widest pod diameter was obtained from both Melka-1 and Melka-5 sown on the 18th of July. The highest dry weight of pods was observed from Melka-5 variety sown on the 18th of July while the same variety sown on the 3rd of July gave the highest total number of pods per plants. More straight pods of green beans were collected from Melka-5 sown on the 3rd of July and the most fibreless pods were collected from after sowing Melka-5 on the 17th of August.

The result of this study therefore indicted that different sowing dates, spacing, varieties and their interactions had significant influences on the growth, yield and quality of green beans. Hence, sowing of green beans on the 3rd of July gave more marketable pod yield as compared to the other sowing dates. On the other hand, sowing on the 3rd of July resulted in better snapping and tenderness of pods, spacing at 40 cm x 7 cm producing more marketable pod yield. Irrespective of varieties and sowing dates, spacing at 50 cm x 7 cm registered better tenderness of pods. With respect to variety; Melka-1 variety gave better tenderness quality as compared to Melka-5. Late sowing of Melka-5 on the 2nd of August revealed more fibrous pods and Melka-5 established on the 3rd of July had more straight pods of green bean. Late sowing on the 17th of August at spacing of 40 cm x 10 cm and 30 cm x 15 cm and 3rd of July at 50 cm x 7 cm similarly produced more straight pods of green bean.

In drawing conclusions, considerations have to be taken in respect of total marketable 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 beans can grow well in the study area and farmers can benefit more by practicing narrow plant spacing (40 cm x 7 cm) and earlier sowing (July 3) with variety Melka-5 to achieve high productivity and quality of green beans. However, repeating of the experiment for more seasons would help us draw sound conclusions and recommendations. Moreover, further studies are needed with regard to the improvement, nutritional quality and packages of agronomic practices for green bean cultivation.

This thesis work provided initial information that snap production is possible around Jimma. Hence, there is a need to establish strong snap bean breeding program which can perform intensive variety testing and /or screening to identify snap bean cultivars with superior yield, disease resistance and marketable quality under Jimma condition. This experiment needs to be repeated for two or more seasons to verify the results, and reach to reliable conclusion. Nutritional quality analysis also need further study. All agronomical practices were not studied under Jimma condition, hence further studies on soil fertility, disease and crop management need to be conducted

REFERENCES

Abdul-Hamid, A. F., Kubota, F., Agata, W., and Morokuma, M., 1990. Photosynthesis, Transpiration, dry matter accumulation and yield performance of mungbean plant in response to water stress. *Journal of the Faculty of Agriculture*, **1-2**:81-92

Ahmet, B. and Elif, D., 2003. The effect of growing bag culture on yield, earliness and quality characteristics in snap bean growing under unheated glasshouse during late autumn season. *Journal of Biological Sciences*, **3-12**:1084-1094

Alem, M.K, Farooque, A.M., Uddin, J.A and Nuruzzaman, M., 2010. Effects of sowing time on the growth and yield of three Radish (*Raphanus Sativus L.*) varieties. *Bangladesh Research Publication Journal*, **3**: 998-1006

Amanullah, J.I., Hayat, T.F., Khan, A.I., and Khan, N., 2002. Effect of sowing dates on yield and yield components of mash bean varieties. *Asian Journal of Plant Science*, **1:** 622-624

Anisa, I., Raghab, W.S., and Samira, M.M., 1995. Effect of sawing date and plant spacing on seed yield and quality of climbing bean *(Phaseohs vulgarisl.)* cultivar Serbo grown under plastic houses. *Egypt Journal of Horticulture*, **22:** 31-40.

Bose, T. K, Kabir. T.K., Maity V.A Parthasarathy., and Som. M.G., 2002. Vegetable Crops. Vol.2, Kolkata. India. pp: 177-201.

BPEDORS. 2000. Physical and Socio economical profile of 180 District of Oromiya Region. Pp.248-251. Bureau of Planning and Economic Development of Oromiya Regional state (BPEDORS), physical planning Development .Finfinne, Ethiopia.

Calvino, P. A, Sadras V. O, Andrade F. H., 2003a. Quantification of Environmental and Management Effects on the Yield of Late-Sown Soybean. Field Crops Research, **83**: 67-77.

Carol, A. M., Thomas, A. L., and Leslie, Z., 1999. Farming West of the Cascades. EDAMAME. A Pacific Northwest Extension Publication Washington .Oregon. Idaho. USA.

Chaudhary, D.C., Singh, R.P., and Singh, N.P., 1989. Productivity of bean varieties as influenced by planting dates. *Legume Research*, **12**: 43-44.

CIAT, 1981. Potential for field beans Easter Africa. Proc. Of a regional workshop held in Lilongwe, Malawi, 9-14 March 1980. Cali, Colombia.

Corokalo, O., Micadinovic Z., Zrdsvrokovic, M., Brkic, S., 1992. The Effects of variety and sowing date on the yield of new snap bean lines. Savermena pol Joprivreda **40 (1-2):** 115-120

Crothers, S. E., and Westermann, D. T., 1976. Plant Population Effects on the Seed Yield of *Phaseolus vulgaris* L. *Agronomy Journal*, **68:**958-960

Cutcliffe, J. A., 1967. Effect of seed spacing on yield and size distribution of snap beans. *Canadian Journal of Plant Science*, **47**:519-522

Drake, S.R., and Silberngel, M.J., 1982. Seed Index, An Estimate of Snap Bean Quality. *Journal of America Society*, **103**:257-260.

Edith, F., Nicolas, T., and Yves, D., 2006. Relationships among growing degree-days, tenderness, other harvest attributes and market value of processing pea (*Pisum sativum l.*) Cultivars grown in quebec. *Canadian Journal of Plant Science*, 86(2): 525-537

EHDA. 2003. Ethiopian Horticulture Development Agency. Exporting Fruit and Vegetables from Ethiopia, Addis Ababa, Ethiopia.

Escalante, J.A., Miranda, S., Kohashi, S. J., 1989. Manual removal of reproductive organs: Their effect on flowering duration and age at physiological maturity in *Phaseohs vulgaris* L; **39(1):**40

FAO, 2009. Production year book. Food and Agriculture Organization for the United Nations, Rome Italy.

Frew, M. 2002. Yield Stability in Common Bean *(Phaseolus vulgaris L.)* genotypes. Euphytica, **130**:147-153.

Gardineri, T. R., Vietor, D. M., and Craker, L. E., 1978. Growth habit and row width effects on leaf area development and light interception of field beans. *Canadian Journal of Plant Science*, **59:**191-199

GenStat. 2008. GenStat for teaching and learning. VSN International Software for bioscience.11th edition.

Gezahegn, A. and Dawit, A., 2006. Marketing of Pulses in Ethiopia. 346-351pp. In: Kemal Ali; Gemechu Keneni; Seid Ahmed; R. Malhotra; S. Beniwal; K. Makkouk, and M.H. Halila (Eds.). Food and Forage Legumes of Ethiopia: Progress and Prospects. Proceedings of the Workshop on Food and Forage Legumes, 22 – 26 September 2003. Addis Ababa, Ethiopia.

Godfrey-Sam-Aggrey G., Yosef H, and Turuwork A., 1985. Review of Green Beans Research in Ethiopia and Proposal for Future Research and Development Direction.

Gomez, K.A. and Gomez, A.A., 1984. Statistical procedures for Agricultural Research. 2nd ed. John wily & Sons, New York.

Gomez, L., and Araya, R., 1986. Evaluation of Planting Dates and Varieties of Common Bean (*phaselous vulgaries)* Intercropped in coffee (*coffea arabica*).Agronomia Costarricense, **10(1-2):** 1-11, (Hort. Abst.58 (9), 5753.

Hagedom D.J and Inglis D.A., 1986. Hand Book of Bean Diseases. Madison, Wisconsin.

Henry G. T., 2009. Green Bean Production. Extension Vegetable Specialist Department of Horticulture Iowa State University. USA.

IDEA, 2001. Fresh Green Beans. ADC Commercialization Bulletin. Agribusiness Development Centre. Kololo, Kampala, Uganda.

Ismail A.M.A. and Khalifa F.M., 1897. Irrigation, Planting date and Intra- Row Spacing Effects on Soybean Grown under Dry Farming Systems. Qatar Univ. Sci, **(7):** 149-167.

Jackson, T.H. A. Sisay, and P. Bruncko, 1992. A Practical Guide to the Horticulture in Ethiopia. Addis Abeba, Ethiopia.

Jadoski, S. O., Carlesso, R., Petry, M. T., Wolschick, D., Cervo, L., 2000. Plant population and row spacing for irrigated dry bean. I: Plant morphological characteristics. *Journal of Ciência Rural,* **30(4):** 559-565

JARC, 2010. Annual Meteorological Data. Jimma Agricultural Research Center, Jimma, Ethiopia.

Kay, D. E., 1979. Food Legumes: Crop and Product Digest, No. 3. London: Tropical Products Institute. Pp 435.

Laurie, H., 1990. Basic Cultural Practices for Commercial Production of Green (Snap) Beans. Extension Historical Materials of Nebraska- Lincoln Extension. University of Nebraska. Lincoln,

Laurie, H., Kenneth, G. H., Mohd, N.S., and Kenneth, G. H., 2004. Growth and Yield of Snap Beans as Affected by Wind Protection and Microclimate Changes due to Shelterbelts and Planting Dates. *Journal of Horticultural Science,* **39(5):**966-1004

Lemma, D. Yayeh., Z. and Helath, E. 2003. Agronomic studies on Tomato and Capsicum. Pp.153.In:E.Helath and Lemma Dessalegne (Eds). Horticultural Research and Development in Ethiopia. Proceedings of the second Horticultural work shop of Ethiopia, 1-3 December, 1992. Addis Abeba, Ethiopia.

Lemma, D. 2003. Snap Bean Production and Research Status (*Phasiolus vulgaris*) in Ethiopia. Melkasa Agricultural Research Center. Nazret, Ethiopia.

Lemma, D. Shimales, A. Selamawit, K. and Abyote, A. 2006. Varietal Development of Major Vegetables in the Rift Valley Region. Pp In: Melksa Agricultural Research Center, Werer Agricultural Research Center, EIAR Proceeding of the Inaugural and First Ethiopian Horticultural Science Society Conference, 27-30 March 2006. Addis Ababa, Ethiopia.

Lucas, E.O., and Miboum, G.M., 1976. The effects of density of planting on the growth of two *Phaselous Vulgaris L.* Varieties in England. *Journal of Agricultural Science,* **87:** 89-99.

Marlene, P.B., Ana María González, A.M., Rodiño, A.P., De Ron, A.M., and Marta Santalla, M., 2008. Effects of planting season and plant cultivar on growth, development, and pod production in snap bean (*Phaseolus vulgaris* L.) *Australian Journal of Agricultural Research*, **59:**1121–1129

Mauromicale, G., Cosentino, S., and Foti, S., 1991. Effects of sowing date on the production of *Phaseolus vulgaris* L. in cold greenhouse. Acta Hort. (ISHS), **287:** 289-298

McDaniel, A, 2009. Beans. Virginia Cooperative Extension. Extension Specialist, Horticulture, Virginia Tech. Virginia, USA.

Michael O. and Kerry R, 2004. Crop Profile for Beans (Snap) in Pennsylvania. Pennsylvania, USA.

Moss, Q. I., and Muirheada1, W. A., 2009. Agronomic assessment of snap beans (*Phaseolus vulgaris*) in a warm-temperate semi-arid environment. *Journal of Agricultural Science*, **101**: 657-667

Ndegwa, A.M., Muchui, M.N., Wachiuri, S.M., and KARI-Thika, J.N., 2001. Evaluation of introduced snap bean (*phaseolus vulgaris* l.) Varieties for adaptability and pod quality. Thika, Kenya

Pawar, S.U., Kharwade, M. L., and Awari, H.W., 2007. Effect of Plant Density on Vegetative Growth and Yield Performance of Different Varieties of French bean under Irrigated Condition. *Journal of Agricultural Science*, **20(3):** 684-685

Poryazov, I. 1985. Breeding of Industrial bean cultivars resistant to bacteriosis and common mosaic virus. Genetics and breeding, **18:** 409-416

Qiu-ying Zhang., Yan-sheng Li., Qing-lu Gao., Herbert, S. J., and Hashemi, A. M., 2010. Influence of sowing date on phenological stages, seed growth and marketable yield of four vegetable soybean cultivars in North-eastern USA. *African Journal of Agricultural Research,* **5(18):**2556-2562

Radulovich, R.A., 1990. AQUA, a model to evaluate water deficits and excesses in tropical cropping. Agricultural and Forest Meteorology, **52**: 253-261

Rahman, A.M.A., Magboul E.L. and Nour. A.E., 2001. Effects of sowing date and cultivar on the yield and yield components of maize in Northern Sudan. Proceedings of 7th Eastern and Southern Africa Regional Maize Conference, Feb.11-15, Southern Africa, pp: 295-298

Rai N. and Yadov D.S., 2005. Advanced Vegetable Production. Research Book Center. New Delhi. India.

Rangaswamy, R. 1995. A Text Book of Agricultural Statistics. New Age International Limited. New Delhi. India.

Rubatzkey. V.E. and Yamagucbi M., 1999. World Vegetable; Principles Production and Nutritive Values. 2nd edition, Aspen publishers. California. USA

Sam-Aggrey, W.G. and Yosef Haile, 1985. Review of Hot pepper Research in Ethiopia and proposals for future Research and development directions.Pp.206.In:W.G. Horticultural work shop, 20-22 February, 1992. Addis Abeba, Ethiopia.

Samih, A., 2008. Effect of Plant Density on Flowering Date, Yield and Quality Attribute of Bush Beans (*Phaseolus Vulgaris L.*) under Center Pivot Irrigation System. *American Journal of Agricultural and Biological Sciences,* **3(4):** 666-668

Singer, S. M., Helmy, Y.I., Sawan, O.M., and El-Abd, S.O., 1996. Effects of plastic tunnels and sowing dates on growth and productivity of bean varieties grown in calcareous soil conditions. *Egypt Journal of Horticulture*, **23(2)**

Singh, S.P., 2001. Broadening the genetic basis of common bean cultivars: A Review. *Crop Sciences,* **(41):**1659- 75

Smartt, J. 1979. Tropical Pulses, Longman, London. pp.348.

Talal, T., and Ghalib, S., 2006. Effects of Planting Date on Faba Bean (*Vicia faba L.*) Nodulation and performance under Semiarid Conditions. *World Journal of Agriculture Sciences,* **2(4):**477-482

Tyson R.V. and Kostewicz., 1986. Weed Control in Narrow Snap Bean Production.Proc. Fla State Hort.Soc.99:358-362

Uddin, M. K., Hasan, M. K., and Alam, A. K., 2007. Effect of Planting Time on Canopy Structure and Biomass Production in Some Soybean Genotypes. *Journal of Agriculture and Rural Development*, **5(1-2):**25-29

Ugen, M. A., Ndegwa, A. M.,Nderitu, J. H., Musoni, A. and Ngulu, F., 2005. Enhancing competitiveness of snap beans for domestic and export markets.

Uslu, N., 1998. Response to inoculation and sowing date of soybean under bafra plain conditions in the Northern Region of Turkey. *Turkey Journal of Agriculture,* **22:**525-531

Uslu, N., and Esendal, E., 1996. Response to Inoculation and Sowing Date of Soybean under Bafra Plain Conditions in the Northern Region of Turkey. *Turkey Journal of Agriculture and Forestry,* **22:**525-531

Vieira, H.J., Bergamaschi, H., Amgelocci, L.R., and Libardi L., 1990. Performance of tow bean cultivars under two soil water availability regimes. II. Stomata1 resistance to vapour diffusion, transpiration flux density and water potential in the plant. Pesquisa Agropecußria Brasileira, **24(9)**: 1045-1053 (English summary).

Wahab, M. N., Dabbs D. H., Baker, R. J., 1986. Effects of planting density and design on pod yield of bush snap bean (*Phaseolus vulgaris l*.). *Canadian Journal of Plant Science*, **66:**669-675

Westphal, E., 1974. Pulses in Ethiopia, Their Taxonomy and Agricultural Significance. Center for Agricultural Publishing and Documentation, PUDOC, Agricultural Research Reports No. 815, Wageningen, the Netherlands.

Yan-sheng, L., Qiu-ying, Z., Qing-lu Gao, S., Herbert, J., and Hashemi, A., 2010. Influence of sowing date on phonological stages, seed growth and marketable yield of four vegetable soybean cultivars in North-eastern USA. *African Journal of Agricultural Research,* **5(18):**2556 – 2562

Yoldas, F., and Esiyok, D., 2007. Effects of sowing dates and cultural treatments on growth, quality and yield of processing beans. *Pakistan Journal of Biological Sciences*, **10**:2470-2474.

Yoldas, F., and Esiyok, D., 2009. The Influence of Temperature on Growth and Yield of Green Beans for Processing. *International Journal of Agricultural Research,* **4(3):**124-130. Izmir, Turkey.

Yusufali, A. N., Alagundagi, S. C., Mansur, C. P., Hosamani, S.V., and Mummigatti, U. V., 2007. Effect of Date of Sowing and Seed Rate on Fodder Production Potential and Economics of Field Bean Genotypes under Rain fed Condition. *Karnataka Journal Agricultural. Science,* **20(1):** 13-16

Zhou, X. B., Chen, Y. H., and Ouyang, Z., 2011. Row spacing effect on leaf area development, light interception, crop growth and grain yield of summer soybean crops in Northern China. *African Journal of Agricultural Research,* **6(6):**1430-1437

APPENDIXES

Appendix 1. Interaction effect of sowing data and variety on growth attribute of green bean

Variety	Sowing date	Plant Height at Harvest (cm)	Root Volume(ml)	Fresh Root Weight(g)	Leaf Area (cm^2/plant)	Days to 50% flowering	Number of primary branches
Melaka-1	July 3rd	16.70[bc]	1.368[a]	1.089[a]	41.52[b]	39.00[d]	2.672 (1.630[b])
Melaka-1	July 18th	16.26[bc]	0.9814[b]	0.7531[b]	32.44[d]	37.00 [e]	2.864 (1.690[a])
Melaka-1	August 2nd	12.01[f]	0.8980[c]	0.4359[d]	36.12[c]	42.54[a]	1.969 (1.398[d])
Melaka-1	August 17th	16.93[b]	0.4727[d]	0.1931[e]	27.05[e]	39.46[c]	1.711 (1.305[f])
Melaka-5	July 3rd	16.11[c]	0.9585[bc]	0.7618[b]	35.19[c]	39.00[d]	2.264 (1.504[c])
Melaka-5	July 18th	15.19[d]	0.9847[b]	0.6531[c]	28.17[e]	37.00 [e]	2.269 (1.503[c])
Melaka-5	August 2nd	13.72[e]	0.9279[bc]	0.4614[d]	50.76[a]	41.80[b]	1.834 (1.351[e])
Melaka-5	August 17th	18.32[a]	0.4983[d]	0.2227[e]	32.56[d]	39.46[c]	1.610 (1.265[g])
Mean		15.655	0.8862	0.4572	5.476	39.4075	2.149 (1.4558)
CV (%)		4.301	8.609	16.50	6.563	0.324	3.769 (1.914)
LSD (5%)		0.6734	0.07635	0.07546	2.329	0.1276	0.08102 (0.02787)

Appendix 2. Interaction effect of spacing and variety on tap root length and days to 50% flowering of green beans

		Parameters	
Variety	Spacing	Tap Root Length (cm)	Days to 50% flowering
Melaka-1	50cmx7cm	13.62^{bc}	39.50^{bc}
Melaka-1	40cmx15cm	12.63^{de}	39.59^{ab}
Melaka-1	40cmx10cm	13.88^{ab}	39.67^{a}
Melaka-1	40cmx7cm	14.34^{a}	39.50^{bc}
Melaka-1	30cmx15cm	14.01^{ab}	39.25^{d}
Melaka-5	50cmx7cm	12.41^{e}	39.25^{d}
Melaka-5	40cmx15cm	13.39^{bc}	39.58^{abc}
Melaka-5	40cmx10cm	11.69^{f}	39.25^{d}
Melaka-5	40cmx7cm	13.59^{bc}	39.08^{e}
Melaka-5	30cmx15cm	13.21^{cd}	39.43^{c}
Mean		13.277	39.41
CV (%)		4.75	0.4054
LSD (5%)		0.6309	0.1598

Appendix 3. Effect of spacing and sowing date on dry weight of shoot and root and dry weight of pods of green bean

Treatments			
Spacing	Sowing date	Dry Weight of Shoot and Root (g/plant)	Dry weight of pods (g/plant)
50cmx7cm	July 3rd	21.37cd	17.87efg
	July 18th	22.39cd	29.12bcd
	August 2nd	17.16de	14.62fghi
	August 17th	7.950f	8.880ij
40cmx15cm	July 3rd	44.03a	34.48ab
	July 18th	19.37cde	35.84a
	August 2nd	12.07ef	10.18hij
	August 17th	7.950f	7.930j
40cmx10cm	July 3rd	22.23cd	13.82ghi
	July 18th	21.32cd	26.20cd
	August 2nd	17.01de	14.40fghi
	August 17th	7.770f	7.580j
40cmx7cm	July 3rd	34.40b	16.33fg
	July 18th	25.26c	20.06ef
	August 2nd	17.92cde	15.18fgh
	August 17th	8.690f	9.510hij
30cmx15cm	July 3rd	42.55a	23.36de
	July 18th	22.20cd	29.55bc
	August 2nd	17.64cde	14.26fghi
	August 17th	8.720f	9.000ij
Mean		19.9	17.901
CV (%)		25.31	28.06
LSD (5%)		6.132	5.024

Appendix 4. Effect of variety and sowing date on rust incidence (%) of green beans

Varity	July 3rd	July 18th	August 2nd	August 17th	Mean	CV (%)	LSD (5%)
Melka-1	12.78 (20.90[e])	19.10 (25.67[bc])	20.10 (26.46[b])	2.781 (1.667[f])	13.69 (18.67)	8.61 (4.649)	1.37 (1.014)
Melka-5	15.79 (23.28[d])	16.32 (23.73[d])	22.20 (27.94[a])	17.69 (24.79[c])	18 (24.94)		
Mean	14.29 (22.09)	17.71 (24.7)	21.15 (27.2)	10.24 (13.3)	15.85 (21.8)		

Appendix 5. Mean square error for the parameters

Parameters	Variety	Spacing	Sowing date	Variety* Spacing	Variety* Sowing date	Spacing*Sowing date	Variety*Spacing*Sowing date
TPY	4.51*	6.86*	146.76**	3.49^{ns}	0.56^{ns}	20.93^{ns}	15.00^{ns}
TMPY	1.12^{ns}	8.16*	114.10**	4.96^{ns}	4.64^{ns}	19.28^{ns}	13.61^{ns}
TUMPY	6.62*	18.62*	137.28**	4.02^{ns}	2.30^{ns}	17.88^{ns}	17.43^{ns}
TNPPP	6.12*	45.46**	143.20**	2.86^{ns}	9.09*	24.38*	14.78ns
DWP	18.38**	14.36*	128.30**	4.25^{ns}	8.18*	35.10**	10.55^{ns}
DWSR	9.63**	6.68^{ns}	100.61**	6.66^{ns}	7.33^{ns}	24.87*	12.10^{ns}
DF	8.05**	7.35^{ns}	2686.38**	11.08*	19.70**	10.11^{ns}	11.91^{ns}
PL	0.55^{ns}	1.96^{ns}	197.31**	3.07^{ns}	42.64**	7.90^{ns}	5.95^{ns}
TRL	10.38**	11.20*	216.19**	11.32*	5.60^{ns}	16.31^{ns}	16.21^{ns}
RV	0.032*	6.31^{ns}	136.10**	4.28^{ns}	19.26**	16.76^{ns}	12.71^{ns}
AIPW	4843.33**	0.63^{ns}	117.14**	4.10^{ns}	32.30**	13.66^{ns}	7.60^{ns}
NPB	32.94 (19.26**)	11.93 (17.84**)	326.40(371.33**)	7.59(8.12^{ns})	20.46(15.40**)	15.89(14.26^{ns})	12.47(13.25^{ns})
NSPP	2.83(1.52^{ns})	1.74(1.74^{ns})	41.93(20.35**)	9.89(5.65^{ns})	4.98(1.17^{ns})	12.85(11.16^{ns})	7.33(9.10^{ns})
PD	6.13*	6.65^{ns}	177.06**	3.33^{ns}	21.77**	9.02^{ns}	8.77^{ns}
FRW	5.54*	7.34^{ns}	164.83**	3.71^{ns}	11.89*	23.87*	8.64^{ns}
FL	0.25 (0.19^{ns})	3.79 (4.03^{ns})	17.94 (20.20**)	4.07 (4.66^{ns})	9.00 (8.77*)	16.34 (16.05^{ns})	0.992 (3.42^{ns})
SN	0.52^{ns}	4.79^{ns}	11.74*	2.12^{ns}	2.59^{ns}	22.77^{ns}	3.88^{ns}
TE	28.64**	27.83**	152.32*	2.19^{ns}	7.93^{ns}	6.11^{ns}	17.91^{ns}
ST	12.12**	3.40^{ns}	31.73**	5.70^{ns}	9.66*	29.35*	14.83^{ns}
LA	2.50^{ns}	9.98*	79.98**	1.30^{ns}	41.23**	16.75^{ns}	14.21^{ns}
RUST	1.26 (1.49^{ns})	1.62 (1.61^{ns})	41.34 (41.38**)	2.76 (2.78^{ns})	8.81 (8.50*)	10.72 (9.97^{ns})	17.67 (17.25^{ns})
ALS	0.69 (0.70^{ns})	5.99 (5.86^{ns})	188.02 (226.46**)	2.84 (2.79^{ns})	3.70 (3.49^{ns})	12.30 (11.95^{ns})	7.94 (7.56^{ns})
FLS	0.85 (0.73^{ns})	1.01 (1.01^{ns})	70.53 (74.49**)	2.39 (2.52^{ns})	1.21 (0.88^{ns})	7.08 (7.71^{ns})	7.16 (7.74^{ns})
PHH	0.97^{ns}	3.40^{ns}	86.87**	2.66^{ns}	10.36*	5.33^{ns}	5.45^{ns}

Appendix 6. Details of treatment combinations of the experiment

Treatments	Varieties	Plant Spacing	Sowing Date
T1= V1 S1 P1	Melka-1	50cmx7cm	July 3rd
T2= V1 S1 P2	Melka-1	50cmx7cm	July 18th
T3= V1 S1 P3	Melka-1	50cmx7cm	August 2nd
T4= V1 S1 P4	Melka-1	50cmx7cm	August 17th
T5= V1 S2 P1	Melka-1	40cmx15cm	July 3rd
T6= V1 S2 P2	Melka-1	40cmx15cm	July 18th
T7= V1 S2 P3	Melka-1	40cmx15cm	August 2nd
T8= V1 S2 P4	Melka-1	40cmx15cm	August 17th
T9=V1S3 P1	Melka-1	40cmx10cm	July 3rd
T10= V1S3 P2	Melka-1	40cmx10cm	July 18th
T11=V1S3 P3	Melka-1	40cmx10cm	August 2nd
T12=V1S3 P4	Melka-1	40cmx10cm	August 17th
T13=V1S4P1	Melka-1	40cmx7cm	July 3rd
T14=V1S4P2	Melka-1	40cmx7cm	July 18th
T15=V1S4P3	Melka-1	40cmx7cm	August 2nd
T16=V1S4P4	Melka-1	40cmx7cm	August 17th
T17=V1S5P1	Melka-1	30cmx15cm	July 3rd
T18=V1S5P2	Melka-1	30cmx15cm	July 18th
T19=V1S5P3	Melka-1	30cmx15cm	August 2nd
T20=V1S5P4	Melka-1	30cmx15cm	August 17th

T21=V2S1P1	Melka-5	50cmx7cm	July 3rd
T22=V2S1P2	Melka-5	50cmx7cm	July 18th
T23=V2S1P3	Melka-5	50cmx7cm	August 2nd
T24=V2S1P4	Melka-5	50cmx7cm	August 17th
T25=V2S2P1	Melka-5	40cmx15cm	July 3rd
T26=V2S2P2	Melka-5	40cmx15cm	July 18th
T27=V2S2P3	Melka-5	40cmx15cm	August 2nd
T28=V2S2P4	Melka-5	40cmx15cm	August 17th
T29=V2S3P1	Melka-5	40cmx10cm	July 3rd
T30=V2S3P2	Melka-5	40cmx10cm	July 18th
T31=V2S3P3	Melka-5	40cmx10cm	August 2nd
T32=V2S3P4	Melka-5	40cmx10cm	August 17th
T33=V2S4P1	Melka-5	40cmx7cm	July 3rd
T34=V2S4P2	Melka-5	40cmx7cm	July 18th
T35=V2S4P3	Melka-5	40cmx7cm	August 2nd
T36=V2S4P4	Melka-5	40cmx7cm	August 17th
T37=V2S5P1	Melka-5	30cmx15cm	July 3rd
T38=V2S5P2	Melka-5	30cmx15cm	July 18th
T39=V2S5P3	Melka-5	30cmx15cm	August 2nd
T40=V2S5P4	Melka-5	30cmx15cm	August 17th

Appendix 7. Detail description of the two varieties

Characteristics	Melka-1	Melka-5
Plant height (cm)	26cm	28cm
Flower color	White	Purple
Ground cover	High	Medium
Pod length (cm)	10.80cm	11.80cm
Pod diameter (cm)	1.20	1.10
Fiber ness	Nil	Nil
Pod curvature	Straight	Straight
Pod shape	Round	Round
Yield (Qt/ha)	124-137	129-146

Source: - Lemma *et al*. (2006)

Appendix 8. Effects of spacing and sowing date on total number of pods per plots of green bean.

Treatments		Total Number of pods per plots per ha
Spacing	Sowing date	
50cmx7cm	July 3rd	314.1[def]
	July 18th	308.7[def]
	August 2nd	214.6[ghi]
	August 17th	127.4[i]
40cmx15cm	July 3rd	619.6[a]
	July 18th	450.4[bc]
	August 2nd	197.3[ghi]
	August 17th	146.4[hi]
40cmx10cm	July 3rd	381.0[cd]
	July 18th	431.8[bc]
	August 2nd	284.8[efg]
	August 17th	149.8[hi]
40cmx7cm	July 3rd	480.3[b]
	July 18th	391.7[bcd]
	August 2nd	286.8[efg]
	August 17th	197.9[ghi]
30cmx15cm	July 3rd	610.3[a]
	July 18th	605.6[a]
	August 2nd	376.7[cde]
	August 17th	229.4[fgh]
Mean		340.23
CV (%)		23.6108
LSD (5%)		80.34775

Appendix 9. Simple Pearson correlation on growth, yield and quality attributes of green bean.

	TPY	TMPY	TUMPY	TNPPP	DWP	DWSAR	DF	PL	TRL	RV	IPW	NPB	TNS	PD	RW	FL	SN	TE	ST	PH	LA	Rust	ALS	FLS
TPY	1.00	0.96**	0.94**	0.76**	0.69**	0.76**	-0.50**	-0.01	0.59**	0.69**	0.23	0.63**	0.45**	0.06	0.79**	-0.09	-0.07	-0.05	-0.06	0.18**	0.27**	-0.17	-0.38**	0.39**
TMPY		1.00	0.84**	0.75**	0.64**	0.81**	-0.40**	0.03	0.59**	0.76**	0.28	0.62**	0.47**	0.12	0.79**	-0.09	-0.09	-0.08	-0.11	0.14	0.36**	-0.08	-0.38**	0.32**
TUMPY			1.00	0.69**	0.65**	0.64**	-0.55**	-0.05**	0.53**	0.60**	0.17**	0.55**	0.40**	0.05	0.69**	-0.07	-0.05	0.02	-0.13	0.20**	0.20**	-0.19**	-0.34**	0.43**
TNPPP				1.00	0.77**	0.68**	-0.38**	-0.09	0.56**	0.63**	0.15	0.64**	0.39**	-0.03	0.73**	-0.11	-0.06	0.08	-0.15	-0.05	0.16	-0.09	-0.34**	0.34**
DWP					1.00	0.48**	-0.48**	0.15	0.56**	0.49**	0.37**	0.52**	0.38**	0.19**	0.56**	-0.14	-0.03	-0.03	-0.09	-0.00	0.13	0.07	-0.18**	0.45**
DWSAR						1.00	-0.21**	-0.05	0.52**	0.84**	0.11	0.64**	0.52**	-0.11	0.93**	-0.04	-0.06	-0.09	-0.11	0.10	0.43**	-0.19**	-0.46**	0.16
DF							1.00	-0.00	-0.47**	-0.12	-0.05	-0.49**	-0.02	-0.11	-0.31**	-0.05**	0.18**	-0.14	0.05	-0.44**	0.35**	0.24**	0.27**	-0.46**
PL								1.00	0.22**	0.04	0.81**	0.00	0.34**	0.79**	-0.04	-0.29**	0.22**	-0.15	0.22**	-0.05	0.29**	0.44**	0.42**	0.18**
TRL									1.00	0.59**	0.37**	0.71**	0.43**	0.35**	0.59**	-0.17**	-0.07	-0.25**	0.099ns	-0.05	0.14	0.03	-0.24	0.38**
RV										1.00	0.26**	0.65**	0.51**	-0.02	0.92**	-0.06	-0.05	-0.22**	-0.03	-0.07	0.49**	-0.12	-0.38**	0.19**
IPW											1.00	0.13	0.39**	0.75**	0.18**	-0.23**	0.12	-0.11	0.11	-0.04	0.48**	0.33**	0.17	0.22**
NPB												1.00	0.42**	0.04	0.73**	-0.04	-0.15	-0.26**	-0.02	0.08	0.09	-0.17**	-0.37**	0.37**
TNS													1.00	0.26**	0.52**	-0.36**	0.17	-0.25**	0.10	-0.11	0.33**	0.10	-0.05	0.29**
PD														1.00	-0.08	-0.28**	0.11	-0.19**	0.15	-0.12	0.21**	0.38**	0.31**	0.21**

Appendix 9 Correlation…………… (Continued)

	RW	FL	SN	TE	ST	PH	LA	Rust	ALS	FLS
RW	1.00	-0.05	-0.06	-0.08	-0.11	0.09	0.39**	-0.21**	-0.49**	0.25
FL		1.00	-0.29**	0.12	-0.28**	0.29**	-0.06	-0.13	-0.25	-0.15
SN			1.00	0.11	0.13	-0.11	0.11	0.17**	0.29**	0.05
TE				1.00	-0.28**	0.39**	-0.01	-0.07	-0.06	-0.22**
ST					1.00	-0.25**	-0.15	0.01	0.17*	0.06
PH						1.00	-0.04	-0.17	-0.18*	-0.09
LA							1.00	0.18*	-0.08	-0.18*
Rust								1.00	0.41**	-0.01
ALS									1.00	0.07
FLS										1.00

*, ** = Correlation is significant, highly significant at $P \leq 0.05$, 0.01, respectively.

TPY= Total pod yield, TMPY= Total marketable pod yield, TUMPY= Total unmarketable pod yield, TNPPP= Total number of pods per plants, DWP= Dry weight of pods, DRWSR= Dry weight of shoot and roots, DF= Days to 50% flowering, PL= Pod length, TRL= Tap root length, RV= Root volume, IPW= Individual pod weight, NPB= Number of primary branches, TNS= Total number of seed per pods, PD= Pod diameter, RW= Root weight, FL= Fibreless, SN= Snapping, TE= Tenderness, ST= Straightness, PH= Plant height, LA= Leaf area, Rust= Rust Incidence, ALS= Angular leaf spot, FLS= Floury leaf spot.

Appendix 10. Mean annual metrological data of Jimma from the year 2000-2009 G.C

Year	Relative Humidity (%)	Temperature (^oC)		Rainfall (mm)
		Maximum	Minimum	
2000	65	26.9	12.6	131.4
2001	68	26.5	12.7	133.0
2002	67	27.3	12.9	120.9
2003	66	27.4	13.5	112.3
2004	67	27.0	14.5	125.4
2005	68	27.1	13.6	131.3
2006	69	26.5	14.8	150.2
2007	67	26.8	14.3	119.3
2008	66	26.8	13.6	141.3
2009	68	26.3	13.5	143.7
2010	69.8	26.6	13.7	188.3

Source: JARC Department of Metrology (2010)

Appendix 11. Mean daily metrological data of Jimma for the year 2010 G.C

No	January				February				March				April			
	RH (%)	Temp.(°C)		RF (mm)	RH (%)	Temp.(°C)		RF (mm)	RH (%)	Temp.(°C)		RF (mm)	RH (%)	Temp.(°C)		RF (mm)
		Max. Temp	Min. Temp			Max. Temp	Min. Temp			Max. Temp	Min. Temp	0.0		Max. Temp	Min. Temp	
1	69	25.5	14.0	0.0	58	30.5	12.5	30.5	60	26.5	14.0	0.0	63	28.0	15.0	0.0
2	71	27.0	14.2	0.0	60	30.5	14.0	30.5	46	28.5	12.0	21.0	66	28.5	15.0	3.8
3	65	26.5	11.0	TR	60	30.0	12.2	30.0	55	28.5	13.0	0.1	63	28.0	13.0	9.6
4	65	27.5	12.0	0.2	69	26.5	15.0	26.5	73	24.5	14.0	0.0	61	28.5	14.5	0.0
5	60	28.0	11.0	0.0	64	26.5	13.0	26.5	61	28.5	13.0	TR	56	28.5	14.0	0.1
6	52	28.5	8.0	0.0	64	28.0	12.0	28.0	62	29.0	15.0	0.1	61	30.0	13.0	3.9
7	61	28.0	8.5	0.2	67	27.0	14.0	27.0	60	29.5	14.0	0.0	64	29.5	14.0	0.0
8	60	28.5	9.0	0.1	82	24.0	12.0	24.0	65	28.5	14.0	0.0	61	26.5	15.0	8.5
9	72	25.0	10.0	0.2	81	25.5	13.0	25.5	65	28.0	13.0	0.0	62	29.0	16.0	0.0
10	69	27.0	11.5	0.2	76	26.0	14.0	26.0	52	29.5	12.0	0.0	62	28.0	14.0	15.2
11	69	27.5	8.0	0.1	77	26.5	14.0	26.5	52	29.5	13.0	0.0	76	26.5	14.0	0.2
12	62	28.0	10.0	0.0	69	28.0	14.0	28.0	47	27.5	10.0	0.0	71	22.5	14.5	0.0
13	61	29.0	9.0	TR	71	28.5	13.5	28.5	55	29.5	10.0	0.0	65	26.0	15.0	3.5
14	62	28.5	8.5	0.0	61	26.0	14.0	26.0	55	30.0	12.0	0.0	67	28.5	14.0	0.0
15	65	28.5	9.5	0.0	68	28.5	13.0	28.5	50	30.5	13.0	0.0	61	28.5	16.0	0.0
16	65	28.0	10.0	0.0	75	25.5	13.5	25.5	60	30.5	14.0	0.0	68	26.0	15.0	0.6

Appendix 11. continued…

17	66	28.5	9.0	0.1	69	25.5	14.0	25.5	57	31.0	13.5	0.0	67	25.5	14.5	0.0
18	63	29.5	11.0	9.0	65	28.0	13.0	28.0	57	30.0	15.0	20.4	63	29.5	15.0	12.7
19	63	24.5	11.0	3.3	66	28.0	12.2	28.0	67	24.0	12.0	18.0	74	26.5	15.0	52.0
20	72	25.5	12.0	0.0	69	27.5	12.0	27.5	69	26.5	12.0	6.5	77	27.5	11.0	0.1
21	64	29.0	11.5	8.7	70	26.5	12.0	26.5	72	26.5	13.0	TR	78	28.0	14.5	0.4
22	68	27.0	14.0	2.5	64	28.0	14.0	28.0	75	26.5	11.0	0.4	61	27.0	15.0	0.0
23	66	27.5	13.0	5.1	68	29.0	14.0	29.0	66	28.0	14.0	0.0	74	26.0	14.5	1.2
24	59	28.0	12.0	0.0	63	26.5	14.5	26.5	65	28.0	13.0	0.0	70	28.0	15.0	0.0
25	58	28.5	13.0	0.0	66	26.5	14.0	26.5	60	26.5	14.0	0.0	69	27.5	14.0	0.0
26	56	28.5	11.0	TR	66	27.5	14.5	27.5	59	28.5	13.5	0.0	68	28.5	15.0	0.0
27	53	28.5	14.0	0.0	70	28.0	15.0	28.0	62	29.5	13.0	5.7	61	28.0	14.5	1.0
28	56	29.0	13.0	0.0	81	28.0	14.0	28.0	65	26.5	15.0	0.4	66	27.5	15.0	0.1
29	57	29.0	12.0	0.0	xx	xx	xx	xx	68	25.5	13.0	41.5	64	28.5	16.0	2.3
30	59	30.0	13.0	0.0	xx	xx	xx	xx	67	27.5	14.0	7.2	67	29.0	14.5	0.8
31	58	30.0	12.0	0.0	xx	xx	xx	xx	68	28.0	12.5	0.0	xx	xx	xx	xx

Appendix 11. continued…

No	May				June				July				August			
	RH (%)	Temp.(^oC)		RF (mm)	RH (%)	Temp.(^oC)		RF (mm)	RH (%)	Temp.(^oC)		RF (mm)	RH (%)	Temp.(^oC)		RF (mm)
		Max. Temp	Min. Temp			Max. Temp	Min. Temp			Max. Temp	Min Temp			Max. Temp	Min. Temp	
1	30.8	28.5	13.5	5.6	68.4	26.0	14.0	1.5	76.2	25.5	14.0	4.5	77.4	25.0	13.0	66
2	30.4	28.5	14.0	4.6	75.8	26.5	15.0	0.9	74	25.5	15.0	11.6	78.4	25.0	14.0	67
3	33.2	29.0	15.0	23.3	70.2	27.0	13.0	8.8	69.6	26.0	14.0	11.1	71	26.5	14	59
4	31.8	25.5	15.0	14.8	75.8	26.0	14.5	26.6	70.8	23.5	14.2	20	75.2	26.0	15	62
5	35.2	24.5	14.5	1.3	70.2	26.5	14	32.6	70.6	26.0	14.0	2.6	76.2	23.5	14.0	64
6	32.2	26.5	15	6.2	74.2	26.0	14.5	28.1	75.4	26.0	13.5	0.1	80.8	25.5	15	69
7	28	24.5	15.0	6.2	70.6	25.5	13	1.9	69.6	25.0	13.0	4.5	73.4	25.0	16.0	61
8	30.4	26.0	14.0	3.8	67.8	26.0	14	9.5	75.2	25.0	14.0	14.1	68.8	27.0	14.0	58
9	31.8	25.5	13.5	7.8	71.2	26.5	14	41.9	74.8	24.0	13.5	25.8	70.4	25.5	14.2	61
10	36.4	25.5	15.0	6.2	71.6	26.5	16.0	1.3	75.4	25.0	15.0	1.9	74	20.5	15.0	66
11	34.4	23.5	13.5	0.0	80	25.0	14	2.4	72.6	25.5	13.0	17	80.8	25.0	14.42	63
12	31.2	25.5	15.0	T.R	75.4	26.0	14.2	4.0	70.2	26.0	14.5	TR	86	25.0	14.0	69
13	33.2	26.0	14.0	0.8	74.8	24.5	15.0	6.8	73.4	25.5	11.0	2.1	79.4	21.5	14.0	72
14	29.6	25.5	16.0	12.5	72.2	25.0	13.5	T.R	83.2	22.5	14.5	7.6	81.4	24.0	15.2	67
15	28.4	25.0	16.0	5.1	79	25.5	16.0	0.0	68.8	25.0	15.0	5.1	76.6	25.5	14.0	67
16	30.2	27.0	15.0	0.0	75.6	26.0	14.5	6.0	80	24.5	16.0	0.6	73.2	25.0	15.0	66
17	33.8	26.5	16.0	22.7	79	26.0	15.0	5.0	73.4	24.0	15.0	0.9	81.2	25.0	14.5	62

Appendix 11. continued…

18	31.6	26.0	14.5	7.0	72.4	26.5	15.0	14.9	91.8	23.0	15.0	10.3	71.2	22.0	14.5	66
19	31	26.0	14.5	1.6	78	24.5	14.5	15.9	78.2	24.0	14.0	9.3	74	25.0	14.5	62
20	33.2	26.0	16.0	1.3	77.4	24.5	14.0	30.2	78.6	23.5	16.0	7.8	86.4	24.0	14.0	61
21	34	28.5	15.5	12.6	80.4	25.0	15.0	0.8	90.4	23.5	14.0	9.9	81.2	25.0	15.0	62
22	32.2	28.5	16.0	1.8	71	26.5	14	6.0	74	24.5	15.0	0.0	75.6		14.5	64
23	35.6	28.5	15.0	2.7	70.8	27.5	16.0	13.3	71	23.5	14.0	49	85.4	26.0	14.0	69
24	29.6	28.0	14.5	T.R	72	25.0	14.0	3.9	86.8	23.0	15.0	12	73.4	23.5	12.5	65
25	31.6	28.5	15.0	0.0	70.2	27.0	14.5	5.5	82.2	20.0	14.0	0.1	73.6	24.0	13.0	65
26	28.4	27.5	15.0	0.3	69	24.0	13.5	5.5	69.6	23.5	15.0	2.2	86	24.5	14.0	66
27	31	27.0	16.0	11.8	75	25.0	14.0	T.R	80.6	21.0	15.0	0.1	83	23.0	14.0	62
28	30.6	28.0	14.0	8.6	86	22.5	12.5	5.3	81.2	23.5	13.0	3.8	81.6	24.5	15.0	63
29	38.4	23.0	15.0	15.8	76	23.0	13.0	5.5	75.6	24.5	15.0	4.1	73.8	24.5	16.0	69
30	34.4	26.5	14.0	0.0	77.2	25.0	15.0	0.4	73.4	24.0	14.0	11.3	75.6	23.5	11.5	69
31	31.6	25.0	15.0					0.8	77.4	24.5	13.5	0.2	77.4	24.5	12.5	70

Appendix 11 continued…

No	September				October				November				December			
	RH (%)	Temp.(°C)		RF (mm)	RH (%)	Temp.(°C)		RF (mm)	RH (%)	Temp.(°C)		RF (mm)	RH (%)	Temp.(°C)		RF (mm)
		Max. Temp	Min. Temp			Max. Temp	Min. Temp			Max. Temp	Min. Temp			Max. Temp	Min. Temp	
1	82.2	25.0	14.5	3.6	73	25.5	13.5	1.2	13.7	29.0	14.0	0.0	57	25.0	11.5	0.0
2	80.8	16.0	14.0	4.9	68	25.0	15.0	0.0	14.3	29.0	13.5	0.1	42	25.0	5.0	0.0
3	75	25.0	14.2	7.3	76	26.0	15.0	TR	12.3	28.0	12.0	T.R	58	24.0	9.0	T.R
4	76.2	26.5	15.5	19.5	78	25.5	14.0	6.5	10.7	28.0	11.0	0.1	54	24.0	8.0	0.2
5	78.6	26.0	15.0	34.2	74	27.0	13.5	13.1	11.0	29.0	10.5	0.0	67	28.0	11.5	0.1
6	76.4	25.5	15.0	1.3	70	27.0	16.5	3.0	41.7	28.5	12.0	0.0	68	27.5	10.0	0.0
7	77.4	26.5	14.0	4.5	66	26.5	14.0	0.1	40.1	28.0	10.0	0.0	63	22.5	10.0	0.1
8	74.6	26.0	13.5	15.7	68	26.5	14.0	0.6	41.2	29.0	10.5	0.0	63	27.0	9.0	0.0
9	79.4	26.0	15.0	28.7	69	28.0	16.0	0.1	43.2	28.0	12.0	0.0	67	26.0	11.0	0.0
10	76.2	25.5	14.5	13.1	67	27.0	15.4	0.5	37.3	29.0	10.5	T.R	72	25.5	14.0	0.5
11	76.8	25.0	14.0	0.1	72	28.0	14.0	0.1	39.4	28.6	11.6	0.0	61.1	26.0	14.5	0.1
12	75.8	23.5	13.5	0.2	69	28.0	13.0	0.2	39.2	26.5	14.0	0.0	0.1	24.0	14.0	0.1
13	74	25.0	12.0	23.0	62	29.0	14.0	0.0	39.0	29.0	13.0	T.R	67	26.0	11.0	0.0
14	76.6	22.5	15.0	23.3	65	29.0	13.5	0.1	41.0	28.0	14.0	5.1	65	23.5	12.0	1.5
15	77.4	24.5	12.0	5.0	62	27.5	15.0	0.0	45.5	27.5	14.5	1.8	59	27.5	13.0	T.R
16	77.2	24.0	14.0	7.1	65	26.0	14.0	12.2	41.5	26.5	15.0	1.0	59	28.0	11.0	0.0

Appendix 11. continued…

17	80.8	23.0	14.5	0.1	68	27.0	15.0	0.0	42.0	28.5	14.5	0.0	59	27.5	13.0	T.R
18	74.6	24.5	14.0	TR	68	26.0	14.0	7.3	40.7	27.0	14.0	10.0	63	27.0	12.5	T.R
19	73.8	26.5	12.5	4.2	67	27.0	14.0	0.1	44.0	25.5	15.0	10.0	63	26.5	13.0	T.R
20	73.8	26.0	14.0	0.3	63	28.0	15.0	TR	43.7	27.5	14.5	0.0	60	27.0	13.0	0.0
21	68.8	23.5	14.0	0.1	64	27.5	14.0	TR	42.3	26.0	13.0	0.0	60	27.5	10.0	T.R
22	72	26.5	15.0	1.0	62	28.5	15.0	0.1	42.9	27.2	14.2	0.1	63	27.0	10.5	0.0
23	69	26.0	15.0	8.5	62	27.5	16.0	0.1	45.0	28.0	15.0	4.3	60	27.5	8.0	T.R
24	74.8	24.5	14.5	9.5	61	26.0	15.2	0.0	42.9	29.5	14.0	57.0	72	27.0	9.5	0.0
25	74.8	23.0	15.5	2.8	61	27.5	15.0	16.9	43.1	29.0	14.0	1.5	56	28.0	11.0	0.0
26	72.6	25.0	14.0	0.2	62	28.0	15.0	1.0	43.2	28.5	12.0	11.0	65	26.5	11.5	T.R
27	66.4	27.0	15.0	0.1	68	27.5	13.0	TR	40.9	25.5	14.0	9.0	62	26.0	10.0	14.2
28	68.2	26.5	15.0	0.1	57	28.5	14.0	2.0	45.2	25.0	13.0	1.0	67	26.0	13.0	7.0
29	75	26.0	14.0	0.0	66	27.0	14.5	0.0	47.8	25.0	13.0	0.5	68	27.5	14.0	6.2
30	69.6	25.0	16.0	5.0	62	27.5	14.0	0.0	44.9	26.0	13.5	T.R	73	20.5	13.5	0.0
31													79	25.5	11.0	0.0

Source: JARC Department of Metrology (2010)